

FishBase 2000

Concepts, design and data sources

Edited by

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D. Pauly^b

2000

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Cover: The cover shows the Nile tilapia, *Oreochromis niloticus*, a species used widely in tropical aquaculture, and the leopard coralgroupier, *Plectropomus leopardus*, a much appreciated marine food fish of the western Pacific.

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- when discussing the features of a FishBase table, cite the section documenting that table, e.g., "Sa-a et al. (2000)."

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FishBase Registration Form

Attention : ICLARM, FishBase Project
Fax No. (63-2) 845-0606
E-mail: fishbase@cgiar.org
3rd Floor, IRRI Collaborators Center
College, Los Baños
Laguna 4031
Philippines

From : _____

Here is my registration information:

Name : _____

Institution : _____

Address : _____

Fax No. : _____

E-mail : _____

FishBase version : _____

Number of users : _____

Comments : _____

Foreword

The FishBase 2000 release summarises the accumulation and structuring of knowledge on fish biology and ecology over the more than 10 years since its inception.

FishBase 2000 now covers over 25,000 species of fish known to science, has over 70,000 synonyms and 100,000 common names in over 200 languages. The names are the key to accessing knowledge accumulated over time and mobilising scientific and non-scientific knowledge systems. Over 25,000 pictures illustrate these fish and information about them has been extracted from 20,000 references. The classification of higher taxa follows the version of Eschmeyer's *Catalog of Fishes* updated in November 2000.

A number of new features blended into tested 'old' ones lifts the user possibilities to yet another level:

The development of 'Key Facts' by species, first implemented on the web-version to great effect in late 1998, allows rapid estimation of key indicators of relevance for managers and conservationists. Estimates of these life-history indicators with 'best estimates with error margin' can now be produced rapidly on the basis of information already inside FishBase and re-estimated with the user's own data, as required. As an additional complement, an October 2000 update of IUCN's list of threatened fishes is incorporated.

FAO nominal catches from 1950 to 1998 and the further improved presentation and analysis of trophic ecology information open to all interested users the avenue for new types of global trend analysis. The first innovative use of these features was demonstrated by the publication in *Science* of the article on 'Fishing down marine food webs' by Pauly et al. (1998) stimulating much further work into trophic analyses.

As a result, additional capabilities to construct trophic 'Lindeman-pyramids' of ecosystems have been included in the 2000 release. Moreover, all the underlying information on species and their key features is never more than one or two mouse clicks away. By the same token, new support for the parametrisation of ecosystem models has been implemented.

The breadth and depth of information achieved so far, allows asking new questions. This, in turn, allows shaping more analytical routines or other outputs with the potential for making the database more useful to scientific users. The constantly growing emphasis on graphical presentations of data and the relationships between different data sets as well as the derivation of synthetic indicators like the ones mentioned above make it increasingly interesting to a wider audience. It is hoped that the various tools will encourage

local applications of global knowledge through interfacing with national data sets.

Even though some have rich aquatic resources, many African, Caribbean and Pacific (ACP) countries are among the least developed. Hence, the need for the creation of an enabling environment for ACP science and research was recognised during the dialogue on the Fisheries Research Initiative demanded by the ACP-EU Joint Assembly (a parliamentary body composed of ACP representatives and members of the European Parliament). Strengthening partnership with these countries to jointly develop concepts and management support for sustainable benefits from their aquatic resources is a matter of priority. Among resulting projects, one entitled 'Strengthening fisheries and biodiversity management in ACP countries' uses FishBase and its analytical capabilities as its technical backbone.

The project therefore fulfills a specific role in relation to FishBase and biodiversity work under Agenda 21 and an enabling role in relation to the wider objectives of the ACP-EU Fisheries Research Initiative. It does so by strengthening the operational and research capacities in ACP countries, by promoting common information production and management tools in ACP research and training establishments and by holding regional 'for a' in which the objectives of the ACP-EU Initiative will be pursued. This approach is also very much in line with the Decision on a Clearing House Mechanism taken by the Jakarta Conference of the Parties to the Biodiversity Convention (November 1995) ratified by record 157 countries. The best way to achieve this long-term goal is through a broad-based partnership and dialogue. The type of cooperation with greatest potential for lasting and multiplying effects on sustainable development is through investment into human and institutional capital with high knowledge content.

This project started in December 1996 and will last until June 2001. Five regional training nodes respectively in Belize, Kenya, Namibia, New Caledonia and Senegal cater for continued support to colleagues using FishBase and the new sustainability concepts for science and management in their subregions and ensuring improved data coverage and information depth in FishBase.

FishBase 2000 is the last output of this project in the form of the concept book, data and image CD-ROMs. It will be again in English, although French and Portuguese versions of the 1999 book will be available on the CDs. This is largely to ensure that users and collaborators in developing countries with still weak or relatively expensive Internet penetration can have access to what more than 60,000 visitors enjoy every month on the website (see www.fishbase.org).

Having incorporated key features by species, the most essential functions of ecosystem analysis and of mapping resources, FishBase 2000 is expected to remain stable in terms of its principal components for the next years to come. The CD-ROMs are thus

expected to serve for the next years, while waiting for the Internet infrastructure to expand. Work on complementing the content of FishBase will, of course, continue.

The newly created FishBase consortium of museums, fisheries research institutes and international organisations with a fisheries mandate has made an open-ended institutional commitment to further develop and consolidate FishBase and keep it in the public domain. The founding members of this open consortium are: Swedish Museum of Natural History (Stockholm), Royal Museum for Central Africa (Tervuren), Muséum National d'Histoire Naturelle (Paris), Institute of Marine Research (Kiel), Fisheries Centre of the University of British Columbia (Vancouver), FAO (Rome) and ICLARM (Los Baños). The consortium members will thus ensure that the shared knowledge platform for the more than 500 individual and institutional collaborators, many joining as a result of the ACP Project, and for the innumerable users around the world will continue to thrive.

Thanks are more than ever due to the highly committed FishBase Team. Thanks are also due to the rapidly growing number of scientists, photographers, volunteers and institutions who share their knowledge through FishBase with all users and who continue to contribute to the development of the system's content and shape. It is an exciting undertaking in which the FishBase Team, the many collaborators around the globe, the ACP countries and the European Union are jointly investing in order to improve coverage and breadth of utilisation for the benefit of all.

Cornelia E. Nauen and Jacques Prade

**Former and New Chairs, respectively, of the
ACP-EU FishBase Project Steering Committee**

Introduction

Welcome to FishBase

FishBase contains different things for different people

FishBase is an information system with key data on the biology of all fishes. Similar to an encyclopedia, FishBase contains different things for different people. For example, fisheries managers will dive into the largest existing compilation of population dynamics data; teachers and students will find numerous graphs illustrating basic concepts of fish biology; taxonomists will enjoy access to the November 2000 update of Eschmeyer's (1998) *Catalog of Fishes* databases; conservationists will use the lists of threatened fishes for any given country (Hilton-Taylor 2000); policymakers may be interested in a chronological, annotated list of introductions to their country; research scientists, as well as funding agencies, will find it useful to gain a quick overview of what is known about a certain species; zoologists and physiologists will have the largest existing compilations of fish morphology, metabolism, gill area, brain size, eye pigment, or swimming speed at their fingertips; ecologists will likewise use data on diet composition, trophic levels, food consumption and predators as inputs for their models; geneticists will find the largest compilation of allele frequencies; the fishing industry will find proximate analyses, as well as processing recommendations for many marine species; anglers will enjoy a listing of all game fishes occurring in a particular country (IGFA 1994); and scholars interested in local knowledge will find more than 100,000 common names of fishes together with the language/culture in which they are used and comments on their etymology.

You can create personal, institutional and national fish databases

Divers, anglers, aquarists, researchers can create their personal/institutional databases of where and when they have seen, caught, or acquired what fish. Biodiversity managers can create national fish biodiversity databases to keep track of local regulations and uses. Anthropologists can create a database on local knowledge about fish.

This information is accessible through an easy-to-use interface on any personal computer with a CD-ROM drive and Microsoft Windows NT, 95 98, 2000, Me or above installed. It is also available on the Internet at www.fishbase.org.

The following chapters present the concepts behind FishBase, the sources, and additional information on how to use FishBase.

FishBase has been developed at the International Center for Living Aquatic Resources Management (ICLARM) in collaboration with the Food and Agriculture Organization (FAO) of the United Nations and many other partners. FishBase has been funded mainly through sequential grants from the European Commission.

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Rainer Froese

What's New in FishBase 2000

The main goal for FishBase 2000 was to cover all 25,000 species known to science.

Additional/new features of FishBase 2000 are:

- over 70,000 names (valid, synonyms, misspellings, misidentifications) assigned to over 25,000 species;
- over 100,000 common names in over 200 languages;
- support for the parametrization of ecosystem models;
- new trophic (Lindeman) pyramids for major ecosystems;
- a new 'Key Facts' page with 'best estimates with error margin' for important management parameters;
- a November 2000 update of Eschmeyer's (1998) *Catalog of Fishes*;
- an October 2000 update of IUCN's threatened fishes;
- over 25,000 pictures;
- over 20,000 references;
- new graphs and reports; and
- more data for more species.

Rainer Froese

Things not (yet) in FishBase

With over 25,000 known species, fish are the largest and most diverse group of vertebrates. Recording key information (taxonomy, biology and human uses) for all these species is a huge task and FishBase is by no means complete. Thus, we thought it would be fair to show a list of things that you do not (yet) get from FishBase:

- Complete checklists (of 296 countries/islands, 70 marine and 140 freshwater checklists were complete in 2000);
- Fish behavior (we only cover reproductive and trophic behavior);
- Traditional distribution maps (as noted by several reviewers, our maps only highlight or mark countries from which a species is reported and plot the occurrence points currently available);

- All references for all species (we only list publications that contain suitable information and that we have used so far, currently >20,000);
- Pictures for all fishes (>25,000 pictures for >10,000 species in 2000).

However, with the help of our many collaborators, we plan to eventually have the above tasks reasonably complete. See the chapter on 'How to Become a FishBase Collaborator ... and Why' if you want to join us in this effort.

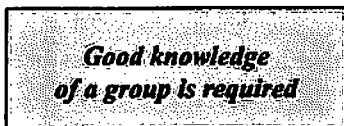
Rainer Froese

FishBase and Groups Other than Fish

Over the years, many colleagues who were pleased, but were not familiar with the design and contents of FishBase have asked why we do not use it to cover other groups, for example, mollusks or crustaceans.

The alert user of FishBase will notice, however, that "covering groups other than fish" is easier said than done. What gives FishBase its ability to accommodate, in compact form, so much information on fish is the fact that it was *designed* to do this. Thus, the tables describing the morphology of the larval and adult forms can accommodate only finfish, and would be inappropriate for the description of crustaceans. Many other tables also contain fields that are specific to finfish, such as length types.

Duplicating such tables (one special set for every major group) would make the resulting database extremely unwieldy, with many tables or fields remaining empty for most species. Alternatively, one could conceive of reducing FishBase to those tables that would be similar among groups (for example, nomenclature, distribution, etc.). The result would be a database similar to FAO's SPECIESDAB (Coppola et al. 1994) which is indeed meant to eventually cover all aquatic groups of commercial importance, and which FishBase should not duplicate.



More importantly, we believe that dealing with major groups such as fish or crustaceans requires a good knowledge of the group, its literature and its specialists, i.e., something that is not easily achieved—by a single research team—for more than one group.

Therefore, we believe that colleagues specialized in groups other than fish should create databases similar to FishBase, for their groups. You are welcome to contact the FishBase Project for tables, and preprogrammed routines that might be used for such databases, and for our collaboration.

Reference

Coppola, S.R., W. Fischer, L. Garibaldi, N. Scialabba and K.E. Carpenter. 1994. SPECIESDAB: Global species database for fishery purposes. User's manual. FAO Computerized Information Series (Fisheries) No. 9. FAO, Rome. 103 p.

Daniel Pauly

Ichthyology

Ichthyology, commonly defined as “the study of fish” or “that branch of zoology dealing with fish” has a long documented history, dating thousands of years back to the ancient Egyptians, Indians, Chinese, Greeks and Romans (Cuvier 1995).

This long, sustained interest in fish is due to their double role as highly speciose denizens of a fascinating, yet alien world, and as human food. It has generated, over the centuries, highly heterogeneous information—mainly taxonomic, but also referring to zoogeography, behavior, food, predators, environmental tolerances, etc.

Information on fish is widely scattered

This huge amount of information, embodied in a widely scattered literature, has gradually forced ichthyologists to specialize, and thus accounts on fish are now either global, but highly specialized (e.g., Eschmeyer’s *Catalog of Fishes* of 1998, or Pietsch and Grobecker’s *Frogfishes of the World* of 1987, to name two outstanding representatives), or local and deep (e.g., Northern European work on cod, or Canadian work on Pacific salmon, both used as paradigmatic fish in many fisheries textbooks). FishBase, as presented in this and, in more detail, in the other chapters of this book, is an attempt to provide key information on fishes of the world, that is both global and deep.

The current version of FishBase contains all fishes known to science and addresses the needs of a vast array of potential clients, ranging from fisheries managers to biology teachers. The features of FishBase that enable it to meet such wide range of needs reside in its architecture, which makes extensive use of modern relational database techniques.

Other features of FishBase:

Standardized qualitative information is structured through multiple choice fields

- all information on a given species in the database is accessible through a unique scientific or common name;
- the wide use of multiple choice field structures standardized qualitative information;
- numeric fields record quantitative information that has been previously standardized;
- numerous cross-relationships between data tables enable previously unknown relationships to be discovered; and
- the hosting of databases provided by others, with explicit credit, makes FishBase the most comprehensive data source of its kind.

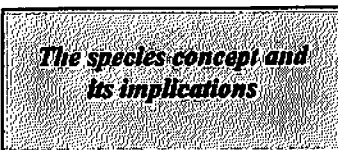
FishBase can be used in ichthyology courses

For teachers of aquatic biology, or of specialized ichthyology courses, the uses of FishBase will range from practical solutions to theoretical issues:

- FishBase is directly useable as data source (i.e., as an electronic encyclopedia on fish), thus complementing classical sources of information on fish (e.g., the Zoological Record, Aquatic Sciences and Fisheries Abstracts), and helping overcome the lack of scientific literature, especially in developing countries;
- the pictures in FishBase can be used, just as those in taxonomic books, to provide students with a visual impression of the diversity of fish, and/or of specific features of various groups;
- students will be able to assess the state of knowledge on various groups of fish, and thus obtain some guidance in identifying worthwhile projects; and
- the species synopses that FishBase can produce by assembling and structuring all entries on one species will help students to obtain material for study (see above) and, perhaps more importantly, to develop a sense of how scattered bits of knowledge can be used to 'reconstruct' species, and to show how these fit into their environments (thus encouraging a 'holistic view', as now required for most of what we do in the biological sciences).

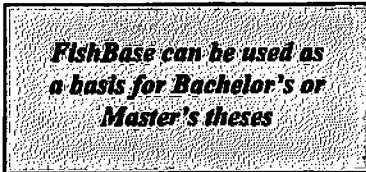
A series of lectures in ichthyology could be structured around FishBase as illustrated in the examples below.

- show FishBase pictures through an introductory lecture, to highlight the diversity and colorfulness of fish and similarity of external morphology in related groups (this hopefully would serve to generate interest in the course as a whole, and introduce fish classification);
- compare the early classification schemes in Cuvier (1995) with a recent one, e.g., that in the *Catalog of Fishes* (Eschmeyer 1998), 'hosted' by FishBase and largely identical with the widely used classification in Nelson (1994);
- introduce the species concept and its requirements (a formal description with figures, a binomen, a holotype, a type locality, etc.) and implications (synonymies, sister species, etc.), using FishBase as source of examples, and its Glossary for definition of terms;
- explain the characteristics (meristics, morphometrics) by which fish species are usually defined and hence identified, and compare identification through keys with computer-based identification using the appropriate FishBase routine (see 'Quick Identification', this vol.);
- show how museum and other occurrence records, as included in FishBase, can be used to define distribution ranges and habitats, which can then be used for ecological inferences;



- show how the latitudinal ranges of fish species can be used to test various hypotheses, e.g., on the relationship between fish biodiversity and shelf area (for marine species) or land area (for freshwater species);
- define and illustrate various life history strategies, and analyze their frequency distribution throughout the world. Show, e.g., that salmon-type anadromy is extremely rare in subtropical or tropical species (it is well documented only in hilsa, *Tenualosa ilisha*, ranging from Iraq to Myanmar). Show how students can identify the relative frequencies of different strategies and draw inferences from these;
- let each student select a species, print out the relevant FishBase synopsis and complement it based on a literature review (and send the result to the FishBase Team); and
- show or let students derive quantitative relationships between different expressions of fish physiology (e.g., respiration, growth) and temperature (and hence latitude) and identify modifying factors (salinity, gill size, food type, etc.).

A document implementing most of these ideas, called 'Fish on Line' is available from the FishBase web site (see Ichthyology course; www.fishbase.org/fish_on_line.htm).



In the context of higher education, FishBase may also serve as background for Bachelor's or Master's theses wherein an area of ichthyology not presently or suitably covered by the tables in this version of FishBase would be 'broken up' into choice, numeric and text fields, captured and then analyzed on a comparative basis.

Two theses of this type, one on Mediterranean fish larvae, and one by Achenbach (1990) on fish diseases, have been guided by R. Froese, working with the candidates on behalf of their theses supervisors.

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Daniel Pauly

The Fish Quiz



We believe that learning about fish should be fun. Therefore, we have designed a simple Fish Quiz that will help sharpen your eyes in recognizing fish, at least at the order or family level.

Basically, the Fish Quiz asks whether you want to test your skills with our family pictograms, with adult fish pictures, or with fish larvae. It then creates a random list of such pictures, displays the first and offers three multiple choices for the class, order and family (and species in case you have selected that option). We have kept this game very simple and have refrained from adding any time pressure or a hall of fame.

Improvements that we have added recently allow you to select species by country and habitat, i.e., you will be able to train yourself in the recognition of the marine fishes of, e.g., Hawaii. Obviously, the game will improve whenever we get permission to include more photos.



Play the biodiversity quiz

At www.fishbase.org/FBQuiz/Menu.cfm, we also present a biodiversity quiz that shows an underwater photo of a fish and lets the user determine its habitat type, size, food and reproduction by clicking on respective icons.

How to play games

On the CD-ROM, you get to the Fish Quiz by clicking the Fish Quiz button in the FishBase Main Menu. You can also use the stand-alone version of the Fish Quiz on the Pictures CD-ROM. On the web, you click on the FishQuiz link in the Search FishBase page.

Rainer Froese

The Making of FishBase

One of the antecedents of FishBase was the work and vision of Walter Fischer, FAO, who inspired experts throughout the world to collaborate on the production of FAO's first set of *Identification Sheets* (Fischer 1973) and their numerous successors, and to publish, through FAO's Species Identification and Data Programme, an extremely useful series of *FAO Species Synopses* and *FAO Species Catalogues* (Fischer 1976). Walter Fischer also perceived the need for a global database of basic information on the exploited fish and invertebrates of the world, and this led to the development of FAO's SPECIESDAB database (Coppola et al. 1994, see below).

Daniel Pauly had followed these developments with keen interest: he had been, since the days of his field work in Indonesia, in the mid-1970s, a user of FAO products, and he knew their worth, especially for work in the tropics. He had assembled a card-index of most of the population dynamics data then available for fishes and, inspired by Walter Fischer's vision, he suggested, in 1987, that these data should be transferred to a standardized and continuously updated database which he intended to use for his own research and to make available to others through what was then known as the 'ICLARM Software Project' (Pauly et al. 1995).



**FishBase was conceived
in 1987**

He discussed this idea with Rainer Froese, then at the Institut für Meereskunde, Kiel, Germany, who was exploring the capabilities of computers and video systems in general and artificial

intelligence (AI) in particular for identification purposes and who had just finalized an expert system for the identification of fish larvae (Froese and Schöfer 1987; Froese 1988, 1989, 1990; Froese et al. 1989, 1990a, 1990b; Froese and Papisssi 1990).

The FishBase idea was first proposed by Daniel Pauly in ICLARM's 1988 five-year plan (ICLARM 1988), already with a widened scope, as follows:

"The information gap [presently hobbling] on tropical fisheries probably cannot be bridged using [only] classical means, such as maintaining extensive libraries, encouraging interlibrary loans and electronic data exchange. Rather it can be expected that shortage of funds for such classic activities will become increasingly problematic, and hence increase the isolation of scientists working on tropical resources from the mainstream of their science and from reference materials.

It is proposed to alleviate this problem by developing a self-sufficient database implemented on standard microcomputers [...] which would provide key-facts and information extracted from the literature. It would largely replace stock assessment text books. The database would constitute an 'expert system' (an artificial intelligence type information system in which commands or queries can be made in simple English).

These facts and information will include species identification keys, morphometric data, a summary of growth and mortality information for each species, and a summary of biological data on each species. Initially, data on about 200 major species will be provided on diskettes, with the ultimate goal of 2,500 species."

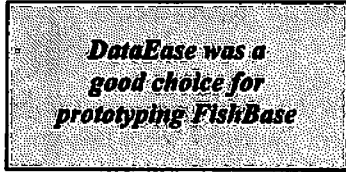
Initially, FishBase was to cover 200 species . . .

Rainer Froese subsequently tried to implement such a system in the AI programming language PROLOG. However, when he realized that this would entail the handling of possibly more than 1,000 variables at the source code level, he discarded this option and, rather, reviewed the relational databases available at that time (dBase, FoxBase, Clipper, Paradox, Oracle, Btrieve, Ingres). He found that these databases were either limited, demanded a lot of programming, could not be distributed without royalties, or were not really meant for PCs. It was by chance that he came across DataEase, a little known DOS database software that combined relational power with exceptional ease of use.

FishBase is not an Expert System

When Rainer Froese was invited by Daniel Pauly to visit ICLARM in the end of 1988, he brought with him the basic design of what was to become FishBase, implemented in DataEase. This design was fine-tuned, table by table, field by field, in a series of meetings with ICLARM scientists Daniel Pauly, Roger Pullin, Ambekar Eknath, Astrid Jarre and Maria Lourdes D. Palomares. Also ICLARM programmers Felimon Gayanilo, Jr. and Mina L.

Soriano had a critical look at the design of the database, and, after long discussions, agreed that:



- using a commercial relational database software was a better approach than programming the system from scratch; and
- DataEase would be a good choice for prototyping FishBase until a better software was found (Froese et al. 1988).

Finally, in December 1988, a computer had been purchased (ICLARM's first 80386 CPU) and data entry started, with research assistants Susan M. Luna and Belen Acosta being assigned half time to the project.

SPECIESDAB

In January 1989, Daniel Pauly and Rainer Froese visited FAO, Rome, to coordinate efforts on FishBase and SPECIESDAB (Coppola et al. 1994), a database conceived by Walter Fischer (see above), implemented in dBase by Rino Coppola, and compiled by Nadia Scialabba. SPECIESDAB contained scientific and vernacular names as well as basic, ecological and fisheries information on the species covered in the *FAO Species Catalogues*. Work on SPECIESDAB had started in 1986. It already covered all catalogues then published so far. The visit led to a Letter of Agreement signed on 15 November 1989 between ICLARM and FAO. It stated that ICLARM and FAO would collaborate in the development of FishBase and would both be entitled to distribute it. This agreement gave FishBase a firm footing and probably helped in attracting the first grant.

The First Grant

Following an initiative of Rainer Froese, the European Commission supported the project in October 1989 with a first grant that allowed the hiring of an additional research assistant (Crispina Binohlan) for data encoding (also Susan M. Luna was assigned full time to the project while Belen Acosta returned to her previous assignment), the purchase of computer equipment (ICLARM's first Local Area Network), and another visit of Rainer Froese to ICLARM in December 1989, to supervise data entry and to write a larger proposal for funding by the European Commission. This funding was granted and, in September 1990, FishBase started as one of ICLARM's major projects under the Directorship of Daniel Pauly, with Rainer Froese as Project Leader.

All Finfish

Soon after the start of full-time data entry it became clear that the distinction between 'commercial' and 'other' fishes was arbitrary, and the original 'goal of 2,500 species' to be 'provided on diskettes' (see above) was changed to include all finfish species, with CD-ROM as the medium of distribution.

Gabriella Bianchi

Gabriella Bianchi, who had worked previously with FAO's Species Identification Programme and had authored and edited several major publications on tropical fishes, stayed with the FishBase Team for two weeks in August 1992. She highlighted the problem of synonymous names that had been entered from older

references; she also reviewed the MORPHOLOGY table, which was modified following her suggestions. Overall, she concluded that "the database appears to be well structured and easy to use and understand. However, for many of the 6,000 species already entered, information is still limited."

Kent Carpenter

FishBase received a second review by Kent Carpenter, project partner from FAO (1990-1995). Kent Carpenter spent two weeks (23 June – 8 July 1993) with the FishBase staff, and had a critical look at the information we had entered on the two families for which he is the world expert, i.e., the Caesionidae and the Lethrinidae. He pointed out that we had no mechanism in place to ensure that information and nomenclature from 'primary' sources (e.g., family revisions done by world experts, such as the authors of *FAO Species Catalogues*) always take precedence over other sources and are not changed unless in agreement with the experts. This criticism applied mainly to information that had come from 'secondary' sources such as checklists prepared by fisheries departments, faunal studies done at a time when insufficient taxonomic information was available or have become outdated because taxonomic information has improved substantially, and faunal studies not done by experts.

We accepted that criticism and started thinking about ways to achieve the required level of quality. The project made an effort to use the latest revisions for as many families as possible to update the SPECIES, SYNONYMS, STOCKS, COUNTRY and MORPHOLOGY tables. Species and families that were updated according to such revisions were marked, to alert encoders and users of their special status. Species still based on other sources were also marked as such. The bulk of the species has now been updated.

The Anilao Workshop

Fish are important to humans in numerous ways, leading to different types of information being available about their biology, distribution, etc. After three years of work we found we had started more mini-projects (= tables) to accommodate this diversity of information than we could possibly fill and keep updated on a permanent basis. Thus, on 9-10 September 1993 the FishBase Team retreated to a beach resort in Anilao, Batangas (south of Manila), to take stock. At the end of two days we had sorted out the wishful from the necessary and streamlined the latter further by an estimate of what each team member could actually achieve in the remaining year before the first release of FishBase. A number of tables were discarded or shelved (AQUARIUM, BREEDSYS, COMPETITORS, ECOREF, ECOSYSTEM, EGGNURS, FRYNURS, GAZETTEER, LARVNURS, MUSEDAT, SHARKMORPH). Others were maintained but with less emphasis (DISEASES, DISREF, OXYGEN, SPEED, OCCURRENCES, GILL AREA, EGGDEV, VISION). In hindsight, this workshop enabled us to overshoot by only two weeks, the deadline for the first release of FishBase on CD-ROM (September 1994), at least as far as data validation was concerned.

From DataEase to Microsoft Access

Microsoft Access required the least programming

Through these early years, preliminary versions of FishBase were installed in many Research Institutes all over the world. However, this installation process also showed the limitations of the DataEase software for creating a royalty-free product.

The DataEase run-time module was difficult to create and limited in its functionality. A slightly better module would have cost twice as much in royalties per user than the current FishBase CD-ROM. Also, as of September 1994, there was no DataEase version that would run from a CD-ROM. Since the PC market was moving towards the Microsoft Windows interface, we decided that FishBase should also make use of that new standard. In mid-1993 we reviewed the available Windows databases (Microsoft Access, Paradox, Foxpro and SuperBase) and decided to use Microsoft Access, mainly because we had the impression that it would be the one requiring the least programming. Programmer Portia Bonilla started recreating the many FishBase tables and procedures under Microsoft Access in December 1993, but it was not before September 1994, i.e., a few weeks before the first release, that we were confident enough to transfer permanently all data to Microsoft Access (see 'FishBase and Microsoft Access', this vol.).

Tony Pitcher and Jeffrey Polovina

ICLARM's Coastal and Coral Reef Resource Systems Program (CCRRSP) of which FishBase was the largest single project was reviewed in April 1994 by ICLARM's Program Committee and by two external reviewers, T.J. Pitcher and J.J. Polovina. The reviewers wrote concerning FishBase: "Scope is huge. Will be very powerful tool and we support transfer to Windows Access system to enable flexible searches. Need to acknowledge that first release may have errors and should openly solicit revisions."

The first CD-ROM

In September 1994, we cut ICLARM's first CD-ROM

One of the early assumptions of the project was that microcomputer hardware, particularly for mass storage, would develop fast enough to hold huge amounts of data at the time of the first FishBase distribution. This turned out to be true and in August 1994, we were able to purchase a first-generation CD-ROM recorder, a one-gigabyte harddisk and a multimedia recording package for altogether US\$8,000. In September 1994, we cut ICLARM's first CD-ROM (a FishBase Demo disk) and in December 1994, we started in-house production of the complete FishBase plus several other ICLARM software on CD-ROM.

FishBase 100

Cutting individual CD-ROMs in-house is one thing, mass-producing 100 or 1,000 copies is another. Requests for FishBase soon outstripped our production capabilities and we had to look for other options. At the time, there was only one commercial CD producer in the Philippines, but unfortunately with no experience in CD-ROM production. It took another considerable effort to overcome a series of annoying problems until, on 6 April 1995, we received a packet with 130 copies of what we called FishBase 100, the first mass-produced version of FishBase to be distributed to collaborators and a few early buyers. Thus, after five years, sweat and tears (but no blood), we had finally turned a vision into a product.

In September 1995, we produced 1,000 copies of FishBase 1.2 which were thereafter widely distributed and which helped to broaden our base to more than 160 collaborators and more than 400 recipients. An analysis of these first recipients showed the following distribution: Universities 36%, Governments 14%, Private Sector 14%, International Research Centers 8%, Museums 7%, Individuals 6%, Non-government Organizations 5%, Libraries 4%, United Nations and their specialized organizations 4%, and Donors 3% (c.f. with Fig. 1 for usage of FishBase). Thus, although FishBase had reached the foreseen range of users, its main target group (Government Fisheries Departments) was underrepresented. This analysis was confirmed by the fact that only 36% of the recipients were from developing countries. It seemed that additional measures were needed to reach the intended audience (see the 'ACP Training Project', below).

**FishBase 1.2 reached
more than 400 recipients
in 72 countries**

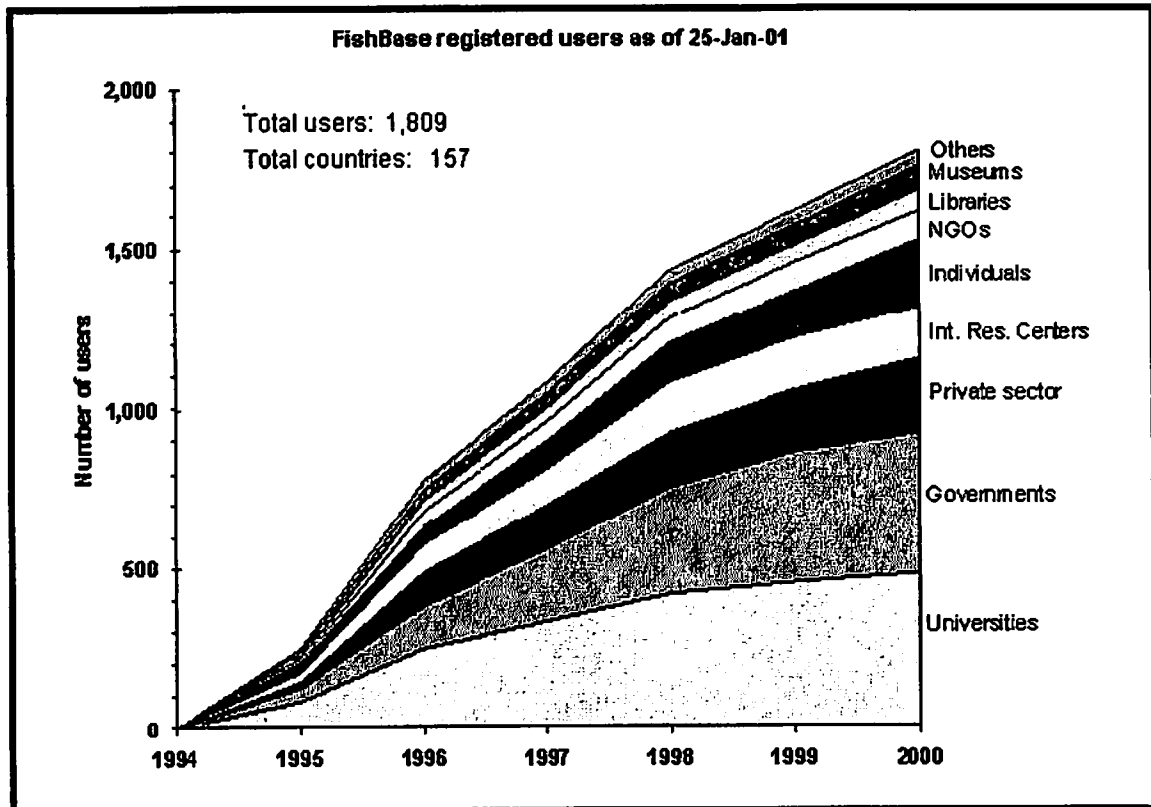


Fig. 1. FishBase registered users by type of institution.

Review in *Nature*

FishBase 1.2 was reviewed by R.A. McCall and R.M. May in *Nature*, Vol. 376:735, 31 August 1995 (see also Froese and Pauly 1995). Under the title *More than a seafood platter* the authors concluded: "In short, FishBase draws together and makes accessible a huge amount of information about fish and fisheries,

which was previously buried in the 'gray literature' of reports from fisheries institutes or working parties. [...] Perhaps most important, and certainly closest to the authors' hearts, it will benefit developing countries, where the lack of comprehensive libraries is often keenly felt."

FishBase 1.2 was also positively reviewed by K. Matsuura (1995) in the *Japanese Journal of Ichthyology*, Vol. 42 (3/4): 342-343. This review (in Japanese) strongly urged Japanese biologists to contribute to FishBase.

The WCP Workshop

On 1-10 October 1995, the FishBase Team organized an FAO-ICLARM-MSI-NORAD Workshop, devoted to the creation of an FAO identification guide to the marine living resources of the Western Central Pacific. During that workshop, 35 renowned fish taxonomists each spent one full day on a close inspection of the information that we had gathered for their respective fish families. The FishBase Team noted all their suggestions and comments, and we marked all records that they had reviewed as checked by the expert. This close contact helped us to understand better the viewpoint of taxonomists and gave us a more secure feeling of our achievements and remaining challenges. It also led to many new friendships and continuing collaboration.

Species 2000

In another form of recognition, FishBase was invited to be one of the Global Species Databases that contribute to a global index of all known species, a project of the Species 2000 Federation (Bisby and Smith 1996; Bisby 2000). ICLARM now hosts the Philippine Office of Species 2000, tasked to produce and update the Species 2000 Annual Checklist on CD-ROM (see also www.sp2000.org).

FishBase 96

In June 1996, we produced 1,000 copies of FishBase 96. The suffix '96' was chosen to indicate our intention to produce annual updates of FishBase.

FishBase 96 presented the first fully tested version of FishBase, thanks largely to the excellent review process organized by Maria Lourdes D. Palomares (see 'Bugs, Blanks and Errors', this vol.). It had a much improved user interface, more and better pictures, the first graphs (see 'Graphs in FishBase', this vol.), a 'Quick Identification' routine, and it covered 15,000 species of finfish.



FishBase 96 reached about 1,000 users, won us many new collaborators, and helped to attract the ACP-EU grant (see below) that supported further improvement and distribution from 1997 to 2000. Due to increased contacts in preparation for this project, the number of users in developing countries had already increased to 47%, up from 36% in FishBase 1.2.

In April 1996, the Program Committee of the ICLARM Board of Trustees reviewed ICLARM's role in database development. It noted that a minimum of US\$70,000-80,000 per year was needed for long-term maintenance of databases such as FishBase. It

recommended a continuing role of ICLARM in database development.

Aquaculture

A review in *Aquaculture* (Rowell 1997) commended the size and scope of FishBase 96, but deplored the 'many gaps and inconsistencies'. It used the herring as example, a temperate species that is extraordinarily well researched and has not received much attention in FishBase. It was correctly noted that in the REFERENCES table, the keyword 'farming systems' overlapped with the keyword 'aquaculture' (the former has meanwhile been removed). The review concluded: "It is a truly impressive undertaking which will, as the wrinkles are ironed out, become an increasingly useful tool for its target audience".

Journal of Fish Biology

FishBase 96 was reviewed in the *Journal of Fish Biology* 50(3): 684-685 by R.J. Wootton (1997). He criticized the poor binding of the FishBase 96 manual (true, compared with the binding of this volume) and the fact that "for taxa with which one is familiar, important sources of published information have not yet been tapped." In addition, he pointed out that "the method of bringing together information from different tables to create new combinations is not transparent." The problem of incomplete information is discussed in the chapter 'Bugs, Blanks and Errors'. The many new boxes in the FishBase 97 book, and expanded in subsequent versions, providing background on the new graphs should—at least partly—have taken care of the latter problem. The review concludes: "Overall, the importance of this database, if it can be progressively expanded, is incalculable."

Environmental Biology of Fishes

A review in *Environmental Biology of Fishes* 50:231-234 (Crawford 1997) noted the ambitious objectives of the project and evaluated the coverage of two temperate species from the Laurentian Great Lakes, which it found to be 'somewhat flat'. It suggested to cover species by ecosystem (which we have started, but what a task!) and to arrange information by life-history "(e.g., embryo, larva if present, juvenile, adult, senescent)", something we actually do for many tables such as metabolism or diet. The advantages of making FishBase available on the Internet were stressed (we got the message, see www.fishbase.org). The review rightfully concludes: "If FishBase is to continue on the road to becoming a useful source of data on world fishes, collaboration is going to be the key".

Reviews in Fish Biology and Fisheries

A review in *Reviews in Fish Biology and Fisheries* 7(3): 374-375 (Turner 1997) criticized the lack of freshwater fish photos, problems with maps, errors on Lake Malawi fishes, incomplete checklists, and uneven coverage of genetics. It concludes that for the fields of freshwater fish biology, inland fisheries and conservation, evolutionary biology, and behavioral ecology "much is omitted and what is presented is strewn with far more errors than I have ever seen in any printed reference book intended for use by scientists". We fixed the reproducible errors, moved the warning

***New Zealand Journal
of Marine and
Freshwater Research***

**The Los Baños
Workshop**

***Long-term goals
of the project***

***In 1996,
FishBase discovered
the Internet***

'incomplete' from the footer to the header of the respective checklists, and decided to continue nevertheless.

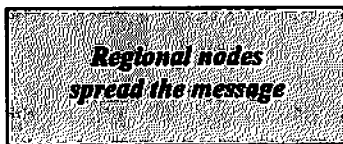
A review in the *New Zealand Journal of Marine and Freshwater Research* 31:281-285 (Francis 1997) commends the goal of FishBase to provide key information on tropical fishes. It noted that references had not been used consistently, e.g., for creating checklists of countries or islands. It noted the limited usefulness of FishBase for temperate countries such as New Zealand. It concludes that "this is a good product that will get much better. [.....] scientists should consider becoming collaborators of the project and help it to improve and expand". We completed the mentioned checklists, improved information for New Zealand, and started a very fruitful collaboration with the author.

In August 1996, the FishBase Team held a two-day workshop at the facilities of the International Rice Research Institute (IRRI) in Los Baños. The team identified short-term tasks to be finalized before the release of FishBase 97, and long-term goals to be finalized by the year 2000. Among the short-term decisions was the new approach to compile morphological information (see the 'MORPHOLOGY table', this vol.), a goal of at least one-graph-per-table, to create a FishBase WebPage (see www.fishbase.org), to complete the coverage of certain areas (Japan, Micronesia, Papua New Guinea, South Africa, Eastern Central Pacific), and to test a new approach to deal with aquaculture information (see 'Aquaculture Species Profiles', this vol.).

The long-term goals included covering all extant fishes; having at least one picture for each species; putting all of FishBase on the Internet (see www.fishbase.org); creating an icon-only interface for laypersons (see Fish Quiz); including some information on morphology for all species; assigning all fish to ecosystems; including all readily available occurrence points; developing a gazetteer for collection localities; and including a table of 'Famous Ichthyologists'. Obviously, most of these long-term goals can only be achieved with the help of collaborators. Thus, if you are already working on any of the above topics please visit the chapter on 'How to Become a FishBase Collaborator . . . and Why', (see below) and consider joining our efforts.

In 1996, it had become clear that the Internet and especially its Worldwide Web was there to stay and would revolutionize the dissemination of information. Making key information on fish as widely available as possible is what FishBase is all about, and thus moving FishBase to the Web was the obvious thing to do. However, while it was possible to query a few tables and display the result in a WebPage (as done with FishBase by David Gee in the context of Species 2000), recreating and testing hundreds of MS Access 2.0 forms for use on the Web was a task well beyond the capabilities of the FishBase Team of 1996. Rather, we thought it would be wiser to wait for Microsoft or another company to create tools that would automate the transfer from MS Access to the Internet.

The ACP Fisheries and Biodiversity Management Project



The European Commission Project Steering Committee

Meanwhile, a FishBase homepage was created by Tom Froese and published on the Internet in August 1996. This preliminary homepage featured some background information, some nice photos by J.E. Randall, an interactive demo with FishBase screens, the full FishBase glossary (2,500 terms), and the full FishBase 96 Book (179 pages).

In May 1997, we hired John Falcon to become the first FishBase Webmaster, to update and to develop the homepage continuously and eventually to make all of FishBase available on the Net.

In the framework of the special support the European Union gives to associated African, Caribbean and Pacific (ACP) countries ICLARM signed in December 1996 a project agreement with the Commission of the European Union on 'Strengthening fisheries and biodiversity management in ACP countries'. The duration of the project was four years, i.e., to December 2000. The project entailed the establishment of regional training nodes in ACP countries, and the gradual building of a functional web of regional and trans-regional cooperation, using modern communication facilities (Vakily et al. 1997a, 1997b).

Training focused on the role biodiversity plays in the assessment of the status of aquatic ecosystems. A major effect of the training was expected to be the gradual building of national biodiversity databases on fish in the ACP countries. To this end, FishBase would serve both as a source of existing information and as a tool to be used as a structuring element in the collection of biodiversity data. Ultimately, the project aimed to contribute to an increased awareness among fisheries researchers and managers in ACP countries of the importance to conserve biodiversity for sustainable use of aquatic resources.

In December 1996, Jan Michael Vakily was hired as Training Coordinator of the ACP Project, supported by Research Assistant, Grace T. Pablico. Five regional outposts were established in Africa (Namibia, Senegal and Kenya), the Caribbean (Belize) and the Pacific (New Caledonia) and two-week training courses for mainly fisheries scientists from the region were conducted at these nodes. Feedback from these courses was used to improve FishBase data, routines and interface. In January 2000, former Steering Committee member Boris Fabres replaced Jan Michael Vakily as Network Coordinator of the project.

To advise the European Commission and to guide and assist the Project Team in executing the 5 million ECU Fisheries Biodiversity Management Project, the Commission of the European Union had invited the following persons as members of the ACP Steering Committee: Dr. Cornelia Nauen, Belgium, Chair; Dr. Tim J. Adams, New Caledonia; Dr. Eduardo Balguerias, Spain; Mr. Amadu Bailo Camara, Guinea Bissau; Mr. Boris Fabres, Trinidad and Tobago; Prof. Guy Fontenelle, France; Mr. Thomas W. Maembe, Tanzania; Dr. Jean Calvin Njock,

Cameroon; Dr. John Tarbit, United Kingdom (later replaced by Dr. Helge Paulsen, Denmark); and Dr. Ben van Zyl, Namibia.

An extremely useful product

The first meeting of the Steering Committee was on 3-5 June 1997 in Manila. After an in-depth introduction to an early version of FishBase 97, they concluded: "The Steering Committee recognized the excellent quality of the work carried out so far by the team. This has led to an extremely useful product." They confirmed the course of the project to cover all fish and to assign them to all countries and large ecosystems. They especially supported the efforts to establish a strong link between FishBase and Ecopath (see Box 21). Four meetings of the Steering Committee were convened between 1997 and 2000, during which continued support was given to the efforts of the Project team and its goal to make FishBase as useful as possible for fisheries and biodiversity management.

FishBase 97

FishBase 97, released in November 1997 covered more than 17,500 species and contained many more and improved pictures, much improved annotated checklists, more occurrence points and thus better maps, many more graphs, a yield-per-recruit analysis routine applicable for the over 1,000 species for which we then had growth parameters, a tool to compare and analyze growth parameters (AUXIM), and more data for more species. Due to the increased number of pictures (about 12,000) FishBase 97 came on two CD-ROMs.

FishBase 98

FishBase 98 was released in late 1998 on two CD-ROMs. It had been transferred to MS Access 97 and therefore required Windows 95, a Pentium processor, and at least 16MB of RAM. The database covered over 20,000 species and the FishBase book had grown to 293 pages. Major improvements were the inclusion of Eschmeyer's (1998) *Catalog of Fishes* databases and a number of new graphs analyzing, e.g., FAO catch data. The number of pictures had grown to over 15,000, and the number of references to over 12,000. With this release the number of registered FishBase users grew to 1,623 in 149 countries.

FishBase 99

The two main objectives of FishBase 99 were to produce a version with French help text and book, and to pass the 23,000 species threshold. These objectives were achieved with the December 1999 release, which came on three CD-ROMs mainly because the number of pictures had increased to 17,000 and the number of fish collection records had increased to 300,000. A new 'Key Facts' form provided 'best estimates with error margin' for essential management parameters such as length at first maturity and length at optimum yield. The number of references used had grown to 16,000. The number of registered users of FishBase CD-ROMs grew to 1,800 in 154 countries.

FishBase 99 was in French

The French-language book documenting FishBase 99 was based on a translation cum update of the FishBase 98 book, by Nicolas Bailly of the Muséum National d'Histoire Naturelle, Paris, and Maria Lourdes Palomares, of the FishBase Project, with the

support of a number of Francophone colleagues, notably the co-editor of the present volume.

A draft of this version was made available to the Francophone participants of the Fourth Training Course on Fisheries and Biodiversity Management in the Context of the ACP-EU project held in Dakar, in 12-23 April 1999, and their feedback was incorporated into the final version. Also, FishBase 99 was presented at one of the preparatory meetings to the Francophone Summit held in Moncton, New Brunswick, Canada, 10-13 August 1999, and devoted to: "New Tools, New Approaches for the Sustainable Management of the Marine Environment". In view of the utility of a French version of the FishBase book in making the database itself accessible to Francophone scientists throughout the world, the participants of the meeting included among their recommendations to the Heads of Francophone States to "make available all databases and information of global utility (for example 'FishBase', now translated into French)".

This provides a strong support for the plan by the Muséum National d'Histoire Naturelle to maintain the French version of FishBase, including a Francophone web site (see below The FishBase Consortium).

The Science in FishBase

Over the years, the data accumulated in FishBase reached a level where they allowed scientific studies that could not have been done otherwise. A first, widely recognized example is the article of Pauly et al. (1998) in *Science* 279:860-863 which used a combination of FAO catch data with trophic data available in FishBase to demonstrate that the world fisheries were 'Fishing down the food web'. Other published examples are an article comparing the 'living fossil' *Latimeria chalumnae* with modern fishes (Froese and Palomares 2000), and a set of empirical equations to estimate important management parameters for all fishes (Froese and Binohlan 2000). A number of exciting new studies, e.g., on generating Lindeman pyramids from the ecosystem-related data in FishBase have started in 2000.

FishBase goes on the Internet

In the course of 1998 it became clear that there would be no magical tool to translate our existing FishBase user interface from MS Access to the Internet, mainly because the increased response time often characteristic of on-line use asked for a completely different design philosophy. In March 1999, we therefore hired Meynard Gilhang as Webmaster (and replacement for John Falcon) and Eli Agbayani as web database programmer, to create a new web interface for eventually all FishBase tables, including graphs and reports. We settled for Cold Fusion as web server software.

**60,000 visitors and
30,000 unique users
in October 2000**

The first FishBase data were searchable on the Internet in October 1998, and by mid-1999, all major tables and a first few graphs were available at www.fishbase.org. Usage on the Internet quickly surpassed that of the CD-ROM with 2,200 user sessions in October 1998, growing to over 30,000 unique users with about 60,000 user

Positive review in Science

sessions and an average duration of 16 minutes per session in October 2000. Following a positive review of the web site in *Science* 286:2423 and the nomination as 'Web site of the week' in the largest North American newspaper *USA Today*, the number of hits reached 554,000 in March 2000.

The SWEDMAR Review

In mid 1999, the Swedish Centre for Coastal Development and Management of Aquatic Resources (SWEDMAR) was tasked to perform a mid-term review of the ACP Training Project and of FishBase. The review team (Lars Hernroth and Roger Lindblom) concluded that the FishBase Team was highly competent and that progress made so far was very impressive. It pointed out that the coverage of several FishBase tables was still incomplete, thus limiting the usefulness of FishBase as a management tool. It stressed the need to continue the FishBase effort and to find a permanent home for it, independent of project-based funding.

The FishBase Consortium

Following up on the SWEDMAR review, the European Commission contacted several European institutions to explore their interest in taking FishBase on as one of their permanent activities. At an extended Steering Committee meeting in Brussels in March 2000 the following institutions were present and declared their interest: Muséum National d'Histoire Naturelle, Paris; Musée Royal de l'Afrique Centrale, Tervuren; Swedish Museum of Natural History, Stockholm; Institut für Meereskunde, Kiel. Together with ICLARM and FAO these institutions agreed to form a consortium to jointly continue the FishBase effort. At a subsequent meeting in November 2000 at FAO, Rome, the Consortium was formally established and the Fisheries Centre of the University of British Columbia, Canada, was accepted as 7th member of the Consortium, represented by Daniel Pauly.

FishBase covers all species

Since Nelson's (1994) count of 24,618 extant species of fish, the most widely accepted estimate for the number of known fishes in the world was 25,000. FishBase passed that magical threshold in August 2000 and celebrated this milestone, together with the press, at a 'FishBase 25,000' event in Los Baños, Philippines, where the team had settled after ICLARM headquarters had moved to Malaysia in January 2000. As the FishBase Team continues to add new species to the database, it will from now on itself provide the current answer to the question 'How many fish are there?' (see recent count at www.fishbase.org).

FishBase 2000

FishBase 2000 comes on four CD-ROMs, to accommodate over 25,000 fish species, over 25,000 photos, and over 600,000 fish collection records. It uses MS Access 2000 as database engine and user interface, but it may well be the last edition to do so as the development and maintenance of two different user interfaces is too demanding. Future CD-ROM (or better DVD-ROM) versions of FishBase are planned to be copies of the Internet version.

FishBase Staff

Over the years, the FishBase Team grew to include a post-doctorate fellow/research scientist (Maria Lourdes D. Palomares), more research assistants (Susan Luna, Crispina Binohlan, Armi

Torres, Liza Agustin (later replaced by Christine Casal), Pascualita Sa-a, Emily Capuli, Rodolfo B. Reyes, Jr., Cristina Garilao), an artist (Roberto Cada later replaced by Rachel Atanacio), a sequence of programmers (Dominador Tioseco, Portia Bonilla, Alice G. Laborte, Ma. Josephine France Rius, Eli Agbayani), and a project secretary (Maria Teresa Cruz). The project also maintained temporary outposts (two years each) in Malawi (Department of Fisheries, Emmanuel Kaunda, Dennis Tweddle), Ghana (Institute of Aquatic Biology (IAB), Mamaa Entsua-Mensah), the Philippines (University of the Philippines, Marine Science Institute (UP-MSI), Emily Capuli) and Peru (Universidad Nacional Agraria La Molina (UNALM), Jaime Mendo) to ensure that FishBase would meet the needs of prospective users in national programs.

Several volunteers supported the FishBase Team

A number of volunteers joined the FishBase Team at different times, Magnus Olsson Ringby from Sweden, Sari Kuosmanen-Postila from Finland, Anelyn Palomares, Ilya and Angela Pauly, Henry Angeles, Neil Del Mundo, Tom Froese, Jayson McArthur, Drina Sta. Iglesia from the Philippines, Anne Johanne Dalsgaard from Denmark and Shen-Chih Wang from Taiwan.

With the start of the ACP Training Project (see above), the team was joined by Training Coordinator, Jan Michael Vakily (replaced in late 1999 by Boris Fabres as Network Coordinator, his assistant, Grace T. Pablico, and Webmaster, John Falcon (replaced by Meynard Gilhang). The existing FishBase could never have been assembled without substantial input from collaborators all over the world (Fig. 2).

FishBase Collaborators

FishBase is host to many databases

Notably, FishBase acts as a host to databases that continue to be maintained and updated by the contributing institutions, with or without inputs from FishBase staff.

Outstanding contributors are:

- FAO's database SPECIESDAB (Coppola et al. 1994) added about 800 commercially important species to FishBase and thus helped FishBase move fast ahead in the early stages of the project. Also, SPECIESDAB was used to check data such as scientific names, FAO names, FAO areas, etc. prior to the first release;
- FAO's database on species introduction (INTRO) prepared by Robin Welcomme helped cover all internationally introduced species (Welcomme 1988);
- the contribution by W.N. Eschmeyer of his GENERA database which was included in FishBase 1.0 allowed standardization of all generic names and higher taxa (Eschmeyer 1990). Since 1998, FishBase also contains the databases underlying Eschmeyer's (1998) *Catalog of Fishes*;
- Thurston and Gehrke's OXYREF database, which provided the largest collection of respiration experiments (Thurston and Gehrke 1993);

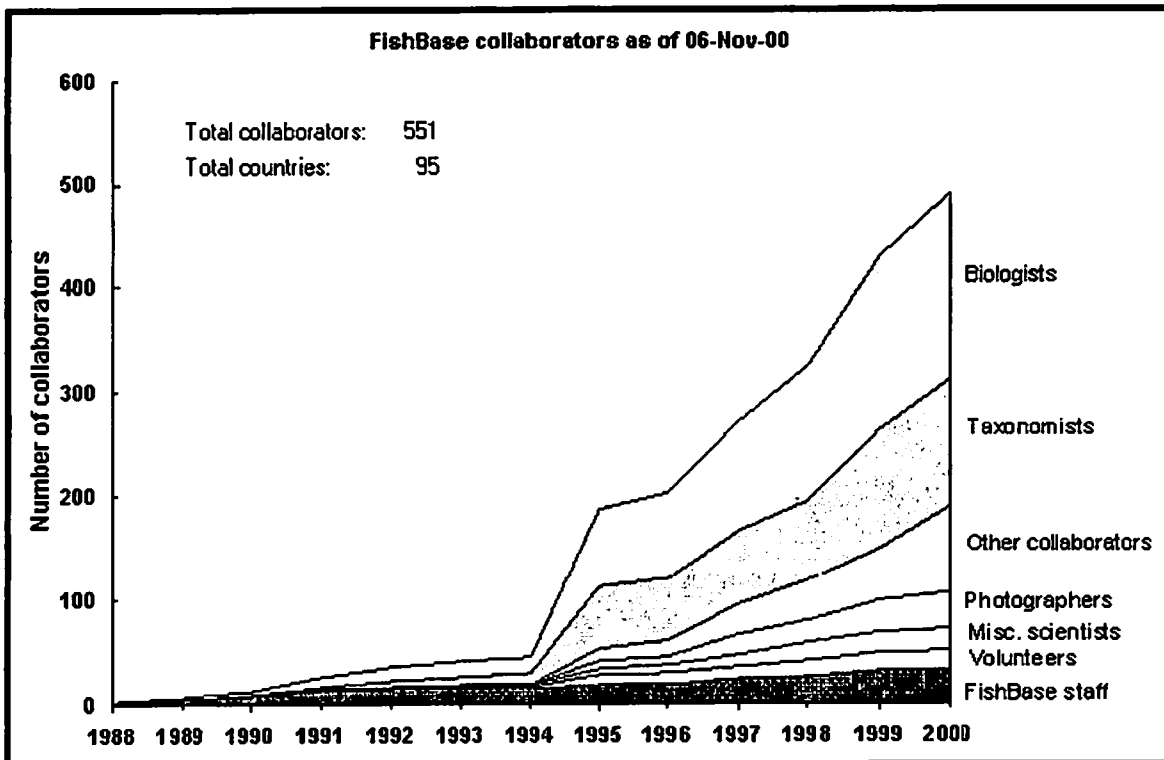


Fig. 2. Cumulative number of FishBase collaborators, i.e., colleagues who contributed data, photos, or complete databases.

- the International Game Fish Association's World Records database (IGFA 1994);
- Craig Hilton-Taylor who made the 2000 IUCN Red List data available for inclusion in FishBase (Hilton-Taylor 2000);
- Guy Teugels of the Musée Royal de l'Afrique Centrale (MRAC), who provided a copy of CLOFFA IV as WordPerfect file and encouraged us, on behalf of the editors, to use all the information in the CLOFFA series (Daget et al. 1991);
- The Musée Royal de l'Afrique Central (MRAC), which made their collection database available through FishBase;
- Jean-Claude Hureau of the Muséum National d'Histoire Naturelle (MNHN), who provided a preliminary set of records from the fish collection database GICIM (Hureau 1991). The Museum and ICLARM signed a Memorandum of Agreement on 12 October 1993 to make all GICIM records available in FishBase and to collaborate on the further development of both databases;
- Ed Houde, who provided his unique database on larval dynamics for distribution through FishBase (Houde and Zastrow 1993);

Ed Houde provided his database on larval dynamics

***EPOMEX contributed a
database on ecotoxicology***

- the Programa de Ecología Pesquerías y Oceanografía del Golfo de México (EPOMEX), of the Universidad Autónoma de Campeche, then led by A. Yañez-Arancibia, which expressed its interest in FishBase rather early, and provided the project through its newsletter, Jaina, a medium for reaching out to colleagues in Mexico and other Latin American countries (see Pauly and Froese 1992). One EPOMEX scientist, Cristina Bárcenas-Pazos, entered ecotoxicological data into a table created for the purpose (see the 'ECOTOXICOLOGY table', this vol.). Also, EPOMEX received a grant from a national donor for collaboration with FishBase to improve the coverage of Mexican/Latin American species;
- Ransom A. Myers, previously with the Department of Fisheries and Oceans, Canada, who made his unique database on recruitment time series available through FishBase;
- Roland Bauchot and his colleagues at the Université Paris VII, who supplied their database on fish brains;
- FAO, for their data on catches and aquaculture production, and also for pictures and other information from the Species Identification and Data Programme, now led by Pere Oliver, made available for distribution through FishBase;
- John E. Randall, who made over 10,000 slides of Indo-Pacific and Caribbean fishes available for inclusion in FishBase.

These and the many other collaborators are listed in the COLLABORATORS table. Their names and/or relevant publications are attached to every record that they have contributed to FishBase.

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- Rainer Froese**

How to Become a FishBase Collaborator... and Why

The chapters of this document are authored by FishBase staff and collaborators

A large project such as that which led to FishBase generates enough credit to share among project collaborators, and FishBase was designed to make explicit the role played by each collaborator.

For example, the chapters of this document are authored by the FishBase staff members and collaborators who have worked with the corresponding tables, data and/or concepts. References to each work from which information was extracted are given in the database, and the names of collaborators are attached to all the records they provided or corrected.

Moreover, three explicit procedures exist in FishBase to give credit to collaborators:

Colleagues who opt to incorporate their work in FishBase make a wise decision

- colleagues who supply data (in form of reprints, reports, unpublished theses, etc., are listed (via their collaborator number) as 'Entered:' on the 'stamp' in the 'Status' section of the respective records. Also, their name appears in the Acknowledgments section of each FishBase species synopsis;
- colleagues who verify FishBase products (e.g., synopses, country lists, common names) appear through their number as 'Checked:' on the stamp of the respective records, and their name also appears on the last page of FishBase synopses;
- colleagues who supply a substantial database for distribution through FishBase have their own tables (such as the GENERA table for Eschmeyer's *Catalog of Fishes* (1998), INTRODUCTIONS table for Welcomme (1988), or LARVDYN table for Houde and Zastrow (1993).

Furthermore, all collaborators' areas of expertise, affiliations, contact address and photo (if supplied) are entered in a COLLABORATORS table, enabling FishBase users to contact directly the experts behind tables and their entries.

In addition to the above, we are working on a concept of Coordinators for certain areas such as taxonomic families (see Box 1), ecosystem or countries (see Box 7), and special topics such as

relative brain size or swimming mode. Coordinators will have their name shown in the headers of the respective tables and printouts, e.g., 'Coordinated by ____.' We are still exploring this concept and invite your comments.

Box 1. An offer to taxonomists.

Keeping track of the status of over 25,000 species in over 500 families is not something that the FishBase Team can do alone. Thus, we would like taxonomists to volunteer to become Taxonomic Coordinators in FishBase for their families of expertise, similar to the approach used in large checklists, such as CLOFFA (Daget et al. 1984), CLOFETA (Quéro et al. 1990) or *Smiths' sea fishes* (Smith and Heemstra 1986). We realize that taxonomists are already overburdened with numerous tasks and may not be keen to take on yet another responsibility. We have therefore thought hard about what we can offer to make such collaboration more attractive. We will provide, to each Taxonomic Coordinator:

- clear and visible credit;
- 3 copies of FishBase 2000;
- printouts (text files) in any required format, from checklist to field guide (database publishing);
- FishBase data, structure, and interface for more specialized CD-ROMs on certain groups, countries, or ecosystems; and
- contacts for collection trips in many countries (FishBase currently has collaborators in 95 countries and registered users in 157 countries).

We will also attach the coordinator's name to every record provided, modified or checked.

Please contact us if you are interested in becoming a Taxonomic Coordinator. We will send you a printout with all the taxonomic information completed so far for the species of your family. We will expect you to edit that printout and to provide us with relevant reprints that we may have missed. A FishBase Team member will be assigned as your contact and will make the changes to the database. We will provide you with a password that allows you to edit FishBase directly through the Internet. Please let us know what you think about this offer.

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Rainer Froese

***FishBase on the Web
received over 750,000 hits
in November 2000***

We believe that colleagues who opt to collaborate with us, i.e., opt to see some of their work incorporated into FishBase, benefit because:

- their published work will reach more people;
- their work will become integrated into a larger whole, and thus becomes easier to assimilate, while remaining theirs in terms of scientific credit;
- the integration in FishBase involves checking of at least the scientific names and generally leads to the identification of

errors which, while easily corrected, may not have been noticed otherwise; and

- also, once a publication is linked to a FishBase species, it is automatically updated if the scientific name changes. For example, the many publications written on *Salmo gairdneri* are now easily found under *Oncorhynchus mykiss*.
- The description of various tables in this volume suggests how we plan to improve these tables and their coverage, and hence FishBase. Please contact us if you wish to become one of our collaborators.

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Daniel Pauly

Publishing for FishBase

With FishBase being conceived as a scientific database, great care has been devoted to identify the sources of the encoded information, both to assign proper credit to its original authors and to allow verification (by checking the documents from which the information was extracted).

This approach is not applied strictly, i.e., there are cases where the FishBase records contain details that are not given in the publication cited as source, e.g., as in the case of occurrence records, extracted from the files of a demersal trawl survey documented through a summary report that does not include the raw data.

Still, the principle holds, and it has an important consequence: unpublished data may not be entered into FishBase.



The FishBase tables were designed, on the other hand, to serve as template for collecting various types of information. Thus, for example, the table used to document length-weight relationships (the 'LENGTH-WEIGHT table', this vol.) is also meant to serve as guide for the type of information that should be included when publishing such relationship.

Consequently, we have encouraged the writing and submission to the Fishbyte section of *Naga, the ICLARM Quarterly*, of manuscripts that followed this format, and thus have enabled the publication of a large number of records for the table in question (see Torres 1991; Kulbicki et al. 1993).

Also, we have made arrangements with the ACP-EU Fisheries Research Initiative for publication of edited collections of related contributions in the report series of the Initiative.

We also have an agreement with the *Journal of Applied Ichthyology* of incorporating in the section devoted to short communications articles in a format standardized such as to match that of FishBase tables (e.g., Froese, 1998). This enables documentation, in the refereed literature, of those key features of fish that are often straightforward to describe but that are commonly neglected, although essential for sophisticated or comparative analyses (L/W relationships, growth parameters, food and feeding habits, reproductive characteristics, etc.).

We believe that such standardized short communications will become a much-appreciated section of journals, as is the case for the standardized, brief descriptions of new compounds included in chemistry journals. Please contact the FishBase Project if you have a suitable manuscript.

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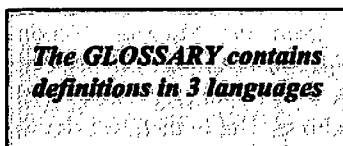
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Daniel Pauly

FishBase Translations

The necessity to communicate and to make information in FishBase available to users other than people familiar with English led to an earlier initiative by the FishBase Team to provide translations of the CD-ROM version of FishBase in, at least, the major languages used in Africa, the Caribbean and the Pacific (see the 'ACP Project', this vol.). This required an approach that would permit annual updates of the translated version, but without the time consuming process of traditional translations.

In order to tackle this enormous task, a strategy was proposed in Froese and Pauly (1998) consisting of four different phases, 1) the translation of terms and definitions in the GLOSSARY table (see FishBase 99 CD-ROM); and 2) the translation of the FishBase 98 book (see Froese and Pauly 1999). These resulted in the following translation related products of FishBase:



- a dictionary of English and French equivalent terminology developed in language interchange format (LIF);
- a glossary of technical and related terminology used in FishBase with word equivalents and definitions in English, French and Spanish;

- a database of English/French sentence pairs on which Froese and Pauly (1999; i.e., the French translation of Froese and Pauly 1998) was based;
- the GLOSSARY table: available in annual versions of the CD-ROM (from 96 to the present) and is searchable on-line in the Internet version of FishBase at www.fishbase.org;
- Portuguese translation of the FishBase 96 book (Froese and Pauly 1996): available in the FishBase 97 version of the CD-ROM;
- Portuguese translation of the FishBase 97 book (Froese and Pauly 1997): available in the FishBase 98 version of the CD-ROM and available in the Internet version of FishBase;
- French translation of the FishBase 98 book (Froese and Pauly 1998): available in the 1999 release and in the Internet version;
- Portuguese and Spanish translations of the FishBase 99 book (Froese and Pauly 1999): currently being developed, and will be made available through the Internet in early 2001.

Because of the recent breakthroughs in Internet technology, FishBase is able to provide links to on-line translation services of websites including its search pages (see website translation links in www.fishbase.org). Such translation services offer a preliminary translations of important information contained in FishBase web pages. They cannot, however, replace traditional (and thus precise) translations.



The new translation strategy

Since the further development of FishBase will focus on the Internet version (in lieu of annual updates of the CD-ROM version), the strategy mentioned above has been recently modified. The new translation strategy involves:

- 1) translation of the fixed text (titles, labels, notes) of the web pages into French and possibly other languages, making best use of XML technology;
- 2) translation of choices in multiple choice fields; and
- 3) simplification and standardization of vocabulary and grammar in English free-text fields, to achieve good results with machine translation 'on-demand', using dedicated dictionaries.

As a first attempt, collaborators from the Muséum National d'Histoire Naturelle (MNHN) will spearhead the development of a French website in 2001. This work will be largely based on the products of the strategy mentioned above. The French website will be hosted and maintained by MNHN.

None of the members of the FishBase Team is a first language speaker of English and we all had to learn English at some point in our lives. Thus, we understand, from personal experience, what it means to be confronted with an English language document that one does not understand. We hope that the FishBase translations will help overcome this language barrier; in the same way that FishBase helps overcome disciplinary barriers in the world of ichthyology and fisheries.

It is hoped that other institutions catering to non-English readers will follow the example of MNHN and help disseminate information contained in FishBase by creating or supporting the development of non-English websites. If you can help with the translation of FishBase into other languages, please let us know. We will supply you with the GLOSSARY and FishBase book text files as well as help facilitate information exchange between those who have experience in creating websites.

Maria Lourdes D. Palomares

Bugs, Blanks and Errors



When Prof. April sat for the first time in front of FishBase, he decided to call up a group of South American killifish, and after a quick look through the list of species, he informed the astonished FishBase Team that “the names are all wrong.” When we followed up and asked for a reference, it turned out that Ms. May, a student of Prof. April, had recently completed a thesis that strongly modified the taxonomy of this group and largely disagreed with a previous revision, the basis for the information in FishBase.

Though the names in the above story (though not the story itself) are fictional, it serves to illustrate a number of issues concerning the quality of information in FishBase. Most first-time users and, unfortunately quite a few of those who wrote reviews of FishBase (see the ‘Making of FishBase’, this vol.) tend to look up the species that they know best. Not surprisingly, as would occur with any encyclopedia, they then find that they know something about these species that FishBase does not know. In contrast to a printed encyclopedia, however, they can supply the relevant reprint to the FishBase Team. They will then find their species well covered in the next update, and their name in the list of people who helped improve FishBase. However, even before this happens they will usually find a new piece of information about the ten species they know best. And of course, they will also find relevant information on the 24,990 species with which they are not familiar.

In the case of Prof. April, the situation was more complicated because Ms. May’s thesis had not yet been exposed to the judgment of other taxonomists, who might decide to ignore the taxonomic re-arrangement proposed therein. However, this is not an attempt to belittle the presence of bugs, blanks and errors in FishBase, but rather to serve as introduction on how we deal with them.

***A work of this size inevitably
contains errors***

A work of this size and complexity will inevitably contain errors and discrepancies. The problems that users of FishBase are likely to encounter are of four basic types, presented here in descending frequency of occurrence:

- i) Empty fields, though information does exist that could have been used;
- ii) Erroneous entries, i.e., either entries not supported by the cited reference, or reproducing a manifest error in that cited reference;
- iii) 'Bugs', i.e., routines that do not perform the functions they were designed to (Myers 1979; Bruce 1980; Ozkarahan 1990; Pfleeger 1992); and
- iv) Tables that should have been designed differently.

***We adjust tables
to fit the data***

To deal first with item (iv); we propose you read in this volume the background to the table in question. If you still think that it should be redesigned, please contact us, let us know of your reasons, and the data which support them. We will very likely adjust the table to fit the data.

Empty fields (i) are a 'problem', and we are doing our best to fill as many fields as possible for as many species as possible. However, the information required may not have been published or may not be available to us, or we may not yet have had the time to use a publication completely. Please send us any publication which you think would be useful for filling in a field or table that would otherwise remain blank (see 'How to Become a FishBase Collaborator . . . and Why', this vol.). Collaborators in countries, provinces or projects who want us to focus on the species of their respective areas are invited to consider supporting us with modest funds (as done by Mexico, British Columbia, Australia and MRAG and considered by New Zealand and the Mekong Secretariat) or sending personnel to work with the FishBase Team (as done by Taiwan and, indirectly, by Denmark, The Netherlands and Finland).

Send us an e-mail

FishBase differs from numerous other databases, especially those created by individual researchers, in that it is widely available. This implies that the errors in (ii) above are exposed to the critical gaze of a large numbers of users. Some may scoff, and perhaps dismiss as unattainable our attempt to present reliable key information on all fish species of the world (e.g., Turner 1997). Other users—and we hope they will be a majority—will send us an e-mail to point out our errors (or those of our sources), and provide alternative entries (and/or sources). We believe that if this happens, most of egregious type (ii) errors will be purged from subsequent versions of FishBase.

*Two months of
bug-hunting found a lot*

The type of problems FishBase users may encounter in (iii) are the true bugs of our title. The following step-by-step procedure was followed (by M.L.D. Palomares) to reduce the number of bugs to a minimum:

- a) For all tables, verify that:
 - all links are properly connected, i.e., that buttons opening other windows do open the designated window and that buttons running routines or graphs, e.g., **Print** buttons, do run the designated routines.
- b) For all fields of a table, verify that:
 - choice fields consist of mutually exclusive and comprehensive choices;
 - fields linked to other windows, e.g., reference fields, are properly connected; and
 - field values that are automatically computed by internal routines are numerically correct.
- c) For all procedures, verify that:
 - the buttons accurately run the designated procedures or graphs.

The extensive list of bugs caught in this annual process is handed over to the persons responsible for the tables in question and to FishBase programmer, Ma. Josephine France Rius for FishBase 2000. Then, the last step was to:

- d) Verify that all bugs spotted in (a) to (c) were fixed.

This process was also used to ensure that all forms of graphs and reports followed an agreed standard, that screen prompts were straightforward and easily understood, and that all technical terms were covered in the GLOSSARY.

FishBase, being as large as it is, precludes us from guaranteeing that this procedure picked up all bugs. However, we do guarantee that we will repair any remaining bug you bring to our attention.

Acknowledgments

We thank all FishBase users, past and future who contributed (or will contribute) to making FishBase as free of bugs, blanks and errors as possible given our means.

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Maria Lourdes D. Palomares, Rainer Froese and Daniel Pauly

A Quick Tour through FishBase



FishBase 2000

The following section will guide you through FishBase, which we assume has been successfully installed in your computer. Click the FishBase icon to start FishBase.

Let us assume that you want information on one of your favorite fishes, the leopard coral grouper *Plectropomus leopardus*. Click the Species button. The Search by ... dialog box will pop up on your screen. You are offered the options to search by scientific name, common name, family, country, and topic; to use our 'Quick Identification' routine; or search in Eschmeyer's GENERA or SPECIES databases.

Click on the Scientific name button. Click on the little arrow on the right side of the Genus field and type **plectrop**; you will notice that FishBase displays an alphabetic list of available generic names, jumping to the next best match as you continue typing, until it reaches *Plectropomus*. Press Enter to select that genus and get to the species field. If you click on the little arrow at the right end of the species field, FishBase displays an alphabetic list of all *Plectropomus* species. Select *leopardus* and click on the Find button.

FishBase now opens the SPECIES table, with the following information:

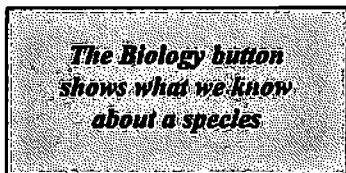
- the scientific name of the species, i.e., *Plectropomus leopardus*;
- the author who first described the species; in this case, (Lacepède 1802);
- the FishBase common name as suggested by FAO, i.e., leopard coral grouper;
- the FishBase reference number of the main source used for the species, here 005222;
- the family (Serranidae) and subfamily (Epinephelinae); and
- the order (Perciformes) and class (Actinopterygii) to which the species belongs.

If you double-click on the reference number, the complete reference will pop up on the screen displaying the author, year of publication, the title and source. Go back to the SPECIES window by clicking on the Close button.

Click on the button with the fish icon to display a full screen picture of *Plectropomus leopardus*. The picture caption includes the scientific name, the filename of the picture in brackets and the number of pictures available for this species. The lower left hand corner gives information on the length of the fish in the picture and

***If you double-click
on any reference number,
the complete reference
will pop up***

the type of length used for measurement, the locality where the picture was taken and the photographer's name. Click on the right arrow button to see more pictures, or click on the **Exit** button to return to the SPECIES window. Click on the button with the **Globe** and then the **Show** button in the resulting SPECIES OCCURRENCE window and on the **Continue** button in the MAP INFORMATION window to display a FishBase map that marks countries and localities where the leopard coralgroupier occurs. Switch off the zoom function by clicking on the QueryON option of the menu bar on the upper left hand corner of the WinMap32 window. Then double-click on one of the dots to open a small window with information on this record. Click on the **Close** button in the menu bar to return to the SPECIES OCCURRENCE window, then the **Close** button to return to the SPECIES window.



In the center of the SPECIES window, there are several buttons which call the different FishBase forms containing information on the leopard coralgroupier. Supposing that you are interested in knowing more about the life history of the leopard coralgroupier, click on the **Biology** button and wait for the BIOLOGY window to appear. This will give you access to what is known about the leopard coralgroupier. All black buttons indicate available information. Conversely, the gray buttons indicate knowledge gaps.

Click on the **Reproduction** button to get information on reproductive biology of the leopard coralgroupier. Click on any of the available buttons in the REPRODUCTION window to view detailed information.

Click on the **Spawning** button from the REPRODUCTION sub-menu. This calls a list of localities for which information on annual spawning activity is available. Click on the **Graph** button on the upper right corner of the SPAWNING SPREADSHEET window. A line graph of the monthly reproductive activity aggregated over the number of samples available is shown.

Close the REPRODUCTION and BIOLOGY windows to get back to the SPECIES window. Click on the **References** button to display a list of all the references that we have used so far, for *Plectropomus leopardus*. You can go to the next, the previous, the first and the last reference by using the recorder buttons at the bottom of the screen. Double-click on any reference and the REFERENCE USED window will pop up with all the details of that source.

Note that the **FB** button in the upper right corner of the SPECIES window will connect you to the 'Species Summary' page of *Plectropomus leopardus* where you may find updated information on this species.

Go back to the Main Menu by closing all the windows so far opened. You can now play with the other buttons, e.g., find a term

in the glossary, look at a slide show of fish pictures, or search the references used for a family, a genus or a species.

You can also try the **Fish Quiz** and test how good you know your fish. Enjoy FishBase.

Maria Lourdes D. Palomares

Information in FishBase

FishBase has 60 Main Tables

***The information
in FishBase equals an
encyclopedia of 40 volumes***

FishBase is large. Its information on fish biology is structured in more than 1,000 database fields grouped into 60 major and 70 minor tables with altogether more than two million records. More than 400 forms and preprogrammed procedures draw on this information to create a variety of screens and reports. These reports have been designed to meet our own needs as well as the anticipated needs of FishBase users in general. If you need a special output not provided so far, please let us know and we will consider it when we update FishBase. Alternatively, you can purchase the Microsoft Access 2000 database software and create your own reports from the data accessible on the CD-ROMs (see chapter on 'FishBase and Microsoft Access', this vol.).

On the web, the result of queries and the data behind graphs can be downloaded and saved in htm format, which can be read directly by most modern text, spreadsheet and database programs.

We present below a description of the information in FishBase, how to access it, and how to output information. Note that some of the fields mentioned might not be visible on the form but hidden under links or buttons. For example, information on who entered, modified or checked information is hidden under the Status button in the CD-ROM version. This is also where you find fields used for internal purposes, such as SpecCode and StockCode. The README file on the Database CD-ROM contains information on any changes, e.g., in the preprogrammed routines.

***The README file contains
latest information***

Search by Species

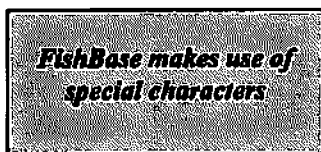
***Many ways to find
your fish***

The following refers to the CD-ROM version of FishBase:

If you want to find information on a certain species, click on the Species button in the Main Menu. You can also select Species by Topic, to generate, e.g., a list of all species for which growth data are available. You are offered a choice to find your species by scientific or common name, or to pick it from a list of species within a family or within a country. You can also use our 'Quick Identification' routine.

After clicking on the Scientific name button you have the choice to either select the generic and specific names from alphabetic lists, or to enter the first few characters, in which case FishBase will automatically complete the names. To do the former, just click on the little arrow at the right side of the field. Note that once you have entered a generic name, the choices for specific names are limited to that genus. Clicking on the Find button brings you to the selected species. If there is more than one match for the name you

have entered, a list of possible species will be displayed. Double-click on a row to go to the desired species.



If you click on the **Common name** button, you will be prompted to enter a vernacular name. Note that a wildcard (*) is automatically appended to your entry and FishBase also searches for the occurrence of the search term in subsequent words, e.g., a search for 'cod' will find 'codlet' and 'cod goby' as well as 'Atlantic cod'. FishBase makes use of special characters available in Windows, i.e., common names may contain any of the following characters: à, á, â, ã, ä, å, æ, ç, è, é, ê, ë, ì, í, î, ï, ñ, ò, ó, ô, õ, ö, ø, ù, ú, û, ü, ß, etc. After clicking on the **Find** button FishBase displays matching common names together with the country where they are used and with the corresponding scientific name. Double-clicking on a name brings you to that species in the SPECIES table. Alternatively, you can click on the **Browse** button on the right of the field and select a name from the alphabetic lists. If you have entered a country and language, the list will be restricted to common names in that country and language. This feature allows you, for example, to find 'Chinook' (the language) in British Columbia, the province of Canada here treated as a 'country'.

If you opted to search by **Family**, FishBase will offer you the choice of picking a family from a list or enter the first few characters to have matching names completed, as described above for scientific names. After you click on the **List species** button, FishBase will display a list of all available species in that family, in alphabetic order together with author and FishBase name. Double-clicking on any row will bring you to the corresponding record in the SPECIES table.

You can also select a species from a list of freshwater and/or marine fishes for a given **Country**. Again, double-click on any row to get to the SPECIES table.

SEARCH BY TOPIC shows the main data categories available in FishBase, and allows you to quickly find all species in a country, order or family for which such information is available.

Quick Identification

Identification of fish is only a side aspect of FishBase. We still cannot imagine fieldworkers and laypersons carrying around notebook computers to identify their catch, although with the advent of Internet enabled cellular phones that time might come soon. For now, thumbing through a well illustrated, handy field guide such as Humann (1994) or Lieske and Myers (1994) is still the fastest and most comfortable way to find information on the more common and well-distinguished species. Identifications that have to stand scientific scrutiny require an altogether different approach: they must be carried out in a laboratory with special equipment and by well-trained personnel.

We use pictograms to let the eye quickly compare the specimen in question with generalized drawings of major fish groups

On the other hand, relational databases are well suited for identification purposes when large numbers of species are involved (Froese 1989, 1990; Froese and Papisissi 1990; Froese et al. 1989, 1990). With relatively few and simple entries, FishBase can guide the user to a short list of possible species with pictures, morphological features, and pointers to the relevant literature. Similar to many field guides, we use pictograms to let the eye quickly compare the specimen in question with generalized drawings of major fish groups. For the many typically fish-shaped species the approach we have chosen is inspired by the fin formula key to bony fishes presented in Smith and Heemstra (1986). The key is based on the fact that in most species of bony fish, counts of dorsal and anal fin rays are relatively stable and easy to obtain. Together with the geographic area, habitat (freshwater, brackish or saltwater), the size and a broad taxonomic classification (order or family) this forms a search pattern that quickly reduces the number of possible species (see also the section on the 'MORPHOLOGY table', this vol.).

Geographic area, size and taxonomic group quickly reduce the number of possible species

After clicking on the **Quick Identification** button, you have the option to specify the **Continent or Ocean**, and **Depth range** where you collected your specimen(s). This information is used to narrow the number of possible species. You can leave these fields blank if you do not have that information. If you already know the **Order, Family, or Genus** then click on the **Taxa** button, which allows you to enter such information and start the search.

Fin ray counts provide a quick entry to identification

If you are not familiar with the taxonomic classification of your specimen(s) clicking on the **Pictures** button brings up pictograms of easily recognized fish families (see Fig. 3). After you identified a group, you can still add fin ray counts or select a genus.

Clicking on the **Fin rays** button lets you enter fin ray counts for the dorsal and anal fin. Note that the resulting list will be drawn from those species for which we have entered such counts, unless you specify also the order or the family. FishBase 2000 contains fin ray counts for over 8,000 species of bony fish and is complete for, e.g., British Columbia, Japan and South Africa. We plan to cover all Western Pacific teleosts to have this routine complete for a larger area. We have started to make a few basic measurements on drawings or photos of adult fish to be used for identification. We also intend to create a similarly simple identification procedure for cartilaginous fishes. Suggestions or offers to collaborate on this are highly welcome.

How to get there

You get to the identification procedure by clicking on the **Species** button of the Main Menu window and clicking on the **Quick Identification** button in the **SEARCH BY ...** window.

Internet

We plan to provide a similar Quick Identification service on the Internet in early 2001.

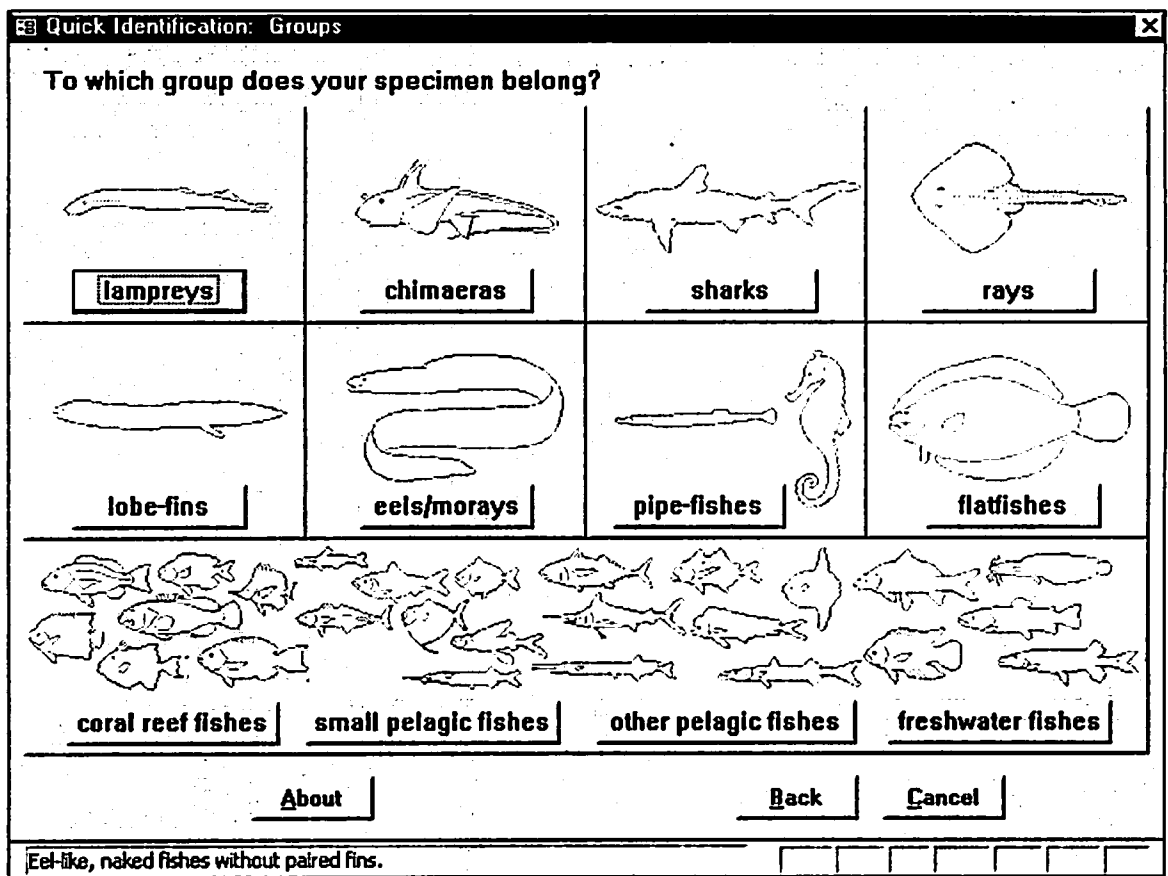


Fig. 3. FishBase 2000 screen for quick identification. Note that the bottom line provides a short description of main characters for the active button, here, the lamprey.

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- Rainer Froese and Rodolfo B. Reyes, Jr.**

Reports

Extracting information from FishEase is made easier through preprogrammed reports which perform global searches and print summary information, such as species synopses and country lists of species. The different types of reports available from the CD-ROM version include:

- synopses of information available in FishBase for particular species;
- checklists of all species, by family;
- different annotated checklists of fishes, by country;
- lists of common names, and the related local knowledge on fish, by country/culture; and
- population dynamics data, by family.

Similar reports by country or family are available from FishBase on the Internet.

Species Synopses

The species synopsis is a standardized report based on the format suggested for such documents by Rosa (1965). Information in this document is printed directly from FishBase, without any subsequent editing. Thus, it must be treated only as a working document and not as a publication.

Two types of synopses are available in the SPECIES SYNOPSIS window: **Short** and **Full**. A short synopsis will give a standardized output of basic information on a given species from selected entries in FishBase, i.e., information extracted from the FAMILIES, GENERA, SPECIES, SYNONYMS, COMMON NAMES, STOCKS, COUNTRY, REFERENCES and COLLABORATORS tables. A full synopsis extracts information from all FishBase tables. It must be noted that for well-researched species, e.g., *Oreochromis niloticus niloticus*, *Clupea harengus* or *Oncorhynchus mykiss*, a full species synopsis will print more than 200 pages.



***A full synopsis may cover
more than 200 pages***

The accuracy of information in these two types of working documents is not guaranteed and we are aware that they will be incomplete. Thus, we invite readers to send complementary information and/or corrections, preferably in the form of reprints or reports to the FishBase Project.

Doing so will make you a FishBase collaborator and earn you a free copy of FishBase.

How to get there

You get to the synopsis routines by clicking on the **Reports** button in the Main Menu window and clicking on the **Species Synopses** button in the PREDEFINED REPORTS window. Since FishBase will ask for the picture CD-ROMs when you click on the **Print** button, keep the picture CD-ROMs at hand.

Internet

On the Internet, the 'Species Summary' page provides some of the information contained in these synopses.

All Species of a Family

The **Reports by Family** menu window has two checklist options:

1. a **Checklist** of all species in a family so far entered in FishBase, which includes summary information on the family and lists for each species, the valid scientific name, the author of its original description, the FishBase common name, geographic range, maximum size so far recorded, depth range, habitat and migratory patterns and the main reference used to obtain this information;
2. a **Checklist with Summaries** which expands option (1) to include information on distinctive characteristics, meristics, environment, habitat, biology, importance and the references used to obtain this information.

The checklists are provided with a bibliography and option (2) gives additionally, a list of all collaborators who worked on the species in a family. Option (1) can be produced on three output mediums (screen, printer and as a file). The screen output in option (1) provides links to other tables, i.e., a doubleclick on the scientific name will open the SPECIES window for valid names and the SYNONYMS window for synonyms. Option (2), however, can only be produced as a printed output.

How to get there

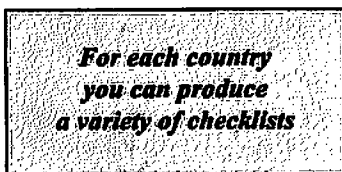
You get to this routine by clicking on the **Reports** button of the Main Menu window and clicking on the **All Species of a Family** button of the PREDEFINED REPORTS window.

Internet

On the Internet, you can create a list with scientific name, author, and English common name in the section 'Information by Family'.

Different Checklists by Country

This routine produces the following checklists for any country:



- all fishes so far assigned to the country;
- all marine fishes so far assigned to the country;
- all freshwater fishes so far assigned to the country;
- all fishes that have been introduced to the country;
- all endemic fishes of a country;



- all fishes under threat (**threatened**) and assigned to the country;
- all game fishes assigned to the country;
- all fishes that are **dangerous** to humans and assigned to the country;
- all **aquaculture** species assigned to the country;
- all **protected** and restricted fishes assigned to the country;
- all **aquarium** fishes assigned to the country;
- all fishes of a **family** assigned to the country;
- **finfish statistics**, i.e., number of species in various categories; and
- a preliminary list of fishes **collected** in the country and now stored in various museums.

The checklists were assembled from country (see COUNTRY table, this vol.) and species records (see SPECIES table) entered in FishBase. Country records indicate the presence of a species in a given country while species records provide information on the use of that species. Although country records do provide fields on the actual use of a species in that country, these may not necessarily be filled in for all species occurring in a given country. In such cases, the importance fields in the SPECIES table will have been filled in. Thus, lists such as fishes used for sport fishing, in the aquarium trade or in aquaculture may include species not presently used for these purposes in that country. Presence of a species in such a list only indicates potential and not current or actual use. Consult the Internet version of FishBase at www.fishbase.org to obtain updated information.

The checklists may be directed to the screen, printer or a text file. Printed and saved to file checklists include some information about the geography, climate, hydrology and environmental status of the country. Also, some statistics are presented on the number, type, use and knowledge of the fishes. There may also be remarks on the occurrence in the country, common uses, museum records, etc.

Species are arranged by Order and Family and include information on: maximum size; habitat; importance for fisheries, aquaculture, aquarium trade, sport fishing, or as bait; potential danger to humans; status of threat; and status of protection.

Screen outputs are interactive, i.e., double-clicking on a species will bring up more information and enable you to access any of the tables within FishBase.

How to get there

You get to any of the choices listed above by clicking on the Reports button of the Main Menu window and clicking on the

Different Checklists by Country button of the PREDEFINED REPORTS window.

Internet

On the Internet, you can create similar lists in the section 'Information by Country/Island'.

Common Names

The **Common Names** menu includes three output routines that generate **Screen**, **Printer** and **File** outputs of information based on the COMMON NAMES table. These are:

A common name often refers to more than one species

Species by Common Name produces a list of the common name(s) found by the search term, the valid scientific name(s) which corresponds to the common name, the Family to which the species belongs, and the country where the common name is used (in brackets). For common names referring to a number of species, e.g., 'shark', 'grouper', 'cod', 'surgeon fish', etc., the list may consist of more than 100 names.

Common Names by Language produces a list of common names of fishes in the selected language and includes the country where the name is used and the valid scientific name of the species to which it applies.

Local Knowledge produces a list of common names used in a selected language and country. This list also includes the scientific name, and may include information on the etymology of the common name and other information on the species in question, relevant to the culture defined by the language and country selected.

Each list is followed by a bibliographic listing of all sources used to gather the information. Note that the list produced on screen is interactive and allows, upon double-clicking, access to the COMMON NAMES table and/or SPECIES window and thus all other buttons leading to more information on a given species.

How to get there

You get to the Common Names Menu by clicking on the **Reports** button of the Main Menu window and clicking on the **Common Names** button of the PREDEFINED REPORTS window.

Internet

On the Internet, a search by common name will produce a list with the fields common name, country and scientific name; this list can be ordered by different criteria.

Population Dynamics by Family

The **Population Dynamics** menu was incorporated in the Reports menu in order to facilitate access to population dynamics data in FishBase, by Family. The four routines presented below provide **Screen**, **Printer** and **File** outputs and a bibliographic listing of all the reference sources used for the related tables. Note that the Screen option is interactive and a double-click on any row will

***You can print population
dynamics data by family***

bring information that is more detailed for a species. The **Start** button initiates the search for information for the specified family, directed to the specified output medium.

The **Growth Parameters** button provides a listing of the von Bertalanffy Growth Function (VBGF) parameter estimates: growth coefficient (K ; year⁻¹), asymptotic length, (L_{∞} ; cm) and age at length zero (t_0 ; years).

The **Maturity Information** button provides a listing of the mean length (L_m) at first maturity, age at first maturity (t_m ; years), the sex and length range of specimens used (cm).

The **Natural Mortality** button provides a listing of natural mortality estimates (M ; year⁻¹), the method by which the estimate of M was obtained, the mean environmental temperature (°C), and the VBGF parameters K and L_{∞} .

The **Length-Weight Relationships** button provides a listing of regression coefficients (**a**) and (**b**), the length range of the specimens in the sample (cm), the number of specimens in the sample, and the coefficient of correlation (r) of the log-linear length-weight regression commonly used to estimate **a** and **b**, if any.

How to get there

You get to this routine by clicking on the **Reports** button of the Main Menu window and clicking on the **Population Dynamics by Family** button in the PREDEFINED REPORTS window.

Internet

On the Internet, you can produce an overview of available information by area if you click on the **Ecopath parameters** radio button in the 'Information by Topic' section.

Reference

Rosa, H., Jr. 1965. Preparation of synopses on the biology of species of living aquatic organisms. FAO Fish. Synops. No. 1, Rev. 1. 75 p.

Maria Lourdes D. Palomares

National Databases

*You can create your
own database*

*You can attach your
own pictures*

In the CD-ROM version, we have included several user databases as FishBase modules that are created on demand and can be maintained and updated by the user.

This is meant to turn FishBase from a *passive* information providing system into an *active* reporting tool for researchers, divers, anglers, aquarists, small museums, reserves, public aquaria, fisheries projects, etc. Users can enter, update and print all information that is relevant to the collection, national occurrence and local knowledge of fish. They can also attach their own digitized pictures (in JPG, GIF, PCX or BMP format). At the same time, all information that FishBase holds on these species—including maps and pictures—is only a mouse-click away. The user databases reside on the harddisk and can be saved to diskette for backup purposes; they will not be overwritten by updated versions of FishBase. You can also **Repair** them in case they get corrupted, and **Compact** them to physically erase deleted records and reduce the size of the C:\FishBase directory. We are looking forward to your comments to further improve these user modules. These databases are available in the FishBase Advanced module.

Internet

On the Internet version of FishBase, we offer a similar service specifically for Fish Watchers, where they can upload information and pictures.

Rainer Froese

The FishWatcher Database

With the advent of SCUBA diving and underwater photography, fish watching is becoming increasingly popular, as indicated by the numerous guidebooks for snorklers and SCUBA divers (e.g., Lewis et al. 1986; Humann 1994; Randall 1996). However, fish watching need not be restricted to tropical seas, as demonstrated by Smith (1994). There are even booklets for certain areas that contain nothing but the scientific and common names of the fishes one might encounter, and space to note date, time, depth and size (Sea Challenger 1995).

The FishWatcher database is our attempt to encourage the systematic reporting of encounters with fish, which—if correct identification can be documented, e.g., by a photo—might help to increase our understanding of fish biodiversity, similar to the contribution of amateur birdwatchers to the understanding of bird distribution and migrations.

In the CD-ROM version, the **FishWatcher** button leads you to the FishWatcher menu where you can create and maintain a personal or institutional database on where, when and how you have seen, caught or acquired what fish. The fields in the table are generally

the same as those described in the OCCURRENCES table (this vol.). The FishWatcher table is embedded in its own database (USER.MDB) and resides on the harddisk in the C:\FishBase directory.

Fields

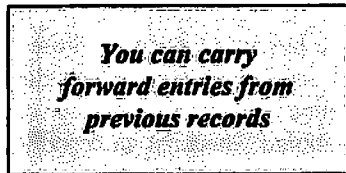
The **Class**, **Order** and **Family** fields are filled from FishBase once a valid genus has been entered. These fields remain empty if the generic name does not match a valid genus in FishBase.

The international common name is filled from FishBase once a specific name has been entered which matches a valid name for which a common name is available.

The **Picture** field is meant to hold the name of a digitized picture file provided by the user. You have to specify the path of your picture directory using the **PicPath** button. If you double-click on the file name, the picture will be displayed.

The **Date** field records the date of collection, observation or acquisition. The year is repeated to accommodate records from the previous and next centuries (we survived the Y2K bug!).

For later assessment of the quality of identification, it is important to know the document on which the identification was based. Double-click on the blank field to search for the reference number; double-click on the reference number to see the full citation.



The fields **Locality**, **Locality type**, **Country**, **Province** and **FAO area** are self-explanatory. **Drainage** refers to the river basin where a fish has been encountered. Since entries in these fields often remain the same, you can use the **Ctrl + '** key combination to carry forward an entry from the previous record.

Coordinates are the best option to pinpoint a locality. Just type in the numbers: degree and minute signs will be added automatically. The coordinates entered here will be displayed as yellow dots on the distribution map.

Click on the **Environment**, **Specimen** or **Misc. info** buttons to enter additional information.

See the Local Knowledge Database below for explanation of editing buttons.

We are planning to develop further the FishWatcher module into a full fish collection database, either as stand-alone or as front end to existing databases. Please contact us if you are interested to participate in this project.

How to get there

You get to the FishWatcher database by clicking on the **User Databases** button in the FishBase Advanced Main Menu, and the **FishWatcher** button in the next window.

Internet

In FishBase on the Internet, go to the 'Species Summary' page of the species that you have observed and click the **Fishwatchers: Add observation** link. You will be assigned an identification number and a password to allow you to later edit your records. After that, a Data Entry page will open with the same fields as described above.

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Rainer Froese

The National Checklist Database



The **National Checklist** module allows users to create national fish databases for any country. Click on the **Create Checklist** button and select the country for which you want to create a national database. A routine will extract all fishes of that country from FishBase and enter them, together with relevant information, into the NATIONAL CHECKLIST table. This table resides in a separate user database (COUNTRY.MDB) and is meant to enable fisheries and biodiversity managers to maintain their own databases on habitats, abundance, uses, regulations, etc. for the fishes in their country. The fields are largely identical to those in the COUNTRIES table (this vol.), and again, complementary FishBase information is only a mouse-click away. You can backup, repair, and compact the National Checklist as described above for FishWatcher.

Internet

On the Internet version, several lists of fishes can be created in the 'Information by Country/Island' section. Note that these lists can be easily saved as htm file and be imported into spreadsheets, databases or wordprocessors.

Rainer Froese

The Local Knowledge Database

Local knowledge (LK) in the FishBase context refers to what is normally called 'Indigenous' (IK) or 'Traditional' Knowledge, usually in developing countries.

However, our definition of LK extends to developed countries as well, and their fishers' perception of fish resources, and to the past, to allow capturing the local knowledge of the ancient Egyptians, Indians, Greeks, etc.

Local knowledge is always assigned to a culture, itself defined by (1) a locality (country or province/state) and (2) a language (which may be extinct, e.g., Ancient Egyptian, Middle High German).

***Create your own Local
Knowledge database***

Note that LK, to be amenable to entry into the database presented here, must be species-specific, i.e., FishBase cannot accommodate knowledge (e.g., on fishing gears) pertaining to 'fishes' in general or to large undifferentiated groups of fish, such as 'sharks'. If LK refers to a genus rather than a species, we suggest that you attach it to the most common species of that genus, and mention in the remarks that it also refers to the other species of this genus occurring in that country.

The Local Knowledge module allows users to create their own local knowledge databases. This is based on a LOCAL NAMES table, similar to the COMMON NAMES table of FishBase, the only difference between the two tables being that the former includes names that are global in scope (e.g., the FAO names), while the latter is meant for names that are strictly local.

Click on the **Local Knowledge** button to open the Local Names menu. Click on the **Create Checklist** button and select a country and language. A preliminary checklist will be created from the over 100,000 common names available in FishBase. Once available, the checklist can be searched through the **Search/Edit** button, which opens the SEARCH BY... window. There are four buttons in this menu, viz.:

1. the **Browse** button which allows sequential access of records;
2. the **Species** button which allows specific access of record(s) using either one or a combination of the **Family, Genus** and/or **Species** fields as search term;
3. the **Language** button which allows access of record(s) using language as a search term; and
4. the **Common name** button which allows specific access of record(s) corresponding to the common name in the search term.

The **Search/Edit** and **Add Records** button leads to the LOCAL NAMES form, which enables the entry of LK for names, which:

- are already in the list as created by the **Create Checklist** button; and/or
- refer to species for which no common name has yet been entered in FishBase.

Note that the **Species** fields are pull-down lists; i.e., clicking on the down arrow key at the right end of the field will give a list of all the genera and species in the checklist. New entries can be added to the list by simply typing the genus and species in the allotted field. The **Class, Order** and **Family** fields (in gray) are automatically linked to the species name and need not be entered. All the other fields are the same as those discussed in Palomares and Pauly (this vol.) with regard to the COMMON NAMES table.



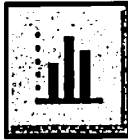
There are five buttons on the upper right hand corner of the form. The top two are the **undo (arrow)** and **delete (x)** buttons for undoing changes made to a record and deleting a record, respectively. The **fish** button shows a picture of the species. The **fish-head** button (FishBase icon) links the LOCAL NAMES database to the FishBase SPECIES table and thence to other information available in FishBase for the species. The **globe** button shows a FishBase distribution map and occurrence records, if any.

The four buttons at the bottom of the Local Names menu are database tools. The **Repair** button enables the user to fix errors generated by deleting and adding records. This is used, together with the **Compact** button, to compress the database and to make more efficient use of harddisk space. The **Backup** button makes a copy of the database in a given drive/directory, while the **Restore** button copies the database from the backup directory to the working FishBase directory on the user's harddisk.

Maria Lourdes D. Palomares and Daniel Pauly

Graphs in FishBase

One of the original purposes of FishBase was to make available to researchers some of the wealth of available data on various aspects of the biology of fishes.



However, before such data can be analyzed, an overview of their key features is necessary, and for this, we provide numerous 'active graphs', constructed on demand by FishBase from records in one or several of its tables after a graph button has been pressed.

These graphs presently come in four different forms:

1. as pie charts (e.g., for diet composition data);
2. as time series (e.g., of nominal FAO catches);
3. as plots of mathematical functions (for length/weight relationships and von Bertalanffy growth curves);
4. as frequency distributions of important variables;
5. as bivariate plots of a few records pertaining to a (group of) species, superimposed (in red) on yellow dots representing all other species for which FishBase has records; and
6. as 2D or 3D graphs illustrating interactive routines.

Items (1-4) do not require much comment, except to point out that we will continue to try to improve their design, based on concepts from Tufte (1983).

Item (5) is an idea first introduced in FishBase 96, which we are quite proud of as it resolved through simple graphs, in one fell swoop, a number of problems associated with the numeric records that they illustrate:

A new type of graph

- i) the records (in red) for a given species or group are accessible in a bivariate context, and hence their magnitude can be directly visualized;
- ii) the backdrop formed by the other species (in yellow) allows a direct evaluation of whether the red records are relatively high, or low, or average;
- iii) patterns in the data can be detected visually, thus encouraging hypotheses formulation and further analyses; and
- iv) outliers (yellow or red) can be immediately detected and, if found to be correct, used to generate further hypotheses.

FishBase features at least one, and often more graphs for most of its tables and forms.

Thus, while this profusion of graphs makes the data in FishBase much more visible, we have also been able to develop a new role

Testing existing hypotheses

for FishBase, that of presenting the data that test major hypotheses concerning the biology of fish, or the status of fisheries.

Examples of new graphs testing previously formulated hypotheses are our plot of frequency distribution of predator vs. prey size (see Fig. 41), which tests an important theory of Ursin (1973), or our plot of DNA contents per fish cell vs. the aspect ratio of their caudal fin (Fig. 58), which presents a first direct test of Hinegardner's hypothesis on the DNA content of fish cells (Hinegardner 1968; Cavalier-Smith 1991).

Examples of graphs illustrating newly discovered relationships are our plots of trophic levels of fishery catches vs. time (see Fig. 4). These graphs were recently presented in the primary literature (Pauly et al. 1998), and had a huge media impact, as they illustrate extremely worrying trends (see e.g., Holmes 1998; Stevens 1998).

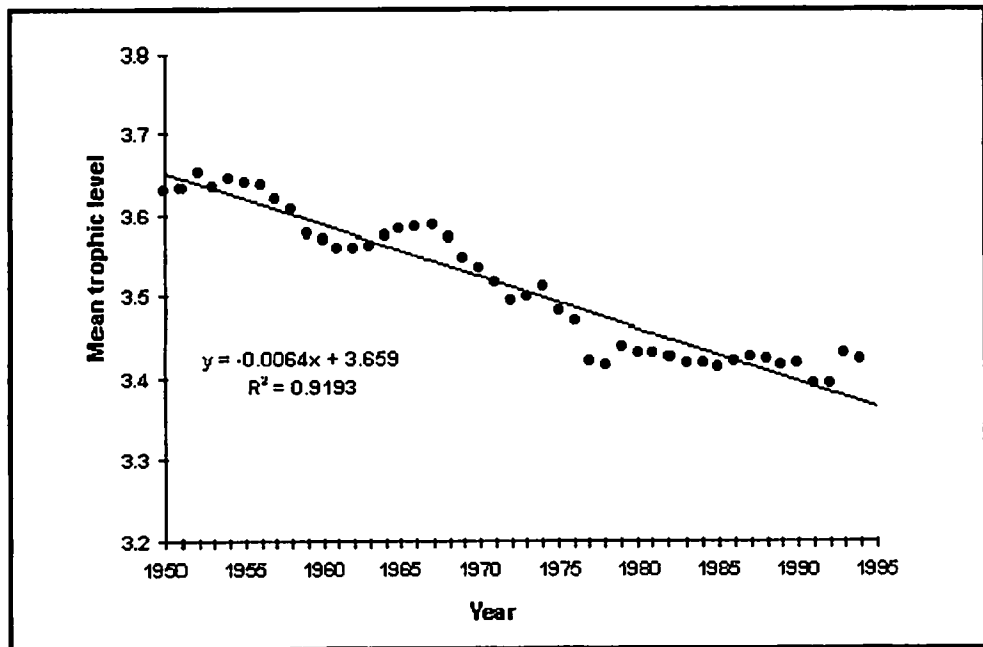


Fig. 4. Trend of the mean trophic level of fishery landings in FAO area 27 (N.E. Atlantic). Note the steady decline, indicating a gradual transition from large piscivorous to small planktivorous fishes and invertebrates in the landings.

The graphs, often constructed from data in several FishBase tables are not always straightforward to interpret, as was noted in a review of FishBase (Wootton 1997). Therefore, we introduced boxes (see Box 2) as devices for explaining the theory behind a given graph, and the related table entries, and to explain how the graph was built, and/or should be interpreted. These boxes, which may be viewed as miniature papers, are authored, and FishBase collaborators are welcome to contribute material for additional boxes (and/or the related graphs) for future publication, following the examples provided here.

Box 2. Uses of boxes in FishBase.

Many chapters of *FishBase 2000: Concepts, Design and Data Sources* include boxes presenting material relevant to, but not part of, the main narrative.

The use of boxes to present such material is to provide details on data selection, algorithms, assumptions and implications, especially of the data used for the construction of graphs, and to provide backgrounds for, and first interpretations of these graphs.

Boxes are authored, and we invite FishBase collaborators and users with interpretative comments on tables or procedures to submit them in form of boxes to be included in future releases of the FishBase book.

Daniel Pauly and Rainer Froese

Here again, suggestions from FishBase users or collaborators are welcome, as are offers to jointly develop new routines.

Internet

The Internet version of FishBase contains already many of these graphs, accessible either under the respective tables attached to a species, or under the 'Information by Family' section if you click on the **Graphs** radio button.

Acknowledgments

I thank FishBase programmers Portia Bonilla, Alice Laborte and Ma. Josephine France Rius for their patience when implementing even my most outlandish design ideas, and Felimon 'Nonong' Gayanilo, Jr. for the first interactive graphs in FishBase.

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Daniel Pauly

Miscellaneous

We have hidden several routines for advanced users under the **Miscellaneous** button of the **Reports** menu and in a separate database named 'FishBase Advanced'. Some of these routines are still under development and might not function properly. We decided to include them here anyhow, if only to get feedback on their usefulness and on possible problems.

Check Names

*FishBase can check
long lists of scientific names*

In 'FishBase Advanced' the **Check Names** button leads to a menu that guides the user through a procedure to check long lists of scientific names against FishBase and Eschmeyer's (1998) *Catalog of Fishes*. The names can be imported from a variety of database, spreadsheet, or text formats. Non-matching names are verified against Eschmeyer's GENERA and CATALOG tables (this vol.) and the 'SYNONYMS table' (this vol.). Several routines are applied to find misspellings that are not contained in the SYNONYMS table. The algorithm was initially described in Froese (1996) and in more detail in Froese (1997).

A variety of reports present the results of this exercise. This procedure has proven to be extremely useful for identifying errors and synonyms in scientific names. See the chapter on the SYNONYMS table (this vol.) for a discussion of this topic.

Country Information

Under the **Country Information** button, you can access a variety of country-specific information described in more detail under the 'COUNTRF table' (this vol.). We are looking forward to comments that will help us complete and update this information.

Finfish Statistics

This procedure creates a printed report on the use of finfish by humans. Over 7,000 species are used in fisheries, ornamental trade, game fishing or aquaculture. Over 500 species have been introduced to other countries and over 1,000 species are threatened with extinction. About 700 species are dangerous to humans. These numbers are based on reported cases, i.e., every record is based on a specific reference.

Internet

On the Internet version, this information is available if you click on the **Fish Statistics** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

Eschmeyer's Museums

This button opens the MUSEUMS table as contained in Eschmeyer's (1998) *Catalog of Fishes* databases (see below).

It allows to create preliminary type catalogs for most museums that hold fish types.

Adverse Introductions

This routine creates a printout with what might be called 'fish pests', i.e., a list of introduced species for which at least three countries reported adverse ecological effects.

Internet

On the Internet version, this report is available in the 'Information by Topic' section if you click on the **Adverse Introductions** radio button.

Expeditions

This button opens the 'EXPEDITIONS table' (this vol.), our attempt to begin structuring the more than 600,000 occurrence records we have compiled so far.

How to get there

You get to the various routines in the Miscellaneous Menu by clicking on the **Reports** button of the Main Menu window and clicking on the **Miscellaneous** button in the REPORTS window.

References

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Rainer Froese

Nomenclature

**Information attached to the
wrong species is actually
misinformation**

It is important to get scientific names right. No one will disagree with that. However, it took us a while to realize that it is of paramount importance and that information attached to the wrong species is actually misinformation and should rather not be published at all. Pietsch and Grobecker (1987) give a classical example of such a case: Bloch (1785) published a description of *Lophius histrio* (original combination of *Histrio histrio* (Linnaeus 1758)) accompanied by a figure that was actually a composite showing the head and body of *Histrio histrio* but the luring apparatus (illicium and esca) of *Antennarius striatus*. The confusion caused by this mistake lasted for nearly 200 years with 21 subsequent taxonomic publications using his erroneous description, often reproducing Bloch's misleading figure.

With this in mind, we have taken several approaches to detect possible errors in our scientific names. First, we double-checked our names, authors, and distributional ranges against available literature, using more than one source wherever possible. To date, this time-consuming work has been accomplished for about 11,000 species records.

Second, we assigned original combinations to all our valid names and checked these against Eschmeyer's (1998) *Catalog of Fishes* databases. In FishBase 98, this was achieved for all valid names and for most junior synonyms. Since then, it is routinely done for every new name that is added to FishBase.

Third, we continue to match our names against other available databases such as FAO's SPECIESDAB (Coppola et al. 1994), NAN-SIS (Stromme 1992), TAIWAN (Shao et al. 1992), and HAWAII (Mundy, in prep.). For this purpose, we have developed a routine that examines lists of scientific names of fishes, identifies synonymous and misspelled names, and makes suggestions for the most probable correct name or spelling (see Check Names under Miscellaneous, this vol.).

All of this work is continuing and should ensure a high level of quality in our scientific names. However, if you come across any remaining errors, please let us know.

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Rainer Froese

The ORDERS Table

*A time dimension for
common ancestry*

The hierarchical Linnean system provides different levels for grouping organisms. One of these is provided by Orders, which break Classes into groups of related Families. The addition in FishBase 2000 of a new table for the 62 Orders of fishes thus provides users a convenient access to their related Families, and thence to Genera and Species sharing broadly similar features. Further, the broad outlines of the classification of fishes are now largely agreed upon by taxonomists (see e.g., Nelson 1994; Helfman et al. 1997; and Eschmeyer 1998). The next step is thus to give a time dimension to this consensus classification, as this added dimension can help answer questions about the timing of major evolutionary events and the spread of diversity at the various levels of classification. It also provides a link into the fossil record. See also Box 3 for a discussion of phylogeny.

The ORDERS table makes use of recent work by one of us (D. Preikshot), wherein trees depicting taxonomic affinities are combined with dated fossils to derive, using cluster analysis, a time scale for the trees' branching pattern. The affinities considered here are those implied in the classification of Eschmeyer (1998), whose tree is very similar to that depicted on the frontispiece of Nelson (1994). Corresponding information from the fossil record was extracted from Carroll (1988), Colbert and Morales (1991), Forey et al. (1993), Forey and Janvier (1993), Helfman et al. (1997), Patterson (1977), Pough et al. (1989), Shirai (1996) and others.

Fig. 5, which can also be called from within the ORDERS table, illustrates the tree thus obtained. This 'tree of fish life' combines temporal and relational information on fish groups in a manner that is readily accessible. One feature of this tree is that it allows straightforward identification of the 'Sister group' of any Order, as well as defining the time since two Orders last shared an ancestor. Because cluster analysis was used to generate the tree, linkages which occur above the level of Order suggest temporal and phylogenetic relationships based on the common ancestor information. Thus, the tree also provides a hypothesis-generating platform for investigating fish relationships at or above the level of Order. Lastly, the tree, or parts thereof, can be expanded to the level of Family, Genus and Species given the input of relevant data.

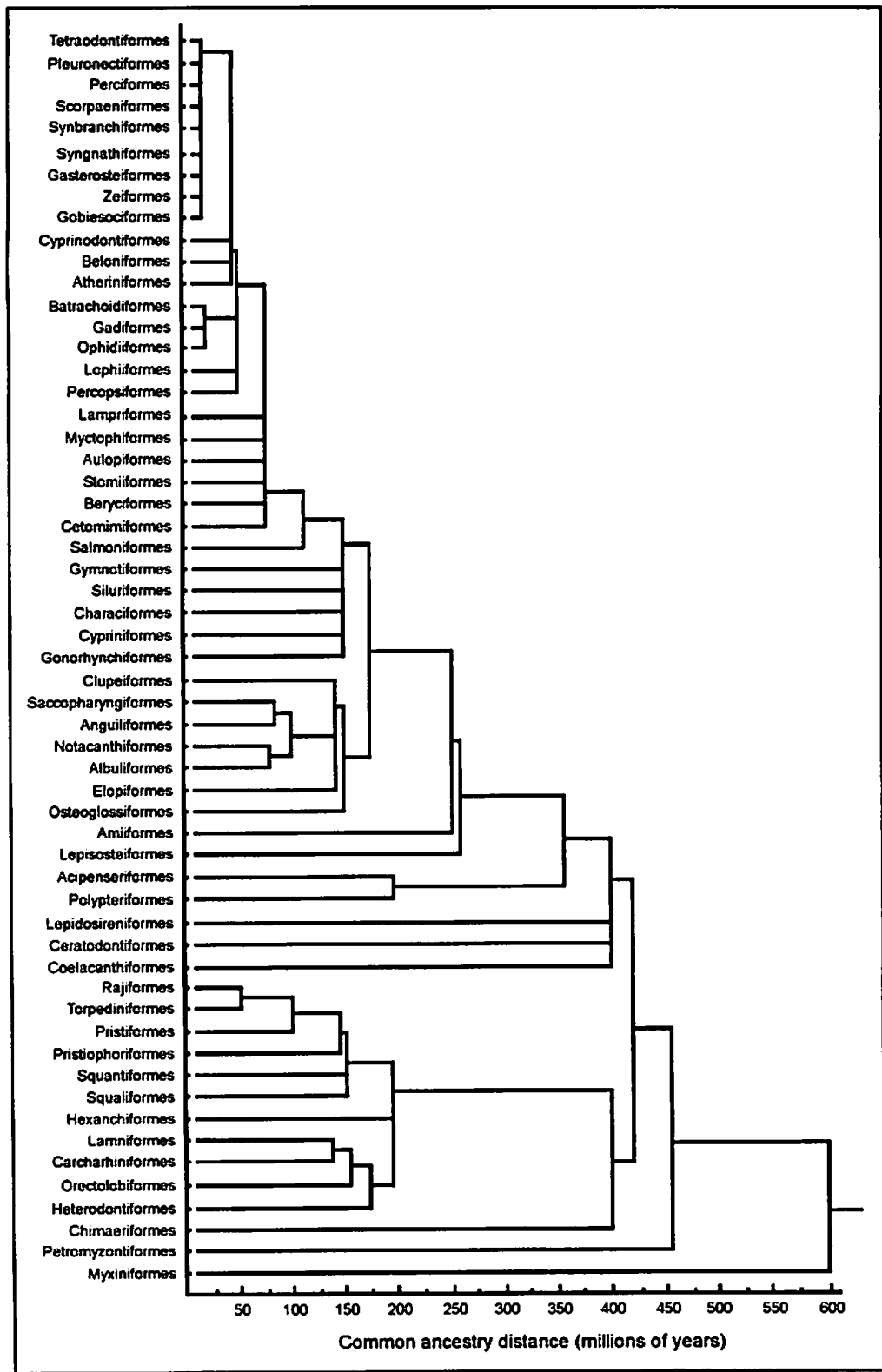


Fig. 5. Cluster analysis of extant of fishes as determined by evidence of common ancestry or by the appearance of fossil forms.

Box 3. What is a fish?

The term 'fish' includes hagfishes, lampreys, chondrichthyans (sharks, rays, chimaeras), actinopterygians (ray-finned fishes), actinistians (coelacanth and lungfishes) containing about 25,000 species. This is almost half the number of extant craniate species. The term 'craniate' (= with head) dates back to the times of non-evolutionist systematics, when creating a group because its members don't have what human beings have was an obvious and common way to classify the living things. In the intellectual context of fixism, the goal of the systematician was to find God's plan in the puzzling diversity of his creatures. Many groupings defined organisms on the criterion of what they did not have, and thus classifications were full of groups for which there was no character exclusively shared by the members of the group. For example, fishes were craniates without limbs. Who has the limbs? The tetrapods, the group in which we find humans. Invertebrates are metazoans without vertebrae. Who has the vertebrae? . . . and so on.

After Darwin, the reason for biodiversity was thought to be genealogy, in other words phylogeny. Classifications were required to reflect descent of species from other species, not the God's creation anymore. The purpose of groupings was not anymore to celebrate the perfection of humans but to demonstrate common ancestry. However, during the century between Darwin and Hennig, systematians did not have efficient tools to fully reach this aim. They all recognized the need to abandon polyphyletic groups that include no common ancestor to all its members. But they remained in the old tradition in being unable to reject paraphyletic groups that contain a common ancestor to all its members, but this ancestor is also shared by organisms that are not included in the group. A true monophyletic group contains one ancestor and all his descendants. At that time however, both types of groups were recognized as valid. As before, paraphyletic groups were not defined for themselves, but to express a step in the increasing complexity of life, with human beings at the top. Such groups are called grades, always defining something else (complexity level, adaptation, ecology) than the organisms we put in it. The grade of reptiles would not exist as distinct from birds if one would not have the will to stress the extreme adaptation to flight in birds. Without the tetrapods, fishes would not exist and would simply be part of craniates (animals with a cranium). Without the eukaryotes, prokaryotes would not exist. What group has the nucleus in the cell? The group that includes human beings. Many other examples could be added.

With Hennig, it became possible to distinguish paraphyletic groups (containing an ancestor and only some of its descendants) from monophyletic ones (containing an ancestor and all its descendants). Hennig thus gave birth to modern systematics, where the paraphyletic groups are finally rejected. For example, the old group Pisces ('fishes') is clearly paraphyletic as there is no character that can exclusively define fishes. There is a common fish ancestor: it is the animal that had the first cranium, between 500 and 600 million years ago. But half of the living descendants of this ancestor are not put in 'fishes'. These are the tetrapods. If we decided to make fishes a monophyletic group, we would have to include tetrapods, and humans would be fishes. Another way to point out paraphyly is to stress that some members of a group are more closely related to other organisms than to members of their group. For example, actinistians (coelacanth) and dipnoans are more closely related to tetrapods than to actinopterygians. Actinopterygians, as 'bony fishes' are more closely related to tetrapods than to chondrichthyans. The term 'fish' therefore disappears from modern systematics and more precise terms are now available, all related to monophyletic groups. These terms are given here only for extant taxa! Craniates have the cranium. They are made of two sister-groups, the hagfishes (mixinoids) and vertebrates, which are divided into petromyzontoids (lampreys) and gnathostomes, the jawed vertebrates. In jawed vertebrates, the chondrichthyans (defined by prismatic calcified cartilage and pelvic claspers) are the sister-group of the osteichthyans (defined by a typical pattern of dermal bones: premaxillar, maxillar, frontals, parietals, etc.). Osteichthyans are divided into two sister-groups, actinopterygians (defined by the acrodine cap on teeth and other characters) and sarcopterygians (monobasal paired fins found in lobe-finned fishes and tetrapods). Sarcopterygians contain actinistians (coelacanth) and rhipidistians defined by the sinuous aortic trunk and many other characters. Rhipidistians are made of two sister-groups, dipnoans and tetrapods.

The rise of cladistics in ichthyology starting from 1967 brought tremendous and sudden advances in systematic ichthyology. In about five years, half the teleostean tree passed from a bush to a cladogram. Today, the 'bush at the top' (a term due to Don Rosen and Gareth Nelson) persists, and much work remains within the terminal crown of the teleostean tree.

Guillaume Lecointre

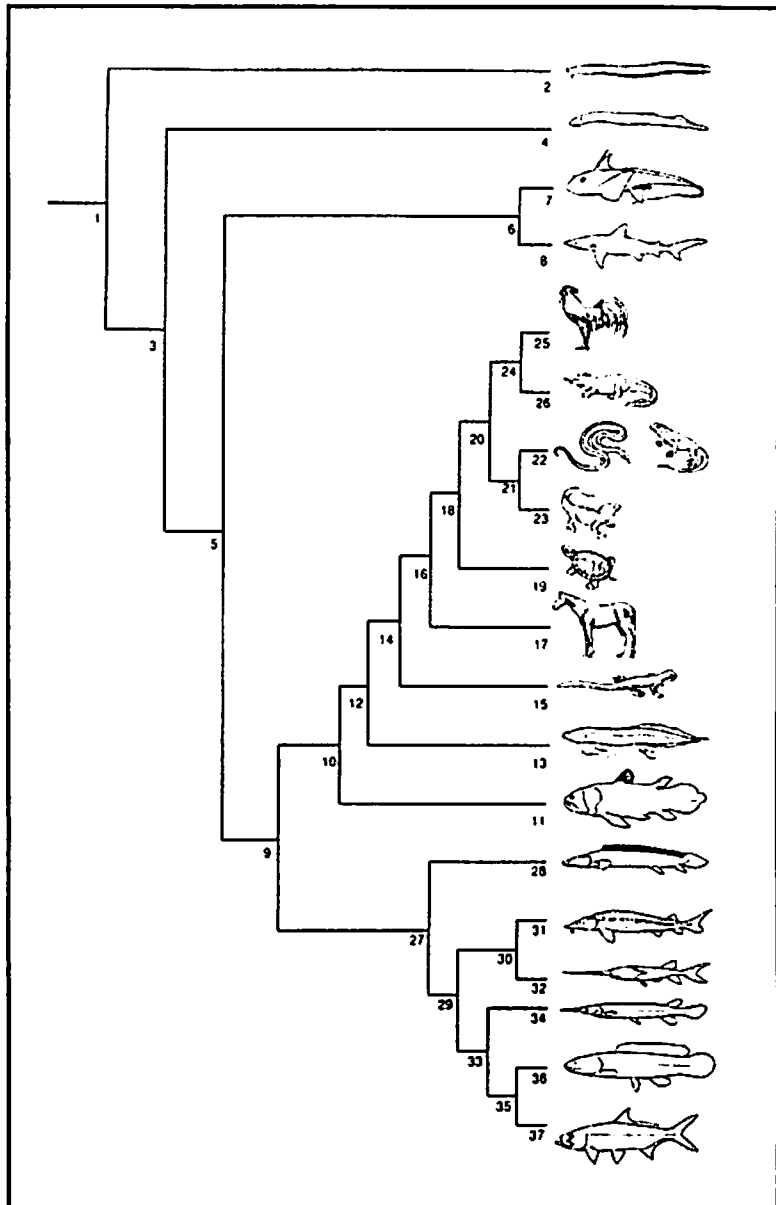


Fig. 6. A phylogeny of Craniata showing the position of the so-called "fishes" (nodes 2, 4, 6, 11, 13, 27). Node number in bold: Scientific name (*Vernacular names*, total number of species in the group). Note that for "fishes", species numbers are calculated from the *Catalog of Fishes*, Eschmeyer, Version November 2000. 1: Craniata (53,721 spp.); 2: Myxini (*Myxiniformes* = *Hyperotreti*: *Hagfishes*, 61 spp.); 3: Vertebrata; 4: Petromyzontiformes = *Hyperoartii* (*Lampreys*, 43 spp.); 5: Gnathostomata; 6: Chondrichthyes (907 spp.); 7: Holocephali (*Chimaeras*, 34 spp.); 8: Elasmobranchii (*Sharks, Guitarfishes, Sawfishes, Saw sharks, Rays, Skates, Electric rays*, 763 spp.); 9: Osteichthyes; 10: Sarcopterygii; 11: Actinistia (*Coelacanth*s, 2); 12: Choanata; 13: Dipnoi (*Lungfishes*, 6 spp.); 14: Tetrapoda (27,541 spp.); 15: Amphibia (*Lissamphibia*: *Frogs, Toads, Newts, Salamanders, Caecilians*); 16: Amniota; 17: Synapsida (*Mammalia*: *Mammals*); 18: Sauropsida; 19: Testudines (*Tortoises, Turtles*); 20: Diapsida; 21: Lepidosauromorpha (*Lepidosauria*); 22: Squamata (*Amphisbaenas, Lizards, Snakes*); 23: Sphenodontida = *Rhynchocephalia* (*Tuatara*); 24: Archosauromorpha; 25: Aves (*Birds*); 26: Crocodylia (*Alligators, Caimans, Crocodiles, Gavials*); 27: Actinopterygii; 28: Cladistia (*Bichirs, Reedfish*, 11); 29: Actinopterygii; 30: Chondrostei; 31: Acipenseroidi (*Sturgeons*, 24 spp.); 32: Polyodontoidi (*Paddlefishes*, 2 spp.); 33: Neopterygii; 34: Ginglymodi (*Gars*, 7 spp.); 35: Halecostomi; 36: Halecomorpha (*Bowfin*, 1 sp.); 37: Teleostei (25,075 spp.).

The Order table includes the following fields:

1. Name of the Order (e.g., Myxiniiformes);
2. Common name of the Order (e.g., Hagfishes);
3. First reported occurrence in the fossil record (multiple choice fields, with Upper/Middle/Lower for both Periods and Epochs);
4. Class to which the Order belongs (e.g., Myxini);
5. Sister Order (e.g., Petromyzontiformes);
6. Order used for Comparison (e.g., Perciformes);
7. Time since shared ancestor (here: 420) million years;
8. Number of Families in the Order;
9. A comment field for free text description of the major features of the Order;
10. A list giving access to the family(-ies) in that Order.

Status: the table is complete in that Sister Orders have been identified for all orders, as well as the times linking all Orders with shared ancestors. However, fossil discoveries and new interpretation of the fossil record will impose occasional updates of the data in this table.

How to get there

You get to the ORDERS table by clicking the Order button in the FAMILIES window, or by double-clicking the Order field in the SPECIES or FAMILIES window.

Internet

On the Internet version, you get to the Orders page by clicking on the Order button in the Species Summary page.

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David Preikshot, Rainer Froese and Daniel Pauly

The FAMILIES Table

The FAMILIES table contains scientific and common names for all recent fish families together with a short description and the estimated number of Genera and Species.

Where available, the first appearance of the family in the fossil record is given. The habitats where members of a family can be found are classified as **Marine**, **Brackish** and **Freshwater**. A choice field indicates whether members of the family are used in the **Aquarium** trade, with choices being: none; some; many. A line drawing depicts the generalized shape of a typical member of the family when the **Fish** button is clicked on.

Sources

The scientific and common names as well as the classification into higher taxa follow the November 2000 update of Eschmeyer (1998), who kindly provided us with a copy of his *Catalog* databases (see below) for inclusion in FishBase. Descriptive information such as distribution and main diagnostic characters is based on recent family revisions or on Nelson (1984, 1994). Fossil records are based on Berg (1958) and other sources. The pictorials were digitized after similar drawings in *FAO Identification Sheets*, *FAO Field Guides*, Nelson's *Fishes of the World* (Nelson 1984), and other sources.

Status

So far, only about 120 families have been checked and not all recent revisions have been used. All family names and higher taxa as well as the genera assigned to a family have been matched electronically against Eschmeyer's *Catalog* databases (this vol.) and should be free of errors.

It is planned to check all family information against recent revisions and against the 1994 edition of Nelson's *Fishes of the World* (Nelson 1994), a task in which Joseph S. Nelson has kindly offered to assist us. We also intend to include new numeric fields for the latitudinal range of a family, which should prove useful in comparative studies. Already WinMap (see 'The WinMap Software', this vol.) can produce preliminary distribution maps which highlight all countries where members of a family occur and plots all available point data for a family.

Additional buttons let you create:

- a list of all genera assigned to this family, based on Eschmeyer (1998); double-click a genus for more information;
- FAO Catch data for this family (see 'FAO Catches', this vol.);
- reports of ciguatera poisoning if available (see the 'CIGUATERA table', this vol.);
- all references in FishBase referring to members of this family;

- all taxonomic revisions used by FishBase for this family. Please let us know if we have missed important revisions.

How to get there

You get to the FAMILIES table by clicking on the Species button in the Main Menu, the Families button in the SEARCH BY window, and, after selecting a family, the Family info button in the SEARCH BY FAMILY window. If you have already selected a species, you can click on the Family button in the SPECIES window.

Internet

On the Internet, you get to the FAMILIES table by selecting a family in the 'Information by Family' section and selecting the Family information radio button. Alternatively, you can click on the family name in the 'Species Summary' page.

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Rainer Froese

Eschmeyer's Catalog of Fishes

Eschmeyer's GENERA table contains all generic names of fishes

A sound nomenclatural system is essential to deal effectively with the estimated 25,000 extant species of fish. W.N. Eschmeyer of the California Academy of Sciences (CAS) has taken on the task to review all published original descriptions of fishes, starting with the 10th edition of *Systema Naturae* (Linnaeus 1758). As a first result, he published the *Catalog of the Genera of Recent Fishes* (Eschmeyer 1990) which reviewed more than 10,000 generic names and which was widely recognized as a standard.

In 1998, he published the *Catalog of Fishes* (Eschmeyer 1998), which contained an updated version of the genera as well as a review of the more than 53,000 names of fishes that have been proposed as new species. The databases used to compile this work are distributed on CD-ROM together with the printed version. W.N. Eschmeyer kindly allowed FishBase to include his SPECIES, GENERA, REFERENCE and MUSEUM tables. The complete *Catalog of Fishes* with CD-ROM can be ordered from the California Academy of Sciences, San Francisco, USA.

The sections below are taken—with permission—from the introduction of the *Catalog of Fishes*. Note that the arrangement of the information in the database forms as presented in FishBase differs slightly from the *Catalog*.

References

- Eschmeyer, W.N. 1990. Catalog of the genera of recent fishes. California Academy of Sciences, San Francisco. 697 p.
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Linnaeus, C. 1758. *Systema Naturae per Regna Tria Naturae secundum Classes, Ordines, Genera, Species cum Characteribus, Differentiis Synonymis, Locis*. 10th ed., Vol. 1. Holmiae Salvii. 824 p.

Rainer Froese

The Role of Taxonomy

The primary way basic information about animals and plants is organized and stored is by taxonomic categories (typically species) [another way is by subject, such as vision or food and feeding]. It is important to understand (1) why good taxonomic databases are essential for studying biodiversity, (2) what taxonomy entails, (3) why a hierarchical classification is useful, and (4) why classifications and names change, thereby making it more difficult to accumulate and keep track of information for many purposes from conservation management to inventories, to species entering commerce, etc.

Taxonomists have two important tasks . . .

Taxonomists have two important tasks: to name organisms and to classify them. The system of hierarchical classification and a two-word system for naming species began with Linnaeus in 1758. The system was codified in 1842 (Strickland et al. 1843), and it became the system used by all zoologists worldwide from 1843 to the present, with changes and improvements along the way. (The present 'Code' which all zoologists follow is discussed in Appendix A of the *Catalog*). The two-word name for species consists of a generic name and a specific name. A genus may contain more than one species, and species are placed together in a genus based on perceived genetic affinity (as determined mostly by morphological differences and similarities, although biochemical techniques are providing new, additional information). (Subspecies are sometimes used to define smaller categories within a species). Taxonomists discover or describe species (1) by assembling specimens through fieldwork and/or by borrowing from museum collections, (2) by studying variation, (3) by grouping the specimens into species categories, (4) by comparing these with previously described species, (5) then naming the new species following specific rules (ITZN 1985, 1999) and (6) by publishing the information in scientific journals and books. Monographs contain thorough treatments of all the species in a larger group, such as a genus or family, and monographs represent the latest summary of information for that group.

Classifications contain information about relationships

Classifications are useful because they contain information about relationships. For example, when a chemical suitable for a pharmaceutical product is found in one species, biochemists can quickly learn from classifications of the close relatives (e.g., other species in the same genus or the 'sister-species') that might contain similar or even better chemicals. All species in the same genus should share many behavioral, biochemical, ecological and biological properties because they are closely related evolutionarily. The effect of pollution on a species at one location should be similar to the effect on a close relative living in a

different area. Those in the same family (next primary category up) similarly share many but fewer features. Classifications thereby have predictive value. Since the late 1960s, most taxonomists have used 'cladistic' methods of forming classifications (i.e., Henning's method, see Box 3), basing them on shared advanced (new) features. This approach results in cladograms or trees that reflect ancestry as well as relatedness of individual taxa.

Names keep changing

The changing nature of classifications and scientific names (because of changing ideas of relationships and because of technical [nomenclatural] rules changes) makes it almost impossible to know under which species, genus, or even family names one will find pertinent information in the prior literature or in specimen collections. For example, in 1989 both the genus name and specific name of the rainbow trout were changed (see Smith and Stearley 1989). Thousands of publications cite *Salmo gairdneri* as the name of the rainbow trout; now we call it *Oncorhynchus mykiss*. The genus name was changed from *Salmo* to *Oncorhynchus* partly based on fossil evidence because the Pacific trouts were thought to be more closely related to the Pacific salmon than to the Atlantic salmon [the name carrier or type of *Salmo*]. Pacific trout and salmon are now classified as *Oncorhynchus*. The species name *gairdneri* was changed to *mykiss* when it was thought that *mykiss* from Kamchatka, Russia, was the same as *gairdneri*; since *mykiss* was described first, that name had priority for use over *gairdneri*.

Another major activity of taxonomists is to make 'synonymies' that summarize prior accumulated knowledge about species. Unfortunately, scientific names change for several reasons, which makes inventory especially difficult since information about a single species may be found under several scientific names. Names change because:

1. One species may have been described more than once (such as from different geographical areas, from different sexes, from atypical specimens, or from a lack of knowledge of earlier descriptions). As these 'duplicates' are discovered, the first described name is selected as the valid name, often resulting in a name change, such as for the rainbow trout.
2. Scientists may differ on what species to include in a particular genus, or species are moved to different genera based on perceived relatedness. This results in the first half (generic) of the name changing; sometimes the ending of a scientific name also changes since, if it is an adjective, it must agree (decline) in gender with the genus.
3. Sometimes names are changed for technical reasons.

Scientific names are frequently misspelled

Another problem is that scientific names are frequently misspelled in scientific publications, in collection records for museum holdings, and by abstracting services. Often a name is misspelled because the spelling as originally presented was not verified by

**Numbering taxa
has not worked**

subsequent workers. Although there are current arguments about how to incorporate fossils into classifications, and especially how to treat them in higher taxa, the present system probably will continue for many years. Numbering taxa has not worked either. Often common names are more stable than scientific names, and they can be useful in some groups.

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William N. Eschmeyer

Introduction to the Catalog

In the fall of 1990, a *Catalog of the Genera of Recent Fishes* was published (Eschmeyer 1990). With continued funding from the U.S. National Science Foundation, the database for species of fishes was completed. At the same time, the genera database was updated with new information and with corrections to the 1990 edition. The present work is produced from these databases. Partial versions of the databases are available on the Internet at <http://www.calacademy.org/research/ichthyology>.

**About 200
new species per year**

The databases contain over 10,300 genera and subgenera and approximately 53,500 records for species and subspecies. About 50,000 names are available for use at the species/subspecies level. We estimate that the number of valid species of fishes is about 25,000. We show valid species at 23,250, assuming that every species described since 1990 is valid; but this figure does not include status for a number of species described in the 1950s through the 1980s for which we lack a status reference. New species of recent fishes continue to be described at about 200 a year, and the number of valid species could reach 30,000 or 35,000 as poorly sampled geographic areas are studied and new equipment becomes available, such as wider use of submersibles.

William N. Eschmeyer

Species of Fishes

**Some original names
have to be changed**

This part consists of species-group names (species, subspecies, and qualifying variety names—and referred to collectively as 'species') arranged alphabetically. The following items are provided:

ORIGINAL GENUS. The genus used by the original author of the new species-group name is given first. If a subgenus was also involved, the subgenus follows the genus in parentheses.

NAME. The species-group name as originally proposed is given next. The original spelling is used except where mandatory changes (based on the Code) are required, such as beginning the name of a species with a lower case letter when it was a capital letter originally, normal removal of hyphens, and providing the required spelling when diacritical marks are removed.

SUBSPECIES AND VARIETIES. When the species-group name was proposed as a subspecies, then the species name follows the original genus. When proposed as a variety or form, the original genus is followed by 'var.' or 'forma' or other attribute. A species described initially as a variety and also involving use of a subgenus would appear as follows: '*alba*, *Scorpaena* (*Sebastapistes*) var.'

AUTHOR. The author of the new name is given next, and the authorship is qualified by 'in' statements, such as Cuvier in Cuvier & Valenciennes, or 'ex' meaning from, such as Lacepède (ex Commerson). The use of these expressions and authorship in general are discussed in Appendix A.

DATE. The year of publication is given (see also discussion on dates of publication in Appendix A of the *Catalog*).

REFERENCE AND REFERENCE NUMBER. Provided first within brackets is an abbreviated citation to the journal or book in which the original description appeared, and this is followed by the unique reference number, e.g., [Proc. Calif. Acad. Sci. v. 43; ref. 1234], which corresponds to a CAS RefNo. the number given in the Literature Cited section (Part V) for the reference containing the original description. For book titles and monographs or other non-journal works, we have coined shortened versions, such as '[Fish. Nile; ref. 6510].'

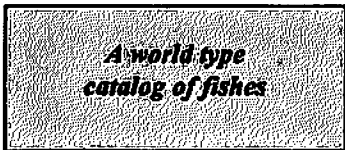
*The page where the
new taxon is described*

PAGE. Usually only one page is cited - the page on which the main descriptive account for the new taxon begins (and not necessarily the page on which the new taxon is first mentioned). When more than one page is given it usually means the new taxon was presented in some detail (such as in a key) in one place and amplified in a second place; usually the secondary treatment is included in parentheses, e.g., (14) 30. Pages in brackets are those assigned in an unpaginated or in a separate work in which pagination differs from that in the original publication, e.g., 456 [25].

FIGURES. Figures accompanying the original description are provided. If a figure is shown on a plate, the plate is given in arabic numbers and the figure is given in parentheses, e.g. Pl. 4 (fig. 2) or Pl. 2 (upper). If a text figure and a plate are involved, the text figure is shown with a capital 'F', as in 'Pl. 4 (fig. 2), Fig. 24.' If only a text figure is provided, then this is shown with a capital 'F', as in 'Fig. 1.' We try to limit plates and figures to ones showing specimens or parts of specimens and not, for example, to figures of maps showing distribution.

TYPES. The location of type specimens is given next. An Abbreviations system is used to denote museums containing the type specimens; a list is provided in the FishBase Glossary and MUSEUM table. Information on various kinds of type specimens and how they are established is given in Appendix A of the *Catalog*. A variety of different numbering systems are used by museums, some with unique numbers, others with numbers preceded by letters, etc. If the specimen(s) was/were first at another museum, then that information is given in brackets - USNM 12345 [ex BPBM 3456].

The single name-bearing type is given first where available, e.g., holotype, lectotype, or neotype. Lectotypes or neotypes require designation (see Appendix A), and this documentation is provided in the account of the species taxon. If no single name-bearing type is provided, then syntypes are listed. Number of specimens in a lot is given in parentheses. If no type specimens are known, this is noted at this point in the account. Question marks are used to indicate doubt as to type status, such as 'Paratypes: ?USNM 34567 (3).'



This is the first attempt at a world type catalog of fishes. We have obtained information on types from several sources. Published collection type catalogs have been consulted, and these are included in the account, such as, "Type catalog: Böhlke 1984:16 [ref. 13621]." Monographic or revisional studies usually involve examination of types, and some status references may include information on types. Sometimes individual articles may deal only with type specimen problems. For a few groups, such as darters, myctophids, and callionymids, there are checklists by families that include information on types. In some cases, we have personally examined type specimens in collections.

Even with these sources, the availability and location of types for many species is uncertain. In some cases, the various sources available to us include more or less specimens than mentioned in the original description; in at least some of these cases we are able to give the original number in parentheses, such as: "Syntypes: (10)..." We provide statements such as "Not found" or "No types known" when that is the best information available to us. In some cases we are able to report the condition of the types, such as dried skin, skeleton, disintegrated, poor condition. The expression 'c&s' refers to specimens that have been cleared and stained for anatomical study.



TYPE LOCALITIES. If there is a unique name-bearing type, then the type locality of this primary type is given; when there are, in addition, secondary types, such as paratypes, then no localities are provided for them. If there are only syntypes and more than one locality is involved, a general locality may be given first, and then more specific localities with syntypic lots. Considerable thought was given to whether we should provide the locality as given in the original description, either alone or in addition to a modern locality, and whether we should improve the locality by

providing more detail. It was decided to provide a locality one would find in a modern atlas, geographical dictionary, or gazetteer, and to improve that locality to include at least the modern country name, and in some cases a latitude and longitude; occasionally we include the original locality in brackets. For example, the locality may have been 'Kosseir,' so we use 'Al-Quseir [Kosseir], Egypt, Red Sea' and for Ceylon we use 'Sri Lanka.' For some localities it is difficult to be more precise than in the original presentation, such as 'Carolinas' to which we add Carolinas, U.S.A. We generally treat localities as specific to general, the latter usually being the country. Vessel station numbers, though not part of a geographic locality as such, are given in some cases, such as for 'Albatross' stations, since for many of these collections published station lists are available. We do not give station numbers of individuals, collectors names, dates of collections and other information that is not part of the geographic locality. The depth of capture is given at the end of the locality information (see also the EXPEDITION table, this vol.). Terrestrial collections may have an altitude of capture, and we give this as, for example, "... elev. 3460 m." As collections worldwide become computerized, the specialists will be able to obtain or refer to more detailed information relating to types directly from on-line databases for specific museums. It was our aim to record the types and the museums holding them to assist the specialists in obtaining type specimens for study.

TEXT REMARKS. A variety of remarks may follow the information on types and type localities, and these generally are presented in a standard order.

a. **ALTERNATE PAGES AND PUBLICATIONS.** When the original description appeared in a separate (offprint, reprint) with different pagination, then this information is given first, such as "Appeared on p. 4 of separate." When the taxon was published at about the same time in another article, this information is provided, and it usually takes the form of, "Also appeared as new in"

b. **ORIGINAL OR MULTIPLE SPELLINGS.** When the taxon was spelled in a way that requires a mandatory correction, the original incorrect original spelling may be provided, such as "Spelled *albo-marginatus* originally." When the original genus was misspelled this is noted. When the taxon was spelled two or more ways in the original description, this is discussed—sometimes one spelling is regarded as typographical error and in some cases a first reviser is needed.

c. **PREOCCUPIED NAMES/REPLACEMENT NAMES.** Primary and secondary homonyms are mentioned, such as for *Dentex rivulatus* Rüppell 1838 is found, "Preoccupied by *Dentex rivulatus* Bennett 1838, replaced by *Gymnocranius ruppellii* Smith 1941." [Over 500 primary homonyms are known in fishes.]

**Over 500 new species
were described with an
existing name**

d. EMENDATIONS. Misspellings and other emendations are provided.

e. OTHER REMARKS. When subsequent type designations are needed, such as for lectotypes or neotypes, this information is given. Actions by the International Commission may be mentioned. Misspellings, when considered significant, and unjustified emendations are also included.

f. STATUS. The status of each nominal species or subspecies is given next. We have limited this to the status of the name at the species level. For example, a name originally proposed as a subspecies may be shown as valid (as a species), or it may be shown as a synonym of another species; its status as a subspecies is sometimes given when it is valid, "Synonym of but as a valid subspecies (Jones 1984 [ref. 12345])." There are several conditions in which a name may be valid—for example, an original species name may be valid exactly as proposed (same genus and species spelling) in which case we record the name as 'Valid.' The species name may be valid but be placed in a genus other than the original one in which it was proposed, and in these cases we give the current genus, such as "Valid as *Serranus guttatus*." Sometimes the name (for example when an adjective) needs to have its ending modified to agree in gender with the genus, so that the original proposal may have been *marmorata* if it originally was in a feminine genus, but becomes *marmoratus* when placed in a masculine genus. When the name is a synonym, we give the author and date for the valid name; if it is a synonym of a genus and species as originally proposed then the author and date of the valid name are not in parentheses – "Synonym of *Melanocetus murrayi* Günther 1887." If the name treated is a synonym of a species that is now placed in a genus different from the one in which it was proposed, then the author and date are in parentheses – "Synonym of *Scyliorhinus stellaris* (Linnaeus 1758)." If a name is not an available name, we use the convention, "In the synonymy of...", since an unavailable name is not really a synonym of an available name. The status reference is given next in parentheses, and all status references include a reference number; typically this includes the author, date, page and reference number, but the page is often omitted if the entire article deals with only that taxon. When a page is given, it refers to one pertinent page in which the status of the taxon is discussed. Typically only publications since 1980 are used for status, although some earlier monographs have been included. [The selection of status references was not systematically organized, and it should be pointed out that thousands of other status references would have been available if time permitted.]

***An unavailable name
is not really a synonym***

FAMILY/SUBFAMILY. Each account provides the family and subfamily (if used) in which the nominal species has been placed (see Part III). Some species or subspecies may be classified only to class, order or suborder.

How to get there

You get to the Eschmeyer's SPECIES table by clicking on the Eschmeyer's SPECIES button in the SEARCH SPECIES BY window, or by double-clicking on the specific epithet in the SPECIES or the SYNONYMS window. The internal name of this table is PISCES.

Internet

On the Internet version of FishBase, you get to the November 2000 version of the database behind the *Catalog* by selecting the Eschmeyer (Species) radio button when you search for a scientific name, or by clicking on the specific name in the 'Species Summary' page. You can also search the *Catalog* databases at www.calacademy.org/research/ichthyology.

Reference

Eschmeyer, W.N. 1990. *Catalog of the genera of recent fishes*. California Academy of Sciences, San Francisco. 697 p.

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Genera of Fishes

This part contains all genus-group names of recent fishes (genera and subgenera—and referred to collectively as “genera” in the *Catalog*). The following items are treated.

NAME. The genus-group name as first proposed is given first, and names are arranged in alphabetical order. The original spelling is given except where mandatory changes are necessary, such as removing hyphens (e.g., changing *Lucio-Perca* to *Lucioperca*).

SUBGENUS OF. When the name was proposed as a subgeneric one, the genus of which it was a subgenus is given in parentheses.

AUTHOR. The author of the new name is given next (see Author in 'Species of Fishes' above).

DATE. The year of publication is provided (see Date in Appendix A of the *Catalog*).

PAGE. Usually only one page is cited—the page on which the main generic description begins (not necessarily the page on which the genus is first mentioned). When more than one page is given, the genus may appear in a key, for example, and be followed later in the text by additional information. In some early works, where a typical generic description may not have been given, several pages that concern publication of the name may be cited. Pages in brackets are those assigned in an unpaginated work or in a separate (offprint, reprint) in which pagination differs from that in the original publication.

REFERENCE AND REFERENCE NUMBER. See the section for Species of Fishes, above.

GENDER. Abbreviations in the *Catalog* are Fem. = feminine, Masc. = masculine, Neut. = neuter.

Pagination may differ

TYPE SPECIES, AUTHOR, DATE. The original genus of the type species, the specific name, author, and date are given next. Mandatory corrections to species names have been made. Occasionally a second species is indicated in parentheses, and the use of this convention may have several meanings (usually amplified in the remarks section). The species in parentheses is typically the senior objective synonym, especially when the author of the genus provided a new (unneeded) name for the older species name. In other cases the author of the new genus or subgenus may attribute authorship of the type species not to the original author of the species but to some later author; normally the original author of the species is given (regardless of the species authorship attributed by the author of the genus), but there are some statements such as, "Type species *Alpha beta* of Jones (= *Gamma delta* Smith 1945)". When an author makes an equivalent type designation statement—i.e., type is so-and-so = so-and-so, amplification is given in the remarks. The use of parentheses does NOT show subjective taxonomic decisions involving the status of the type species; only objective synonyms are dealt with.

TEXT REMARKS. Remarks, given next, cover such items as the method of type designation, the subsequent designator, comments on preoccupation, misspellings, emendations, and other pertinent remarks.

a. **METHOD OF TYPE DESIGNATION.** First is given the method by which the type species was established (fixed). This subject, which is discussed in some detail in Appendix A, seems to cause current workers many problems. Although 'type by original designation' takes precedence over other designations, a distinction is made between 'original designation (also monotypic)' and 'original designation'; the former insures that the likelihood of the name having a different type is remote; the latter means there was more than one originally included available species treated as valid. Other amplification is sometimes given, e.g., 'Type by monotypy (also by use of *typus*),' but in these instances the use of *typus* or similar denotation is a form of indication that comes into play only when other designations do not take precedence, and when there are two or more originally included species in the taxon. When the type species is designated after the original description, amplification is provided, such as a citation to the subsequent designation.

***It was not uncommon
to publish a new genus
in more than one place***

b. **SECONDARY APPEARANCES.** If the genus appeared in a second work at or near the time of the first appearance, a citation to this second work is provided. It was not uncommon in the early literature for an author to publish a new genus description in more than one place.

c. **PREOCCUPIED NAMES.** Names that are unavailable because of previous use are preoccupied. To be sure that a genus of fishes is in fact preoccupied—for example in insects—would require going to the original description of the insect and confirming the

**Generic names must be
unique in the
Animal Kingdom**

original spelling, date, availability and other details. Preoccupied names in fishes were verified, but names preoccupied in other groups were not.

d. MISSPELLINGS AND EMENDATIONS. Misspellings that are included are ones made by the original author in later papers, or made in Jordan's '*Genera of Fishes*,' in the '*Zoological Record*' the first time the genus was listed there, in major treatments (such as monographs), or in references used to document the status of the genus. Many other misspellings were not included. Emendations require careful study; some were evaluated as to whether they were justified emendations or unjustified ones (or merely misspellings). In those not so evaluated, the expression "Spelled ..." is often used to show that the investigation was not made.

e. OTHER REMARKS. Such items as action by the International Commission on Zoological Nomenclature (ICZN), nomenclatural remarks, and other comments are included.

f. STATUS. When given, the status of the nominal genus is provided next. Citations documenting the status include the author, date, page and the reference number. When a page is not given, the entire article typically deals with only that taxon. For example, under *Brochus*, the citation 'Nijssen & Isbrücker 1983 [ref. 5387]' is found; reference 5387 treats only the genus. When a page is given, it refers to one pertinent page in which the status of the taxon is discussed, although the taxon may be mentioned on other pages in the same article. For genera that are junior synonyms the page given usually refers to the page on which a generic synonymy occurs.

**Some taxa
are not mentioned
in recent literature**

The status of some genera is not provided. Some of these taxa are old synonyms not mentioned in current literature, whereas others have just not been treated recently. In some cases, the status has been obtained by looking for the placement of the type species in current genera, even though the genus in question is not mentioned; these are qualified with statements like, "Synonym of ... (Paxton et al. 1989:470 [ref. 12442] based on placement of type species)."

In general, only literature from the last 15-20 years has been used to document status, although some earlier monographs have been included, especially when that monograph is the only thorough treatment available that mentions the taxon. In some current systematic papers, authors tend to omit old synonyms. The aim in documenting the current status of taxa was not to provide extensive synonymies, but to be able to give one or a few recent references that can serve as an entry or source to other literature treating the taxon. Information can be obtained from both the genera and species accounts; for example, a status reference for a genus may not be listed under species, and the reverse may be true.

FAMILY/SUBFAMILY. Each account provides the family and subfamily (if used) in which the genus has been placed in the classification (see below).

How to get there

You get to the GENERA table by clicking on the **Eschmeyer's GENERA** button in the SEARCH SPECIES BY . . . window, by clicking on the **Genus** button in the SPECIES window, or by double-clicking on the generic name in the SYNONYMS window.

Internet

On the Internet version of FishBase, you get to the November 2000 version of the GENERA table by selecting the **Eschmeyer (Genera)** radio button when you search for a scientific name, or by clicking the generic name in the 'Species Summary' page.

You can also search the GENERA database at www.calacademy.org/research/ichthyology.
William N. Eschmeyer

Genera and Species in a Classification

*There is no generally
accepted classification*

The classification used for the species (Part III of the *Catalog*) and for the genera (Part IV of the *Catalog*) is identical, but the classification has been modified since the publication of Eschmeyer (1990, 1998). The original goal was to provide a framework of orders, families and subfamilies (with occasional use of suborders). The classification portion, however, was secondary to the goal of compiling Parts I and II of the *Catalog*. Unfortunately, at this time in ichthyology there is no generally accepted classification, and many workers are actively engaged in research on higher-category taxa. Many follow Nelson (1994), and we have used his classification in most areas. At the same time, cladistic studies produce hypotheses of relationships, often based on examination of a very few taxa in each larger taxon, but these hypotheses need to be corroborated by other workers. Cladistic studies offer a rational and logical methodology for studying relationships, but reversals, parallelisms and problems of polarizing characters and outgroup selection for such polarization can be problematic. Often, many trees may be generated from computer programs, sometimes with substantial differences among them. To adopt each new hypothesis as proposed is not warranted in a work such as here presented, where stability for communication to many audiences is desired. The aim of the classification is to group related genera or species together, rather than attempt to reflect relationships evenly. For example, if a group of genera has been recognized as a family but a more recent study shows that these genera are specialized or highly modified members of another family, the genera are moved to the 'new' family but may be retained there as a subfamily, thereby keeping those related genera together. In some groups, subfamilies are not used, although they may be used in current literature; these include some small families with only a few genera, but also some large families, such as the Cyprinidae, where some 'specialized' subfamilies could be recognized, but the family as a whole has not been divided into subfamilies on which there is general agreement.

Stability is desired

Synonyms of family group names are not provided, and the indexes to higher taxa names presented at the end of Parts III and IV include only those names actually mentioned. However, it is possible to determine the current placement of a family or subfamily that is not specifically included in the classification. For example, in the literature one may encounter a species placed in a family that is not included in the *Catalog*. Since family group names are based on a stem-genus (by dropping the terminal letter or letters and adding -idae for a family or -inae for a subfamily), one may look up the genus in Part II of the *Catalog*, go to the end of its account, and find where that family is now placed.

Family names are based on a genus

Family-group names used in the classification follow current use. Some problems involving family-group names in fishes include currently used family names that are not the oldest for the family and should be replaced by the older names unless a case can be presented to retain the younger name, some family names are being misspelled in the current literature, or two spellings are used (such as Engraulidae or Engraulididae). See Robins et al. (1980:4 [ref. 7111], Steyskal 1980 [ref. 14191] and Géry 1989 [ref. 13422]). These problems are not addressed directly in the *Catalog*, but some comments regarding family-group names are mentioned under their type genera (e.g., see *Phosichthys* and *Bovicthys*).

A few genera or species are not placed within families in the classification. Some are based on mythical specimens, or are indeterminable, or they are names only (without a description); many of these are unavailable names. They are often listed under a class, order or suborder. In the genera listing, unplaced genera appear at the end. The internal name of this table is LINEAGES.

References

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Literature Cited

Author names need standardization

This section includes citations to all literature mentioned in the previous parts, along with some additional references that complete a series in which only some works in that series are actually cited.

AUTHOR. Author's initials are given, and to obtain a date-ordered printout, these have been standardized. For example, Theodore Gill published as T. Gill, T.N. Gill, and Theodore Gill;

these are treated as authored by T.N. Gill, although both abbreviations did not appear in some of his publications. If an author's name normally has a diacritical mark, it is added to all citations of that author, for example Géry publishes both as Géry and Gery. We are unable to provide diacritical marks for some languages, such as Romanian. Chinese names are given as they might appear in an English language journal. Typically there is a family name plus two given names, and the two given names are often written together or hyphenated. Wu is given as H.-W. Wu although in the actual article his name may be given as Wu Hsienwen, Wu Hsien-Wen, H.-w. Wu, H.-W. Wu, or H. W. Wu.

All names with 'de' are entered in one form; de Buen, for example, published as Buen and as de Buen. Some cross-referencing of names is provided.

Many large books, such as *Smiths' Sea Fishes* have chapters authored by specialists, and in order to show the specialists' involvement, especially for status documentation, we have a separate entry for each author with an individual reference number for the families in *Smiths' Sea Fishes* treated by that author.

Arrangement by author is alphabetical, but in outputting from databases to word-processing, those names with diacritical marks occur further down than anticipated, e.g., Günther references appear at the end of the G's and were 'manually' moved up. Alphabetizing is on the first two authors, so entries with more than two authors may or may not be in the correct sequence alphabetically.

*Dates may differ from
that on the publication*

DATE OF PUBLICATION. The year given is that in which the publication appeared first in an available (published) way. The date may differ from that appearing on the journal or publication, and dates may be advanced because of preprints (see Appendix A). When available, the month or month and day of publication is given in parenthesis after the year. References are ordered by year, not by date of publication within a year.

REFERENCE NUMBER. Each reference has a unique reference number, and this is given next in brackets. The number corresponds to the entry of that reference in a larger database maintained at the California Academy of Sciences. A unique number is used instead of 'a, b, c., etc.' that one might find in a smaller bibliography. The unique numbers were an aid in proofing original descriptions that could be accessed by reference number/page. The use of reference numbers also allows on-line searches by reference numbers and downloading of them electronically.

TITLE. The title of the article is given as published with the article; not the title as given, for example, in a table of contents (which sometimes differs). Scientific names are italicized even though, because of constraints in type style, they may not have

been so treated in the title as published. Titles in Russian, Japanese, and Chinese are given in English.

BOOK AND JOURNAL CITATIONS. Journal abbreviations in general follow the BioSciences Information Service 'Serial Sources for the BIOSIS Data Base, volume 1984.' We have composed comparable abbreviated journal titles for old, discontinued journals not treated in the BIOSIS list. We capitalize the first letter of all nouns and adjectives, so we give, for example, 'Proc. Acad. Nat. Sci. Phila.' rather than 'Proc. Acad. nat. Sci. Phila.' To aid in finding literature, we designate volume ('v'), number (no.), part (pt), or other amplification, but usually if a foreign word (e.g., tome, fascicle) corresponds to an English word, we give the English equivalent abbreviation. This is followed by the inclusive pages of the work and plates if any.

REMARKS. Information in brackets includes the original language of the article if not clear from the title, sources for information on dates of publication, or dates of appearance of parts of the work if it was published in sections. The entry 'Not seen.' at the end of a reference indicates that the work or article has not been examined.

How to get there

You get to the REFERENCES table by clicking on the Eschmeyer's References button in the REFERENCES window, by double-clicking on the Author field in the SPECIES window, or by double-clicking on the Author field in the SYNONYMS window.

Internet

On the Internet version of FishBase, you can search the references of the *Catalog* by selecting the Eschmeyer radio button in the 'References' section at the bottom of the 'Search FishBase' page. You also get to this database if you click the Author of a species either in the Species Summary or the Synonyms page.

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Errors and Discrepancies

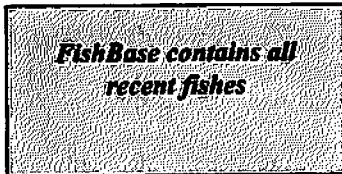
Dates in the reference section are more accurate

A work of this size and complexity will have many errors and discrepancies. Some discrepancies can be anticipated, and the more likely of two or more choices can be identified. For discrepancies in dates, the dates of publication given in the references section are more accurate than corresponding dates elsewhere in the work. Many problems remain, however. For example, a number of Steindachner papers appeared in 3 places. While in Vienna an effort was made to determine the order of publication. This information has been used in Part I but not fully in Part II of the *Catalog* [resulting in discrepancies]. The spelling, authorship and date of type species in the 'Genera' section may differ from the information in the 'Species' section; the information in the 'Species' section is more accurate. The taxa in a classification (Parts III and IV of the *Catalog*) were electronically prepared, and the taxa, authors and dates should agree fully with the information in the respective alphabetically-arranged sections. The short-version citation before the reference number was

electronically entered in the alphabetically-arranged 'Genera' section, but in the 'Species' section, entry of the short version citation was a two-step process, and some may differ from information in the references section. The reference number associated with an original description was electronically assigned, and these should all be in agreement, but some reference numbers in the status portions may involve typographical errors. The family/subfamily assignment was done electronically, so the family/subfamily at the end of the alphabetically-arranged section should be in agreement with the placement of taxa in the classification. Because of the way we entered status references using 'function' keys, the page on which the author treated the taxon may be in error by one or more pages, but the reference number should be accurate. Museum collection abbreviations are usually used in taxonomic papers to abbreviate the name of the repository containing specimens, but these changes and many new ones have been introduced; there are some discrepancies in our use of abbreviations, and some may appear in our list of abbreviations and some may not.

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The SPECIES Table



Sources

The SPECIES table is the backbone of FishBase, and has the scientific name as its basic unit. Every bit of information in FishBase is attached directly or indirectly to at least one species and it is mostly through this table that information is accessed.

The SPECIES table covers all of the estimated 25,000 extant fishes.

The information in the SPECIES table has been derived from more than 3,500 references such as the *FAO Species Catalogues* (e.g., Nielsen et al. 1999), the *Indo-Pacific Fishes Series* (e.g., Randall, 2000), other taxonomic revisions, e.g., (Pietsch and Grobecker 1987) as well as faunal checklists such as Daget et al. (1984, 1990), Shao et al. (1992), Kottelat et al. (1993), Smith and Heemstra (1995), Myers (1999) and Smith-Vaniz et al. (1999). For a discussion of the difficulties arising from using secondary sources, see the 'SYNONYMS table' and the 'Reviews' section in the chapter 'The Making of FishBase'.

The SPECIES table presents the valid scientific name and author of a species or subspecies and assigns it to a family, order and class. Where available, a unique English common name is given (see discussion on FishBase name below). Additional information in the SPECIES table relates to maximum age and size, habitat, uses, and general biological remarks. The references used to derive the information are given.

On a click of a button you can access additional information such as a picture of the fish, a map showing distributional information, higher taxa, synonyms, common names, available life history parameters, all references used, all colleagues who contributed or verified information, etc.

Box 4. We don't believe in codes.

Over the years, it has often been suggested that we should use FishBase to introduce a global system of unique codes for finfish; such coding systems are especially popular with system analysts, probably because they fit well with programming languages such as assembler, FORTRAN or C and operating systems such as Unix. The following advantages of codes are usually given:

- shorter than scientific names;
- less storage space, faster retrieval, faster entry;
- better grouping, e.g., at the family level; and
- more stability than with scientific names.

However, none of these alleged advantages has stood the test of time. Coding systems that started with 3-5 digits have grown to 8-12 digits. A numbering system for all taxa would need codes of 40 or more digits (Pinborg and Paule 1990). The advent of fast computers, large storage capacity, and modern relational database software has made the listed advantages all non-issues.

Also, working with codes instead of names is prone to errors (J.-C. Hureau, pers. comm.) and it is very difficult to detect typos (W.N. Eschmeyer, pers. comm.).

The main reason why coding systems become unmanageable after a while is that the assumption of stability is wrong. As our understanding of the living world increases, two formerly separate species are found to be the same, another species is found to actually consist of two separate species, a closer study puts a certain species in a different genus, and a group of fishes thought to have a common ancestor at the family level is found to actually have two different ancestors and is split into two families. All these discoveries change the scientific name of a species and/or its place in the classification. A complex set of rules, i.e., the *Zoological Code of Nomenclature* (ITZN 1985, 1999) regulates the establishment and change of scientific names, and synonymies keep accurate track of these changes. Coding systems provide snapshots of the taxonomy at certain points in time. However, names continue to change and coding systems now have to keep track of former and current codes (see Smith and Heemstra (1986) as an example). Depending on the degree to which a coding system tried to incorporate the taxonomy, it might even need changes for unchanged scientific names, e.g., when a genus is transferred to another family. To avoid this problem, the recent Australian coding system (Yearsley et al. 1997) decided to continue the family classification of Greenwood et al. (1966), thus ignoring 30 years of taxonomic research (Nelson 1984, 1994; Eschmeyer 1990, 1998).

Therefore, we strongly support the view that scientific binomina with their established rules and synonymies are the 'coding system' that should be used globally.

Codes in FishBase (SpecCode, StockCode, SynCode, FamCode) are just counters to reduce the number of linking fields between tables. The codes are not used for data entry and they are hidden in the user interface.

In summary, any attempt to provide a stable coding system for a continuously changing taxonomy is bound to fail. Either it will perpetuate outdated knowledge, including known mistakes such as misidentifications, or it has to create and maintain extensive synonymies of code numbers, a somewhat absurd exercise.

References

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Rainer Froese

Author: This refers to the name of the person who first described the species and the year the description was published. An author's name in parentheses indicates that the species has been placed in another genus since it was originally described. In the case of more than one author, the ampersand is used to indicate multiple authorship, e.g., Temminck & Schlegel, 1844. Double-click on the **Author** field to see the full citation in Eschmeyer's REFERENCES database.

A unique English common name is provided

FishBase Name: A unique English common name suggested by FishBase in order to stabilize common names, and derived as follows:

an existing FAO name; or else
an existing AFS name; or else
an existing English name that has not yet been used as **FishBase Name** for another species.

A double click on the FishBase name field opens a spreadsheet window with a list of countries and languages using the chosen common name.

So far, we have refrained from coining common names. There are over 13,000 species without a **FishBase Name** (see discussion under the 'COMMON NAMES table', this vol.).

The species is then classified into **Family, Subfamily, Order and Class** following the November 2000 update of Eschmeyer (1998).

Main Ref.: This is the code number of the main source used for the nomenclature and other information in the species record. Preferably, this should be the latest revision of the respective family or genus, or an equally reliable primary source (see **Sources** below). Other sources used for particular information are placed in additional **Ref.** fields.



Clicking on the **fish** button gives a slideshow of all pictures available for this species in FishBase.



Clicking on the **map** button opens different map views when the various map options are selected. You can choose to highlight all native or introduced countries where a species occurs, plot introduction paths, or plot occurrence points up to the family, genus or species level. Special maps, available for some countries, are also offered.



Clicking on the **FishBaseWeb** button opens the Species Summary page in the FishBase Internet version. Species information may be more updated in this version since uploading of current information or data is done monthly.

Status information

Clicking on the **Status** button gives information about the current record. Most fields are for internal use only. Such fields include:

*Codes in FishBase
are just counters*

Author Ref.: Code number of the original publication which first described the species. Double-click on the field to view the full citation of the reference.

SpecCode: Code number (counter) of the species.

FamCode: Code number (counter) of the family to which the species belongs.

Source: A single character text field that indicates what kind of reference was used, **R** = information derived from recent Revision (i.e., the preferred source); **O** = information derived from Other sources (i.e., a less reliable source, to be replaced as soon as possible).

Synopsis checked: The first field gives the number of the FishBase staff or collaborator who printed and checked the full synopsis. It is followed by a field that indicates the date when this was done.

ASFA checked: The field indicates the date when (and if) a search from the Aquatic Sciences and Fisheries Abstracts was made and used for the species in question.

ISSCAAP code: The International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP) code number to which the species belongs (FAO-FIDI 1994; see also the 'ISSCAAP table', this vol.).

Entered, Modified and Checked: These fields give the number of the FishBase staff or collaborator as well as the date when the record was entered, modified and checked. Double-click on the number to get information on the FishBase staff or collaborator (e.g., contribution to FishBase, contact numbers, etc.).

Environmental information

*FishBase indicates
the preferred environment*

You get to the following fields by clicking the **Environment** button.

Freshwater, Brackish and Saltwater: Yes/no fields that indicate whether the species occurs in the freshwater, brackish and/or marine environment(s), at any stage of its development.

Habitat: Indicates the particular environment preferred by the species, with the following choices (adapted from Holthus and Maragos 1995):

- pelagic: occurring mainly in the water column between 0 and 200 m, not feeding on benthic organisms;
- benthopelagic: living and/or feeding on or near the bottom, as well as in midwater, between 0 and 200 m;
- demersal: living and/or feeding on or near the bottom, between 0 and 200 m;

- reef-associated: living and/or feeding on or near reefs, between 0 and 200 m;
- bathypelagic: occurring mainly in open water below 200 m, not feeding on benthic organisms; and
- bathydemersal: living and/or feeding on or near the bottom, below 200 m.

While this classification works well for marine species, it is often difficult to apply to freshwater fish. Suggestions to improve on this are welcome.

Migrations: Migration patterns of the species, normally for spawning or feeding, with the following choices: anadromous; catadromous; amphidromous; potamodromous; limnodromous; oceanodromous; non-migratory. Descriptions of these patterns may be found using the **Glossary**.

Depth range: The depth range (in m) reported for juveniles and adults (but not larvae), from the most shallow to the deepest.

Common depth: The depth range (in m) where juveniles and adults are most often found. This range may also be calculated as the range within which approximately 95% of the biomass occurs.

Remarks: A text field for additional comments on the habitat, food, behavior, uses and other pertinent information.

Size and age

We record the age of the oldest specimen ever found

You get to the following fields by clicking the **Size/Age** button.

Longevity: Age (in years) of the oldest specimen(s) ever found in the wild and/or in captivity (reported from aquaria and ponds).

Max. length: Size (in cm) of the largest male/unsexed or female specimen ever caught. Choice of length type: **SL** (Standard Length); **FL** (Fork Length); **TL** (Total Length); **WD** (Width of disc; used only for rays); **NG** (not given); **OT** (Other);

Common length: Size (in cm) at which male/unsexed or female specimen(s) are commonly caught or marketed. Choice of length type as above.

Max. weight: Total weight (in g) of the largest male/unsexed and/or female specimen(s) ever caught.

Clicking on the **L-W relationship(s)** button will give, where available, a general impression of the relationship between body length and weight of the species (see the 'LENGTH-WEIGHT table', this vol., for more information).

Clicking on the **Growth curve(s)** button will give, where available, a general impression of the relationship between body length and age of the species (see the 'POPGROWTH table', this vol., for more information).

Box 5. Temperature and the maximum size of fish.

There are several relationships linking the environmental temperature of fishes and their maximum sizes, and graphs are available in FishBase that use plots of maximum size vs. temperature to illustrate different biological features of fishes.

The most important of these relationships refers to the fact that given sufficient evolutionary time, any large taxon will fill all potentially accessible habitats and niches, including those requiring very small and very large body sizes, leading to the 'Full House' of Gould (1996). This is here illustrated by a plot showing roughly the same range of sizes (from 4 to 400 cm) being 'filled' within the range of temperatures commonly tolerated by fishes. This is particularly evident in the version of the graph where the logarithms of the maximum lengths are used, which reduces the visual impact of a few very large species (> 200 cm) (Fig. 7).

The second biological feature of fish illustrated by the plots of maximum length vs. temperature is that within a taxonomically (and anatomically) well-defined group, maximum lengths decline with increasing temperature, as predicted by the theory of fish growth in Pauly (1979, 1994) (see also Longhurst and Pauly 1987, Chapter 9). The log-length vs. temperature plot illustrates this phenomenon as well. [This does not apply to temperatures from -2 to 3°C, wherein the phenomenon known as 'cold adaptation' (Wohlschlag 1961) induces stress similar to that caused by higher temperatures (Pauly 1979)].

The maximum lengths used for these graphs stem from the maximum length field of the SPECIES table; the temperatures are, for the species in question, taken as the midrange or mean of the temperature fields in the STOCKS table.

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Daniel Pauly

Important fishes

*We classify fish
according to their
importance to people*

You get to the following fields by clicking on the **Importance** button.

Fisheries: Importance of the species in capture fisheries, with the following choices: highly commercial; commercial; minor commercial; subsistence fisheries; of potential interest; of no interest. The field to the right gives information about the importance and use of the species in fisheries.

Catches: Average global landings/production for the species (in t/year), with the following choices: up to 1,000; from 1,000 to 10,000; from 10,000 to 50,000; from 50,000 to 100,000; from 100,000 to 500,000; and more than 500,000 (see FAO 1995 for more information). The field to the right gives information on the countries and areas with the highest contributions to landings of the species.

Method: Two fields give the primary method used for catching the species, with the following choices in the first field: seines; trawls; dredges; liftnets; castnets; gillnets; traps; hooks and lines;

various gears; others. In the second field, choices given are the various kinds of seines, trawls, gillnets, longlines, traps and others. There are several yes/no fields for other fishing methods used.

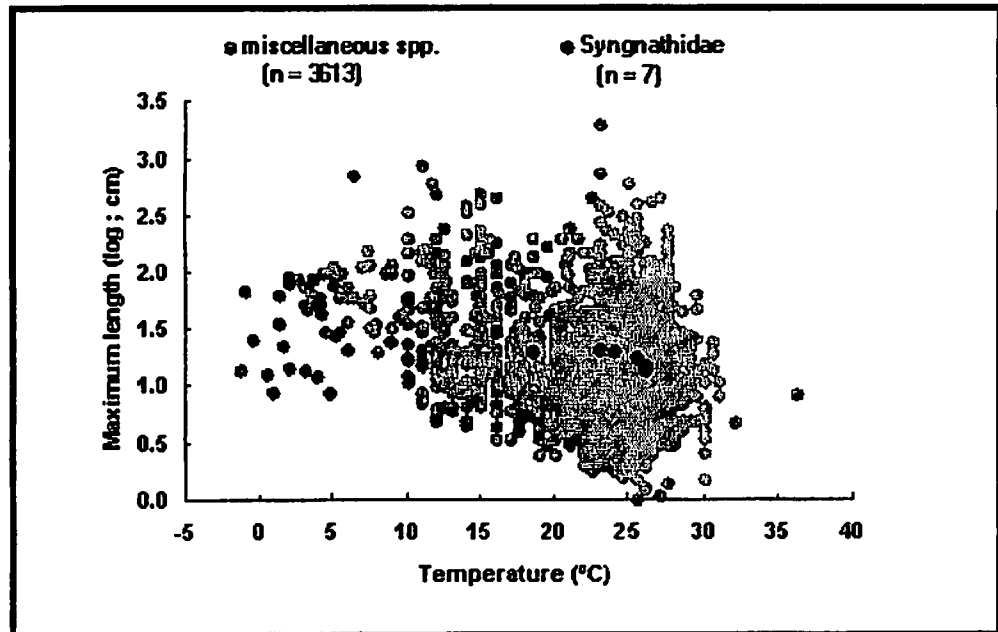


Fig. 7. Maximum length vs. temperature of Syngnathidae and miscellaneous species.

Aquaculture: Indicates the use of the species in aquaculture, with the following choices: never/rarely (default); commercial; experimental; likely future use. This is followed by a field that indicates whether the life cycle of the fish is closed or not and if in use in experimental or commercial culture systems. Core information on the use of the species on aquaculture, when available, is provided by clicking the aquaculture species Profile button (see section under Genetics and Aquaculture chapter).

Bait: Indicates the use of the species as bait in capture fisheries, with the following choices: never/rarely (default); occasionally; usually.

Most marine aquarium species are taken from the wild

Aquarium trade: Use of the fish in the aquarium trade industry, with the following choices: never/rarely (default); commercial (for fishes found in aquarium shops all around the world); potential (for fishes which are small, easy to keep and remarkable in coloration, shape and/or behavior); show aquarium (for fishes shown in public aquaria but which are normally too large or too difficult to keep in home aquaria). This is followed by a field that indicates whether the demand of the aquarium market is met by either breeding the fish (e.g., guppies) or taking them from the wild (e.g., most marine species).

Game: A yes/no field that indicates whether the species is included in the list of World Record Game Fishes, published annually by the International Game Fish Association (IGFA, Pompano Beach, Florida, USA), or reported as a game fish in other sources.

***FishBase contains
all fishes that are
dangerous to humans***

Dangerous fish: Indicates whether the species is dangerous to humans, with the following choices: harmless; poisonous to eat (where the liver, intestines or skin naturally contain poisonous substances); causing ciguatera poisoning (where toxins are accumulated in the fish through the food web); venomous (fishes which have spines or mucus containing venom); traumatogenic (fishes that could possibly injure with a bite, sting or puncture); and 'other' (including electrogenic fishes, capable of delivering a painful electric shock). If a fish has been reported as ciguatoxic in FishBase, double-clicking on the field indicating this will lead to the CIGUATERA table (this vol.).

***Many fishes can generate
electric fields***

Electrobiology: The entries in this field deal with a phenomenon which has fascinated naturalists for centuries: the ability of many species of freshwater and marine fishes to generate electric fields and stun their preys, or unsuspecting humans.

These electric fields, which may be extremely strong, are used for various purposes, such as orientation, defense, predation and others, some not fully explored. The publication of P. Moller's comprehensive book on *Electric Fishes* (1995) has provided an opportunity for covering this ancient, but still very active area of research through a single field, based on the classification presented in that work. The electric 'status' of a fish is thus captured by one of the four following choices, arranged in evolutionary sequence:

1. **No special ability:** this option implies a 'normal' (i.e., extremely weak) electrogenic activity for the nerves and muscles of the species in question. This status (default) is the one from which the other three have been repeatedly and independently derived in various groups of fishes;
2. **Electrosensing only:** this ability, widespread in, but not limited to elasmobranchs (sharks, rays, chimaeras), implies organs capable of detecting the weak electric fields generated by other animals, e.g., potential preys;
3. **Weakly discharging:** the ability to generate a relatively weak electric field, used mainly for orientation when visibility is low, and for prey detection. (Note that this option implies an electrosensing ability as well);
4. **Strongly discharging:** the ability to generate strong electric fields, and to stun potential preys and predators. This ability implies electrosensing as well, except in stargazers, family Uranoscopidae.

The references for this field consist mainly of Moller's book, or of one of its authored chapters, these sources jointly representing the most comprehensive and up-to-date review of this topic. The **Remarks** field may contain additional information, attributed to its original source(s), as identified by FishBase staff, or as cited in Moller (1995). Another recent source is Mago-Leccia (1994).

Remarks: A text field for additional remarks on the habitat, behavior, food, breeding, electrobiology and other pertinent information about the species.

Other Information

From the species window, other information on the species is easily obtained with the click of a button. You can get information about the **Family** and **Genus** to which the species belongs, **Common Names used**, the known **Range** and countries where it occurs, other information with regard to its **Biology**, **References** used to obtain the different records and **Collaborators** who entered or provided information. Please refer to the different chapters for specific discussions of the different tables.

How to get there

Click the **Species** button in the FishBase Main Menu. You can then search for a species by scientific name, common name, family, country, quick identification, or topic. A list is generated according to the search and by double-clicking on a scientific name, you enter the SPECIES window of that particular species.

Access to the FishBase Book for this section is possible by clicking on the **About** button. The **Glossary** button is used to find definitions of terms and the **Print** button for printing species information.

Internet

Most of the information described in this chapter is available in the 'Species Summary' page in FishBase on the Internet.

Acknowledgments

We thank FishBase staff Susan M. Luna, for her previous contributions to the SPECIES table and to this chapter.

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- Rainer Froese, Emily Capuli, Cristina Garilao and Daniel Pauly**

The COMMON NAMES Table

*Common names
are all that most people
know about most fish*

Claiming that the common names of fish are one of their most important attributes is an understatement. In fact, common names are all that most people know about most fish as shown by the fact that most people accessing FishBase on the Internet do so by common name.

Hence, FishBase would not be complete without common names. This fact has been considered very early in the design of FishBase (Froese 1990) and has resulted in the compilation of over 107,000 common names, probably the largest collection of its kind. It has taken us a long time, to realize, however, that each pair of 'country' and 'language' fields uniquely define a culture, and that a large fraction of what the people belonging to a certain culture know about fishes (i.e., local knowledge) can therefore be captured through the COMMON NAMES table including these fields.

Languages

The languages that can be accommodated through the COMMON NAMES table of FishBase differ in character. Some, such as English, French, Spanish or Portuguese, are very widespread and have names for many fishes not occurring in the countries where the language is spoken. Other languages are spoken only in a single country or locality. These languages usually have names for only those fish species that occur in the area. Users of FishBase should be aware of this distinction when evaluating our coverage of common names (see Fig. 8).

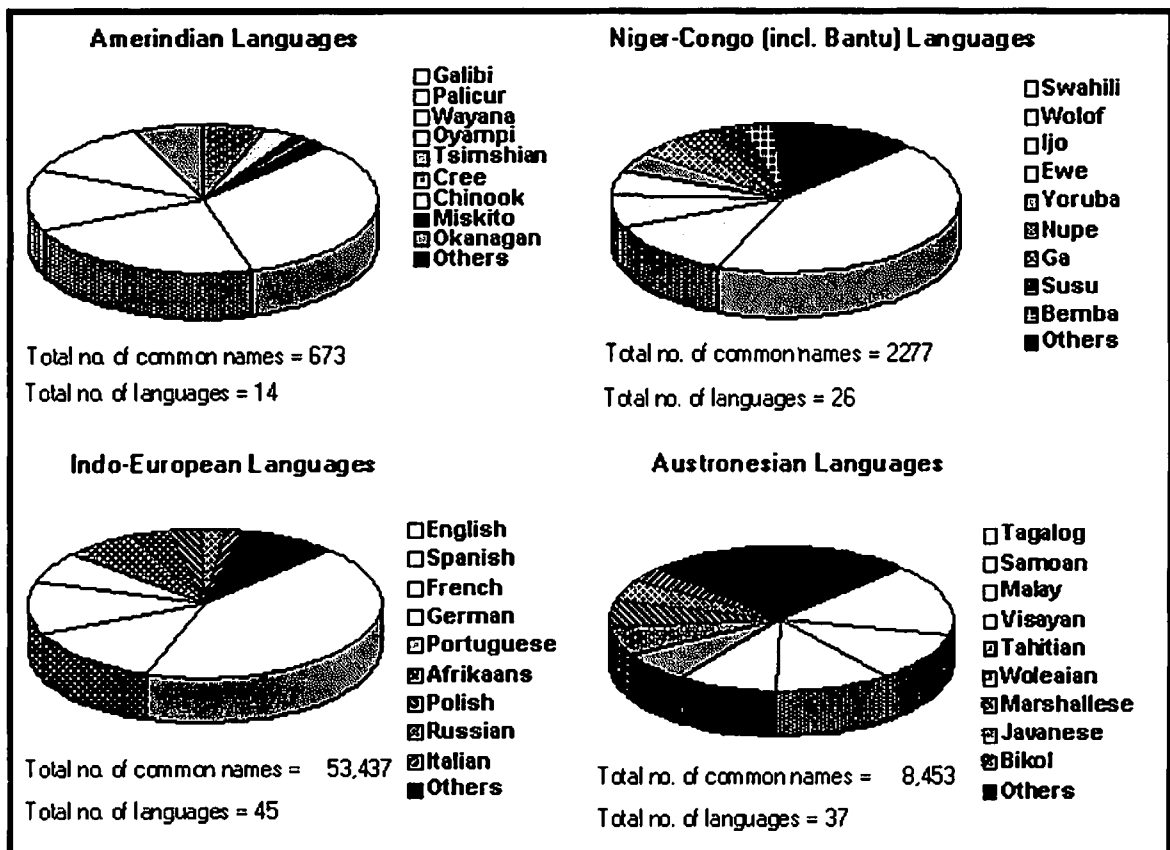


Fig. 8. An overview of the coverage of common names in FishBase, shown as percentage of four major language groupings; note that other language groupings exist for which FishBase also includes common names.

The combination of country and language defines a culture

As conceived, the COMMON NAMES table also allows entry of names from past cultures (if the sources allow unequivocal attribution to species level). We shall use this feature later to enter names from Ancient Egypt (Brewer and Freeman 1989), Greece (Thompson 1947), Rome (Cotte 1944), Medieval Germany (Bingen 1286) and others.

Important 'language-types' considered in FishBase are AFS, referring to the English names selected by the American Fisheries Society (Robins et al. 1991a, 1991b), and FAO referring to FAO's suggestions for stabilizing—at the global level—common names of fish in English, Spanish and French. To assist with such stabilization, FishBase staff have identified unique FishBase English names (for the SPECIES table), consisting of an FAO name, or if not available, of an AFS name, or if not available, of another English name, selected from amongst available names using the criteria in Robins et al. (1991a). The identification of unique names will continue in collaboration with FAO and AFS staff and other colleagues, until all species in FishBase, and eventually all fish species of the world have a potentially stable English common name.

***The COMMON NAMES
table has several uses***

The most obvious use of the COMMON NAMES table is to identify the scientific name of a fish. Note, however, that non-standardized common names may point to more than one species. Other, less obvious, uses include:

- preserving and making widely accessible ethnoichthyological knowledge from endangered cultures (Palomares and Pauly 1993; Palomares et al. 1993; Pauly et al. 1993);
- testing qualitative or quantitative hypotheses about traditional classification schemes (see e.g., Hunn 1980; Berlin 1992; Palomares and Pauly 1993);
- enabling mutual verification of facts from ethnoichthyology and its scientific counterpart (as in Johannes 1981); and
- following the evolution of the linguistic subset represented by fish names, in space and through history, and test related hypotheses.

Sources

The information contained in the COMMON NAMES table was obtained from over 1,700 references, 545 of which were used for 95% of the common names in FishBase. The ten most used references, accounting for 25% of all common names in FishBase are: Organisation for Economic Co-Operation and Development (1990; 3.85%); Zaneveld (1983; 3.43%); Coppola et al. (1994; 3.34%); Robins et al. (1991; 3.11%); Masuda et al. (1984; 2.81%); Koltzar (1984; 2.70%); Herre and Umali (1948; 2.34%); Robins et al. (1980; 2.10%); Mohsin et al. (1993; 1.74%); and Grabda and Heese (1991; 1.44%).

Status

There are, so far, over 16,000 species (63.7% of all species covered in FishBase) with common name records. Of these, over 12,000 species have standardized English FishBase names; over 3,000 species with no English names so far recorded; and about 1,000 whose existing English FishBase names and over 9,000 without any common name records at all.

The common names records cover a total of 205 languages, 69 of which represent 95% of the total number of common names. The ten most represented languages are: English at 36.5%; Spanish, 10.0%; French, 7.01%; Portuguese, 5.16%; Japanese, 3.74%; German, 3.64%; Malay, 2.95%; Afrikaans, 1.80%; Polish, 1.5%; and Arabic, 1.4%.

Verification of common names in the present version of FishBase was done by comparing names from several sources. To date, 17% of the 107,820 common names have been checked against Ngeddly (1990) for the almost 11,000 FAO names; and Robins et al. (1991) for the over 4,000 AFS names. A total of 42 collaborators (see acknowledgments below) helped us check names in different languages including FishBase staff that did visual checks for languages they mastered (English, German, French and several Philippine languages). Over 39,000 English and about 7,600 French vernacular names were verified through a spell checker.

Check your language!

You can generate lists of common names and local knowledge by species or by language in the Reports section accessible from the Main Menu. Similarly, a routine is available from the User Databases button in FishBase Advanced which deals with a user database on local names (see the 'Local Knowledge Database', this vol.).

Extension of the present coverage will continue to emphasize major single sources, e.g., Sanches (1989) for Portuguese, but will also include the shorter lists emanating from ethnozoological studies in the Americas, Africa and the Asia-Pacific regions. Interested colleagues are welcome to join in this effort.

Fields

The fields of the COMMON NAMES table are presented in some detail below with emphasis on the multiple choice fields:

Name: A text field that pertains to the vernacular or common name of a given species in a given culture.

Life Stage: A choice field that pertains to the life stage for which the common name is used. The seven choices included in this field are eggs; larvae; juveniles; juveniles and adults (default); adults; large adults; product. The last item pertains to the name of a fish product when different from that given to the fresh specimen. As this may refer to a commercial product, this allows covering of names used in the fishing industry as well as the ethnoichthyology of advanced trading societies.

Sex: A choice field that pertains to the sex of the fish to which the common name refers. The available choices are: females and males (default); females; spawning females; males; spawning males. Note that different names often are given to the different reproductive stages of female and male fish, sometimes in conjunction with religious rituals.

Language: A choice field for the language in which the common name is used. This covers over 200 languages in alphabetic order ranging from 'Adangme' to 'Zande' (see Fig. 8, for examples). The language field is linked to the Language Name in the LANGUAGE table which contains information on the language's taxonomy (Language Family, Language Branch and Language Group), and the country or countries where it is spoken by the majority of its first language speakers. The data that complete the LANGUAGE table were obtained from Ruhlen (1991) and Grimes (1992) and are meant as additional hints on sources of local knowledge. Double-click on the language name to access information about the language.

*FishBase contains
common names in over
200 languages*

*Search for
'Schillerlocken'*

Type: A choice field classifying the 'language', i.e., source or use of the common name. The choices are: vernacular; market; aquarium; FAO; and AFS. FishBase includes all Australian market names (Yearsley et al. 1997); market names recognized by the American Food and Drug Administration (FDA; Randolph and Snyder 1993); and most European market names from the

Organisation for Economic Co-operation and Development (1990).

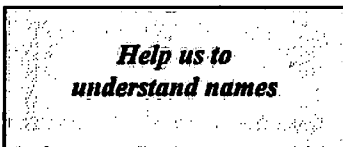
Etymology: consists of three choice fields, the first for describing the 'core' of a name (e.g., 'cod' in 'coral rockcod'), the second and third being used for the first ('rock') and second ('coral') modifiers, if any. The choices for the first of these three fields, loosely based on, and expanded from Foale (1998), are as follows: primary lexeme; morphology; color pattern(s); behavior; habitat/ecology; taste/smell; person (generic); person (eponym); other fish; non-fish animal; plant; inanimate object; affinity; locality/area; other/n.a.



Categories of 1st and 2nd modifiers of core or root word: primary lexeme; morphology; color pattern(s); behavior; habitat/ecology; taste/smell; person (generic); person (eponym); other fish; non-fish animal; plant; inanimate object; locality/area; mod. for size; mod. for abundance; mod. for affinity; other/n.a.

Note that several choices other than 'color pattern(s)' do in fact refer to color patterns as well. Thus 'person (generic)', 'non-fish animals', etc. may indirectly indicate colors, (e.g., 'convict surgeonfish', so named because of its stripes, and the spine on its caudal peduncle, or 'leopard shark', because of its spots). This feature must be taken into account when analyzing the entries in terms of the number of color-related terms.

This approach, developed in 1998, for dealing with the etymology of fish names was applied, so far, to a little below 20,000 common names covering 79 languages and 11,635 species. The bulk of these (46.8%) are in English, followed by Japanese (18.2%), Spanish (12.0%), French (6.1%), Portuguese (3.1%), Swahili (2.3%), German (1.5%), Tagalog (1.4%), Tuamotuan (0.9%), Tamil (0.7%) and the 69 other languages comprising the rest.



Since this information is language specific, we hope that collaborators who speak languages other than English will help us in deciphering the meanings of common names for which these fields have not been filled in.

Remarks: A memo field is provided for details on the etymology of a given common name or additional information relevant to the understanding of that common name (e.g., the name 'Lapu-lapu', a common name for grouper in Tagalog and other languages of the Philippines, is also the name of the Philippine hero who, on 16 March 1521, slew Magellan, a would-be conquistador). To date, more than 24,000 common names contain information on their etymology covering 125 languages and about 15,500 species. English is the most represented with 45%, followed by Japanese (14%), French (10%), Malay (4%), Tagalog (3%), Spanish (2%), Portuguese (2%), Javanese (2%), Danish (2%) and Samoan (1%).

Like the three **Etymology** fields described above, this information is language, and in addition, culture specific. Thus, we hope that

collaborators wishing to widen the coverage of their own ethnological knowledge as captured in this particular field will eventually take in the responsibility of improving its contents.

Rank. A numeric field, which indicates the importance of the language within the country where it is used. So far, four categories have been identified, viz.: Rank = 1, name adapted by the AFS or the FAO and may have been adopted in the country as the official name of the species; Rank = 2, name used in the national or official language of the country; Rank = 3, name used in other indigenous languages not considered official or national; Rank = 4, name used in a language not indigenous to the country but has been adopted either for its official or international use.

*We rank common names
by commonness*

The Rank field is used in FishBase to display the national common names (Rank = 2) in a species by country list (see Reports, this volume), immediately after their standardized English FishBase name. There are cases, however, where Rank 2 names occur in several languages, e.g., as in Mauritania where Arabic, French and Wolof are all recognized as official languages. In such cases, only the standardized English FishBase name will be displayed. Also, there are cases where several Rank 2 names in the official language are available for the species. Here, FishBase displays the first occurrence of a Rank 2 name.

We have strived to fill in the rank fields of all common names in FishBase according to the definitions outlined above. Changes to the Rank field or additional definitions may occur in future versions of FishBase as we review its usefulness within the COMMON NAMES table. Your comments and suggestions regarding its use will be highly appreciated.

How to get there

You get to the COMMON NAMES table by: (1) clicking on the **Common names** button in the SEARCH BY window; (2) clicking on the **Common names** button in the SPECIES window; or (3) double-clicking on the common name in any of the reports generated on screen.

You get checklists of (1) species by common names, (2) common names by language, and (3) local knowledge by language and country, by clicking the **Common names** button in the PREDEFINED REPORTS window.

You get a graph of common names by language, divided into four language groups (see Fig. 8), by clicking on the **Miscellaneous plots** button in the GRAPHS window and then on the **Common names by language** button in the MISCELLANEOUS PLOTS window.

Internet

On the Internet version of FishBase, click on the **Common Names** link in the 'More information' section of the 'Species Summary' page to obtain a list of all common names used for the respective species.

Acknowledgments

Our thanks to the late M. Warren for helping us realize that FishBase could be used to record and structure ethno-ichthyologic knowledge and to FishBase Team members for helping with the entry of common names, notably, Ms. T. Cruz and Ms. C. Garilao whose joint efforts account for more than half of the common name records in FishBase. We also thank the various collaborators who either checked or provided lists of common names, notably: R. Kristo (Albanian); D. Preikshot (Alutiiq and Newfoundland English); S. Dammous, M.M. Fouda (Arabic); A. Chan (Chinese languages); M. Doray (Creole, French); V. Christensen, A.J.T. Dalsgaard (Danish); L. Abbott, T. Bishop, Kent Carpenter, A. Miyasaka, J. McArthur (English); S. Kuosmanen-Postila (Finnish); C. Lhomme-Binudin, J. Moreau, C. Papisissi, G. Rouleau (French); R. Froese and M. Vakily (German); R. Jones (Haida); T. de Feu (Hausa); M. Goren (Hebrew); E.A. Buchary and D.S. Wahyuningsih (Indonesian languages); E. Nic Dhonna (Irish); F. Gagliardi (Italian); W. Swartz (Japanese); E. Nsiku and E. Kaunda (various Malawi languages); A.K.M. Mohsin (Malay); M.N. Trevor (Marshallese); C. Appleby (Norwegian); L. Coelho, M. Vasconcellos, K. Freire (Portuguese); V.V. Arkhipchuk, E.V. Romanov (Russian); A.G. de Sola Simarro, R. Robles, F. Sánchez Delgado (Spanish); B.A. Gottwald (Swedish); R. Chuenpagdee (Thai); S. Watkinson (Tsimshian); T. Hatton-Ellis (Welsh); K. Ruddle (various Southeast Asian languages); and J. Wadanya (various Ugandan languages).

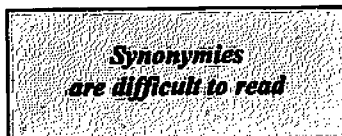
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- Maria Lourdes D. Palomares and Daniel Pauly**

The SYNONYMS Table

When we developed the FishBase concept, back in 1988, we had the notion that fish taxonomy was in a reasonably good state, that most names used in the literature would be correct, and that the rest could be dealt with through synonymies. While these assumptions were largely true, we dreadfully underestimated the remaining difficulties such as inconsistencies in recent publications, the necessity to keep track of and completely understand taxonomic works, and the sometimes detective-like work needed to assign a piece of information to the proper biological species.



Synonymies are difficult to read. This fact is largely ignored by non-taxonomists who tend to think that any name listed in a

synonymy is an alias for the species in question. Unfortunately, taxonomic convention facilitates such thinking, by not forcing authors to highlight cases for which the above assumption is wrong; i.e., when the listed name actually is a valid name or synonym of another biological species, and it appears only in the synonymy because someone at some point confused the two species (see also, 'The Role of Taxonomy', this vol.). Some colleagues will know that such cases should be marked by a statement such as ('non Lacepède') following the species name. They may not be aware that—depending on the context—a comma, colon, or period following the species name might also flag misidentifications, i.e., names that are not aliases for the current name.

The most common—although usually harmless—confusion in reading synonymies is between the original author (such as in *Scopelus dumerilii* Bleeker 1856) and a subsequent user of the name who, e.g., assigned it to a different genus (such as in *Diaphus dumerili* Fowler 1928).

It was only when we started classifying synonyms into **Status**: original combination (e.g., *Scopelus dumerilii* Bleeker 1856); new combination (e.g., *Diaphus dumerilii* (Bleeker 1856)); misspelling (e.g., *Diaphus dumerili* (Bleeker 1856)); junior synonym (e.g., *Myctophum nocturnum* Poey 1861 of *D. dumerilii*); misidentification (e.g., *Diaphus effulgens* (non Goode & Bean 1896) of *D. adenomus*); questionable (needs further research); other (see **Comment** field); that we realized the many mistakes we ourselves had made when reading synonymies.

Status

We ran numerous logical checks to detect errors in the SYNONYMS table

We ran a number of logical checks to identify possible erroneous records, such as: list all synonyms that match valid names in the SPECIES table and are not classified as misidentifications; list all synonyms that point to more than one valid species; list all junior synonyms with the same specific name as the valid species to which they are attached; list all original or new combinations with an author different from the author of the valid name; list all synonyms with the characters 'non', 'not', or 'nec' in either the author or the comment field, and which are not classified as misidentifications; etc. Since FishBase 98, we have also compared all original descriptions and most junior synonyms with Eschmeyer's (1998) *Catalog of Fishes*. We believe that, through this exercise, we have identified and repaired most errors.

Nomenclatural Changes

Scientific names are more than labels

Scientific names are more than labels in that they also reflect our current understanding of the evolution of fishes. Thus, all species in a given genus are thought to have a common ancestor, and no offspring of that ancestor must occur in another genus (i.e., the genus must be monophyletic). The same is true for the higher taxa of family, order and class, only that the common ancestor dates further back in time with each higher level.

Box 6. Chronology of species descriptions.

For zoologists, scientific taxonomy began with the publication, in 1758, of the tenth edition of C. Linnaeus' *Systema Naturae*. The FishBase graph showing the number of fish species described since, here grouped in classes of 5 years (see Fig. 9), takes the same approach.

As might be seen, the graph depicts a see-saw pattern reflecting individual achievements (Linnaeus 1758; Bloch 1785; Lacepède 1798; Cuvier and Valenciennes 1828 ff; Günther 1859 ff.; and Boulenger 1909 ff.), showing a steady rise through the 19th century—the age of European colonial expansion—from about 50 to about 500 new species descriptions per 5-year period.

There is an interesting gap from 1880 to 1890, possibly caused by the fact that Cuvier, Valenciennes and Günther had described most specimens available in the collections (Tyson Roberts, Calif. Acad. Sci., pers. comm.). The graph also shows the devastating impact of World War I (1914-1918), and especially of World War II (1939-1945), when new species descriptions dropped to the level of the late 1700s.

Note that most of Linnaeus' species are still valid today, because no previous descriptions could turn his names into junior synonyms. However, some of his names were found to point to the same species and were synonymized by the first revisers. Most of his names are now in different genera, thus reflecting our better understanding of the evolution of fishes.

Note also the high rate of duplicate descriptions from the early 19th to the mid-20th century, probably caused by a widespread rush to describe new species, coupled with inadequate access to published literature.

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Lacepède, B.G.E. 1798. *Histoire naturelle des poissons*. Paris. 8 + cxlvii + 532 p.

Linnaeus, C. 1758. *Systema Naturae per Regna Tria Naturae secundum Classes, Ordinus, Genera, Species cum Characteribus, Differentiis Synonymis, Locis*. 10th ed., Vol. 1. Holmiae Salvii. 824 p.

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*10% of the names
change in 10 years*

As ongoing taxonomic work continues to clarify relations between species, scientific names keep changing. In fishes, as a rule of thumb, about 10% of the names in any given work will be outdated after 10 years (Froese 1996, 1997). The unique way in which scientific names and references are linked in FishBase allows to trace such changes and to print a list of nomenclatural changes for major taxonomic works.

Sources

The SYNONYMS table contains more than 70,000 synonyms, including junior synonyms, new combinations, misspellings, misidentifications, and over 25,000 valid names. The information is drawn from references such as FAO Species Catalogues, regional checklists such as CLOFFA and CLOFETA, and family revisions such as Pietsch and Grobecker (1987).

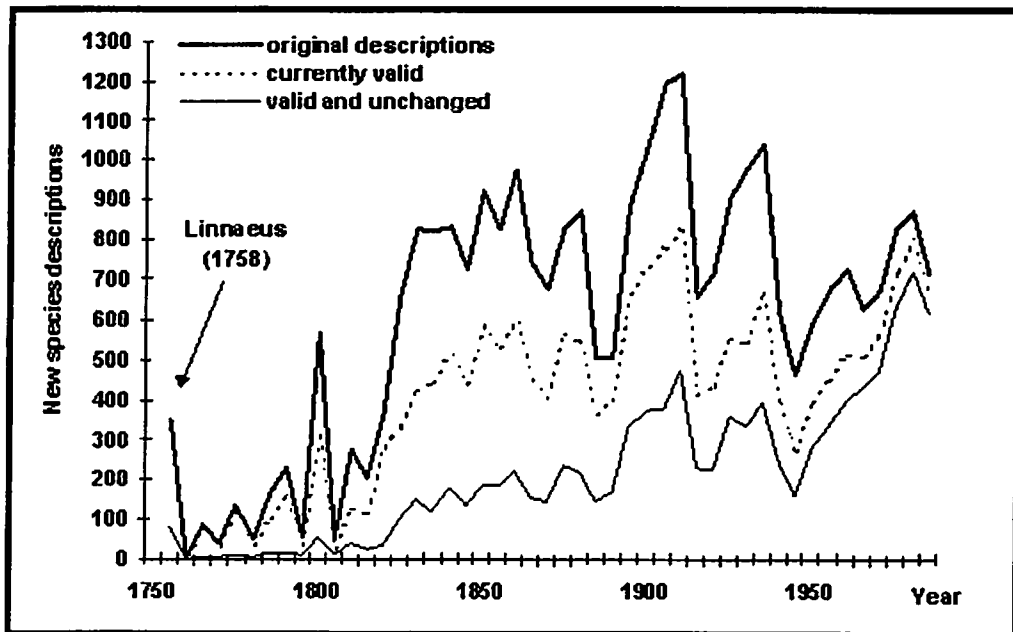


Fig. 9. Species descriptions of fishes at 5-year intervals over time as contained in FishBase. See Box 6 for a discussion of this graph.

Fields

The table gives the synonymous **Name**, **Author**, the **Reference** and **Page** that state the classification or **Status** of the synonym (see choices above for **Status**), and a **Comment** field for further information regarding the name, author or references. Double-clicking on the **Name** and **Author** will give species and author information from Eschmeyer's **PISCES** and **REFERENCE** databases, respectively; on the **MainRef**, the full citation of the reference; and, on the **Comment** field, a **SEARCH** window for finding full citation of references mentioned. Further information regarding original combination of the name may also be found by clicking on the buttons for Eschmeyer's **PISCES** and **GENERA** databases. Additional buttons for **About** (Synonyms chapter in the manual), **Glossary**, **Print** and **Status** (internal codes and credits) are also provided.

How to get there

You get to the **SYNONYMS** table by clicking on the **Synonyms** button in the **SPECIES** table. You get to the **Nomenclatural changes** routine by clicking on the **References** button in the **Main Menu**. Eschmeyer's **SPECIES**, **GENERA** and **REFERENCE** tables can also be accessed for reference in this table.

Internet

In the Web version of FishBase, click on the **Synonyms** link under 'More information' in the 'Species Summary' page to get to the information described in this chapter.

Acknowledgments

We thank Kent Carpenter for suggesting to classify synonyms as described above. We thank Susan M. Luna for her contributions to an earlier version of the **SYNONYMS** table. We applaud W.N.

Eschmeyer for sorting out the above mentioned problems in his *Catalog of Fishes* (Eschmeyer 1998). We also congratulate Theodore W. Pietsch and David B. Grobecker for their excellent monograph on *Frogfishes of the World* (1987), which helped us to understand synonymies.

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Distribution

The STOCKS Table

Linnaeus established the binominal system of nomenclature

When Linnaeus established the binominal system of nomenclature with the 10th edition of his *Systema Naturae* in 1758, he laid a strong foundation for taxonomic work: a unique combination of a generic and a specific name had to be assigned (fixed) to a specimen (the holotype), which thus became the ultimate reference point for a biological species. Unfortunately, this beautiful concept was confused by the subsequent acceptance of subspecies, also fixed to a specimen but declared a subunit of a species and thus described by three names (e.g., *Oreochromis niloticus eduardianus*). The original species then becomes *Oreochromis niloticus niloticus* and we have the confusing situation that its holotype now points to a subspecies as well as to a species supposed to include all other subspecies. This undermines the widely used biological species concept that explicitly includes populations by defining species as “groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups” (Mayr 1942, p. 120), and thus leaves no space for subspecies (see also Sinclair 1988 for an excellent discussion of marine populations).

The distinction between a population and a subspecies is unclear

Fisheries scientists work with the exploited part of populations which they term ‘stocks’. Similarly, aquaculturists work with ‘strains’, i.e., races or varieties of a certain species. Again, the distinction between a population or ‘race’ and a subspecies is unclear.

We do not like subspecies

For the structure of a relational database, the conceptual confusion between species, subspecies and populations translates into unsatisfactory design.

In the current version of FishBase—as in the taxonomic literature—a subspecies is treated similarly to a species, i.e., with its own record in the SPECIES table, but with a two-word entry in the specific name field. If a subspecies has been entered then the original species itself also becomes a subspecies (see above). The downside of this approach is that a search for, e.g., *Oreochromis niloticus* will not find a record in the SPECIES table and the subsequent automatic search for *Oreochromis niloticus** will find a total of seven subspecies with *Oreochromis niloticus baringoensis* being first because of alphabetic sorting; the user has to go through the list to find *O. niloticus niloticus* as record number five. From a design point of view it would be better to treat a subspecies as a stock or population; however, that would create incompatibilities with the taxonomic literature and create new design problems (e.g., synonyms of subspecies would have to be linked to populations). It probably would be best if taxonomists would make up their mind and either consider the characters of a subspecies distinct enough to raise it to the species level, or consider it a

population of a species and synonymize it, as done by Kottelat (1997) for European freshwater fishes.

Fields

In order to be able to separate information for a stock or strain from that relating to the species in general, each record in the SPECIES table is linked to one or several records in the STOCKS table (a one-to-many relationship). All biological information that may differ between populations is attached to the STOCKS table and assigned a Level such as: species in general, subspecies in general, wild stock/population, cultured strain, hybrid.

In the CD-ROM version, if FishBase contains more than one stock or strain for a given species, the STOCKS table opens a tabular view with each row describing one stock or strain. Double-click on a row to switch to form view. Alternatively, use the up and down arrows to select a stock and press Enter to switch to form view.

The Stock definition field gives the distributional range for each of the above categories. For strains, it describes the origin and size of the founder stock and its common name. For hybrids, which are attached to the female species, it states the male species and other details. The field also points out doubtful range extensions and common misidentifications.

FishBase contains published information on all threatened fishes

The Status field describes the status of threat following the categories defined by IUCN: Extinct; Extinct in the wild; Critically endangered; Endangered; Vulnerable; Lower risk; Lower risk: conservation dependent; Lower risk: near threatened; Lower risk: least concern; Data deficient; Not evaluated; Not applicable; Not in IUCN Redlist (Hilton-Taylor 2000). Note that the last two categories were added to accommodate, e.g., hybrids or artificial strains, and the many cases for which we have no information.

Biological information is categorized into Trophic ecology; Genetics; Reproduction; Population dynamics; Fish as food; Morphology and physiology. If a category is represented by a black button, the specific biological information is available (gray buttons represent information gaps).

The related buttons can be used not only to get that information, but also to avoid duplication of research. For a number of species such as *Plectropomus leopardus*, the buttons largely reflect the actual state of knowledge and thus can be used to identify research gaps. We expect that many of our users will provide us with hints, or reprints to help us cover as many species as completely as possible. Click any of the black buttons to open the respective tables.

Status

To date the STOCKS table contains over 20,000 records, including 72 cultured strains, 9 hybrids and 9 populations/stocks. We expect the latter number to increase once we start incorporating the 160 stocks currently recognized by the International Council for the Exploration of the Sea (ICES), the stocks treated in R.A. Myers'

RECRUITMENT table (this vol.) and, e.g., the trout strains recognized by Kincaid and Brimm (1994).

How to get there

You get to the STOCKS table by clicking on the **Range** (for the status of threat of the stock) or **Biology** (for biological information of the stock) buttons in the SPECIES window.

Internet

On the Internet version the fields of the STOCKS table are integrated in the 'Species Summary' page.

References

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The FAOAREAS Table

Describing the occurrence of species is a multi-layered task. In FishBase, the first standardization of the general range description includes the 27 major fishing areas that have been internationally established for statistical purposes (i.e., catch statistics) and which are described in some detail in FAO Yearbooks (e.g., FAO 1995). Such standardization should prove useful when, e.g., relating catch statistics and biodiversity.

Fields

The FAOAREAS table lists all the FAO statistical areas in which a species occurs, and vice-versa. A choice field classifies such occurrence into: native; endemic (i.e., naturally occurring in no other FAO area); introduced; extirpated (i.e., extinct in this area but still existing in other FAO areas); reintroduced (i.e., after extirpation); unclear. Note that strains and artificial hybrids are always classified as introduced, even if the strain originates from the FAO area in question, because hybrids and strains are by definition genetically distinct from wild populations.

Status

The distributional range of many species is not well established

We made an effort to have this basic geographical standardization complete for all species. Note, however, that the distributional range of many species is not well established and it is often not clear whether or not they extended into adjacent FAO areas. Also, the borders of FAO areas cut across faunal regions and therefore the number of species in, for example, area 61, Pacific, Northwest is not representative for the Northwest Pacific because it includes many tropical species which extend northwards to Taiwan and southern Japan, both included in area 61. We intend to use Longhurst's (1995) biogeographical provinces for a finer, and ecologically more meaningful subdivision of the oceans.

Only diadromous fishes such as the European eel (*Anguilla anguilla*) are assigned to both inland and marine areas; the many amphidromous tropical marine fishes that regularly enter the lower reach of rivers or coastal lakes for feeding are not assigned to FAO inland areas to avoid confusion.

How to get there

You get to the FAOAREAS table by clicking on the **Range** button in the SPECIES window and the **FAO areas** button in the STOCKS window.

Internet

On the Internet version, you get to the FAO Areas table by clicking on the respective link in the 'More information' section of the 'Species Summary' page.

References

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The FAOAREAS REF Table

The FAOAREAS REF table contains the names of the 27 statistical areas as defined by FAO, together with some notes on these, based on data from the World Resources Institute (WRI 1990, 1996). These include the length of the **Coastline**, the estimated **Shelf** area to 200 m depth, and the area of the exclusive economic zone (EEZ) [not presently shown in user version]. Note, however, that coastline length has a fractal dimension and thus should not be used in comparative studies unless measured with the same 'stick length'. WRI is working on such standardized coastline lengths, and we will use these as soon as they become available.

The coordinates of a point in the **Center** of the FAO area are provided for displaying a label at this locality, e.g., in WinMap (this vol.). The coordinates of a rectangle or what we call the **Range**, together with the FAO area are used to find gross errors in species occurrence data. Clicking on the **Status** button gives the number of species and families FishBase assigned to the area, and when available, the estimated number of species in the area derived from literature.

On the click of a button, area-specific information such as included **Countries**, **Nominal catches** and **FAO aquaculture production** become available.

How to get there

You get to this table by clicking on the **Range** button in the SPECIES window, the **FAO areas** button in the STOCKS window, and the **More information on the area** button in the FAOAREAS window. Alternatively, you can click on the **Reports** button in the Main Menu, the **FAO Statistics** button in the PREDEFINED REPORTS window, and the **FAO Areas** button in the FAO STATISTICS window.

Internet

On the Internet version, you get to this table by clicking on **FAO Areas** in the 'More information' section of the 'Species Summary' page, and then clicking on any of the **FAO Areas** in the resulting list.

References

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WRI. 1996. World Resources 1996-97. Oxford University Press, Oxford, UK. 383 p.

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The COUNTRIES Table

Country governments are the political bodies that deal with fisheries management, research and conservation at the national level. It is therefore important to know all the countries where a species occurs, and vice-versa. As mentioned above, the distributional range of many species is not well established. Country-specific checklists of fishes prepared by non-taxonomists often contain misidentifications and generally cannot be verified; on the other hand, complete checklists published by taxonomists and based on verifiable specimen collections do not exist for many countries.

Sources

Taxonomic revisions are the most reliable source of information

It has taken us quite some time to fully grasp the extent of these problems and learn how to deal with them. The main task here is to distinguish between reliable and less reliable sources of information. Taxonomic revisions of species, genera, or families usually include a list of all examined specimens with the localities where they have been collected. This is the most reliable type of information; however, the locality names may be taken from very old original vouchers and may not be easily related to current countries.

The distributional range given in such revisions as a descriptive text often contains country names and these we regard as a good source. We also accept countries that are not explicitly mentioned but clearly part of a range, e.g., "Along the west African coast from Mauritania to Angola" would be considered to include all the coastal countries between Mauritania and Angola. However, statements such as "From the Red Sea to southern Japan" would only allow us to select Japan, not e.g., Oman, Pakistan or India, because such wide ranges are often discontinuous. Another good reference for country records are faunal studies done by taxonomists such as Allen's (1989) *Freshwater Fishes of Australia* or Randall et al.'s (1997) *Fishes of the Great Barrier Reef and Coral Sea*, although the latter is not a complete listing. Maps published by experts in taxonomic books such as the *FAO Species Catalogues* or Skelton's (1993) *A Complete Guide to the Freshwater Fishes of Southern Africa* are also regarded as good sources.

Museum collections often use old names

Computerized museum collections, although a good source in principle, often contain old names, rarely indicate whether an identification is reliable or preliminary, often contain locality

descriptions that need interpretation, and often have not been checked at all for errors (see below). Other problematic sources are various checklists or lists of common names that are produced by non-taxonomists and often based on interviews with fishers or on (tacit) assumptions about distributional ranges. We have used such sources only when they confirmed occurrences already likely from the range given in a good source.

Fields

***The most reliable reference
plus additional evidence
is given for each
country record***

The COUNTRIES table lists all countries where a species has been reported to occur. Double-clicking on any one country gives country-specific information on the species. You can double-click on any of the reference fields to view the full citation.

The MainRef. field gives what we consider the most reliable reference for the country record. Please let us know if you disagree with our choice.

The Other Ref. field gives the next best reference to support the occurrence in the country.

The Status field indicates how the species is reported to occur in a particular country with the following choices: native; endemic; introduced; reintroduced; extirpated; questionable (in cases where an occurrence needs confirmation); and misidentification (for records that are known to be wrong).

The Freshwater, Brackish and Saltwater yes/no fields indicate whether or not the species at any stage of its development is found in the freshwater, brackish or saltwater environment of the country.

Box 7. An offer to country and ecosystem experts.

Keeping track of information specific to several hundred countries, islands and ecosystems is far beyond the capabilities of the FishBase Team. Similar to the concept of Taxonomic Coordinators, we are looking for local experts to become coordinators for their country, island or ecosystem. In exchange for helping us to keep annotated checklists complete and up-to-date, we will provide:

- one copy of FishBase 2000; and
- printouts (text files) in various formats from checklists to field guide (database publishing) for use by the Coordinator.

We will also attach the Coordinator's name to every record that was provided, modified or checked.

Please contact us if you are interested in becoming a FishBase Coordinator for your country, island or ecosystem. We will send you an annotated checklist with the information we have compiled so far. We expect you to edit that checklist and to provide us with copies or reprints of relevant publications that we may have missed. A FishBase Team member will be assigned as your contact and will make the changes to the database. Please let us know what you think of this offer.

Rainer Froese

The **Abundance** field aims to indicate the population density of the species within its known range in the country. Choices are the following: abundant; common; fairly common; occasional; scarce.

The **Importance** field indicates to what extent the species is utilized for human consumption, with the following choices: highly commercial; commercial; minor commercial; subsistence fisheries; of potential interest; of no interest.

The **Aquaculture** field indicates how the species is utilized for aquaculture. The choices include: never/rarely (default); commercial; experimental; likely future use.

The **Regulations** field indicates whether or not measures have been provided to control, protect or preserve the species from various human activities. The choices include: no regulations (default); restricted; protected.

The **LiveExport** yes/no field indicates whether or not the species is exported, be it as an aquarium fish (ornamental or for show aquaria), as live food for restaurants, or exported for aquaculture purposes (e.g., larvae, juveniles, adults used as brood stock).

The **Game** yes/no field indicates whether the species is regarded as a sport fish.

The **Bait** yes/no field indicates whether the species is used as bait.

The **Comment** field accommodates any other information such as local distribution, country-specific biological information, type locality, uses, etc. Museum records are also entered; usually the term 'Museum' is followed by the locality and museum and catalog number of the sample(s); other information pertaining to the museum record is enclosed in parentheses. The full meaning of the museum acronyms and contact addresses are given in the GLOSSARY. Most museum records in this field have been taken from family, genera and species revisions and therefore, have been checked and verified by experts. The term **Also Ref.** gives the reference number(s) of sources explicitly stating the occurrence of the species in the country. **In range Ref.** gives the reference number(s) of sources giving a distributional range for the species that includes the country without explicitly mentioning it. Double-clicking within the **Comment** field reveals—as elsewhere in FishBase—a little pop-up box which allows you to search for a reference mentioned in the text.

Double-clicking on the Comment field allows the user to search for relevant references

Whereas every country falls into only one inland FAO area, a country may have up to four marine FAO areas around it, as is the case with the USA. Each country record states the respective FAO areas where a species regularly occurs. These may be accessed by clicking on the **FAO areas** button within the country record. Note that only diadromous fishes are assigned to both inland and marine FAO areas.

***FishBase can be used as
national fish database***

Annual FAO nominal fish catch data and general information about the country can be looked up by clicking on the **FAO Catches** and **CountryInfo** buttons, respectively.

We are filling the different fields as information becomes available but we realize that this is a big task. FishBase, the Fisheries Centre, University of British Columbia and the Fisheries Branch, Province of British Columbia, Canada completed a project that has incorporated available information on the fishes that occur in British Columbia, to explore the usefulness of FishBase at the national/provincial level. Information in FishBase now includes localities, records, uses and fishing regulations. Similar projects have been completed for Alaska and Australia. We look forward to this sort of collaboration with other national or provincial/state groups. Similarly, we are looking for local experts to become country and ecosystem coordinators (see Box 7). The National Checklist database (see 'National Databases', this vol.) may be found useful as a tool to compile such information and make it available to FishBase.

Clicking on the **Status** button shows who entered, modified and checked the country record. Also shown are the SpecCode and the Countrycode, which are for internal use only. The **About** button accesses the FishBase Book, opens this chapter in the **Glossary** button opens the SEARCH window for definitions of terms, and the **Print** button prints out the species-country information.

Note

Note that the country and fishing area names follow the list contained in FAO (1995) and do not imply the expression of any opinion on the part of the FishBase Team or ICLARM concerning the legal status of any country, territory or area and its boundaries. We are aware that several country names are outdated. The list will be updated as the opportunity arises.

How to get there

You get to the COUNTRIES table by clicking on the **Range** button in the SPECIES window followed by the **Countries** button in the STOCKS window.

Internet

On the Internet version, you can access the COUNTRIES table by clicking on the **Countries** link in the 'More information' section of the 'Species Summary' page.

Acknowledgment

We thank Susan M. Luna for her contributions to an earlier version of this table and chapter.

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The COUNTREF Table

The COUNTREF table holds country-specific information such as the official names in English, French and Spanish, the UN statistical name and code number, name and coordinates of the capital city, FAO areas, aquaculture production, shelf area, languages, international bodies and legal instruments, etc. (see buttons: **FAOareas**; **FAO Aquaculture**; **Statistics**; **Intl. Legal Inst.**). Information has been derived from sources such as the New York Times Atlas (Anon. 1992), the FAO Yearbook (FAO 1995), World Resources 1996-97 (WRI 1996), and the Microsoft Encarta 97 World Atlas (Microsoft 1996). This information was compiled mainly for internal purposes and does not imply the expression of any opinion on the part of the FishBase Team, ICLARM or any of the FishBase collaborators. We are aware that several country names are outdated and we will update them whenever feasible. Most of the information in this table has not yet been verified and we advise users to contact the countries or their respective representatives directly for more accurate and up-to-date information.

*FishBase contains
counts of finfish species
for each country*

The COUNTREF table also contains an estimate of how many fish species (marine, freshwater, total) occur in a country (**Biodiversity** button) and gives some statistics on their uses and status of threat (**Uses** button). This information is based on a count of country records in FishBase and on the literature (see 'Different Checklist by Country', this vol.).

We also included an estimate on how well the fishes are known, by presenting the percentage of fishes for which essential information such as growth, diet and reproduction is available in FishBase, (**Key Info** button).

Other buttons available are the **References** button which lists all references used for a particular country; the **Occurrences** button which gives all occurrence records of the country, and the **Ciguatera** button which records all reported ciguatera incidents in the country.

How to get there

You get to the COUNTREF table by clicking on the **Range** button in the SPECIES window, the **Countries** button in the STOCKS window, and the **Country Info** button in the COUNTRIES window. Alternatively, you click on the **Reports** button in the Main Menu, the **Miscellaneous** button in the PREDEFINED REPORTS window, and the **Country Information** button in the Miscellaneous Menu.

Internet

The COUNTREF table is not available on the Internet. Instead, we provide links to regularly updated information sources, such as the CIA factbook. We also link to national fish databases if we are aware of them, such as for New Caledonia, and to national fishing authorities such as in Australia, Japan and New Zealand.

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The INTRODUCTIONS Table

Introductions have led to major changes in aquatic communities

The introduction and transfer of exotic species of fish have led to major changes in aquatic—and human—communities and represent a significant threat to aquatic biodiversity. On the other hand, the utilization of exotic species has also resulted in increased production from the aquatic sector, a noted success story being the introduction of the freshwater sardine *Limnothrissa miodon* into the newly created Lake Kariba, Zimbabwe. The INTRODUCTIONS table is only concerned with movements of aquatic species across international borders. Although within country movements are omitted here, these are also important and hence should be monitored and regulated by national authorities.

In the early 1980s, Robin Welcomme of FAO began to assemble a database documenting the movement of inland fish species between countries (Welcomme 1988; FAO 1997). In 1991, he offered this database for distribution through FishBase. The database on international introductions and transfers has since been expanded through close collaboration between Devin Bartley of FAO and the FishBase staff to also cover marine fish transfers and introductions (based mainly on Walford and Wicklund 1973) and to include non-intentional introductions, such as those resulting from the opening of the Suez Canal and the ensuing Lessepsian migrations (Por 1978).

The current database is an updated version of the original of Welcomme (1988), edited to correspond to current taxonomy and new information. New records were derived from a search of the literature and information was retrieved from FAO questionnaires that were translated into the working languages of the United Nations and distributed internationally to national resource agencies, agriculture-related ministries, scientific institutions and national agriculture research centers. The questionnaires were modelled after the format of the INTRODUCTIONS table of FishBase so that information would be compatible. A listing of each country's introduced fishes that were already included from Welcomme (1988) was included with the questionnaire so that old information could be checked and new information could be added in the new format.

The 'Top Ten' of introduced fishes

The current database can be analyzed either by predefined or user-specified queries to provide both summary statistics and scientific aspects relating to introductions. There are now over 2,900 records of 530 species from 101 families. The ten species of fish most

often introduced or transferred are (in decreasing order): *Cyprinus carpio*, *Oncorhynchus mykiss*, *Oreochromis mossambicus*, *Ctenopharyngodon idella*, *Oreochromis niloticus*, *Hypophthalmichthys molitrix*, *Micropterus salmoides*, *Gambusia affinis*, *Hypophthalmichthys nobilis*, and *Carassius auratus*. Aquaculture was the most often cited reason for an introduction and national governments were the group most often responsible for an initial introduction. The number of introductions by area (continents), or by reasons can be seen through cumulative graphs such as Fig. 10, inspired from Ruesink et al. (1995).

**The 'Top Twenty'
of potential pests**

Introduced species have been recognized as one of the most effective fishery management tools for increasing production from inland waters (Coates 1995), but they also have been recognized as one of the most significant threats to native aquatic biological diversity (IMO 1994; ICES 1995; FAO 1995, 1996). A list of 'Adverse introductions' is available under Reports, Miscellaneous, and under 'Information by Topic' on the Internet.

**Introductions can be
reported on-line**

The database still contains many gaps and missing information, especially on the impacts of an introduction, and we acknowledge that the records, especially those derived from the questionnaire may be a biased account of international introductions. If an introduction failed immediately or did not have any significant impact it may have been simply forgotten and not reported. Therefore, in assessing impacts and percent establishment, we should not forget that absence of evidence is not evidence of absence. Users of the database with information on new introductions/transfers or with more complete information on existing records are requested to contact the authors. A version of the INTRODUCTIONS table with an 'input form' to enter new data is now available on the Internet on the FAO Fisheries website at <http://www/fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/mainpage.htm>.

Fields

The INTRODUCTIONS table includes fields indicating from which country the species came, year of introduction, reason for the movement and impact.

From: Refers to the country or geographic area where the species originated. The UN name of the country and the FAO area are also given.

To: Refers to the country into which the species was introduced. The UN name of the country and the FAO area are also given.

Year: Refers to the year of introduction.

Range: Refers to the range of years of introduction.

Period: A multiple choice field which gives a wider range of years of introduction. The choices include: pre-18th century; 18th century; 19th century; 1900-1924; 1925-1949; 1950-1974; 1975-present; unknown.

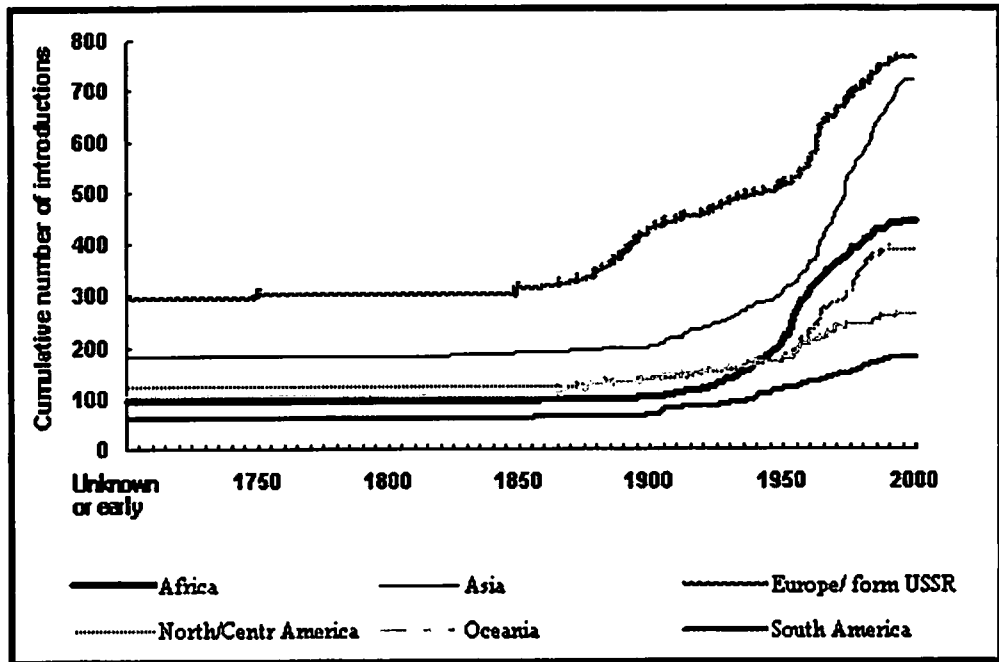


Fig. 10. Cumulative number of international introductions of freshwater fishes, over time and by FAO inland areas. See Box 8 for discussion of this graph.

Box 8. Chronology and success of freshwater introductions.

Fig. 10 shows the cumulative number of freshwater introductions to the different inland FAO areas over the years. The records with unknown dates of introduction were placed before the 18th century mark, together with the early introductions, not only to show the magnitude of these unknown introductions, but also to include them in counts of all introductions. As shown from the graph, Europe and the former USSR combined have the most freshwater introduction records and South America has the least. The graph also shows a steep rise in introductions to Asia from the 1960s to the 1980s, due to the expansion of Asian aquaculture.

Whether an introduced species will become established in the wild is an important concern that is often difficult to predict. Successful establishment will depend on the species' biological characters and on the environment. To examine the hypothesis of Pimm (1989) that introduction success should be (positively) correlated with a fish's maximum size, Pullin et al. (1997) plotted percentage of successful introduction, by species, against maximum length from the SPECIES table. The result was that for the overall dataset in FishBase, success rate is *negatively* correlated with maximum size.

Other factors may also be related to success rate, such as age at maturity, fecundity, mode of reproduction, temperature tolerances, or feeding strategy.

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***Some introduced species
are maintained through
continuous imports***

Reason: A multiple-choice field that states the reason for the introduction. The choices include: aquaculture; fisheries, angling/sport; ornamental; mosquito control; snail control; weed control; phytoplankton control; other pest control; forage; bait; diffusion from introductions in neighboring countries; research; off-site preservation; to fill ecological niche; accidental (alone or together with other species); accidental with ships; Lessepsian migration; removal of natural barrier; other; unknown.

Other reason: Another multiple choice field which gives another or secondary reason for the introduction. The choices are similar to the reason field.

Introduced by: Another multiple-choice field referring to those responsible for introducing the species. The following choices are provided: government; international organization; private sector; individual; other introducer; unknown.

Established in the wild: Refers to whether the species is established in natural water bodies or reservoirs (yes; no; probably yes; probably no; unknown), either self-reproducing, continuous stocking, or both.

Established in aquaculture: Refers to whether the species is currently used in aquaculture (yes/no), and whether that use is wide or rare. Another field states whether the species requires assistance from farmers or breeders to reproduce in aquaculture systems, or whether it is maintained through continuous imports, such as *Anguilla anguilla* in Israel or *Psetta maxima* in Spain.

Significant ecological interactions: Refer to the presence of impacts of the introduction on the ecosystem: yes; no; probably yes; probably no; unknown. The available choices for the effects on the ecosystem include: beneficial; adverse; undecided. This refers to effects on the genetic structure, hybridization, stock size, community structure, survival, adaptive behavior, homing accuracy, migration patterns, disease resistance, etc.

Significant socioeconomic effects: Refer to the presence or absence of impacts on the socioeconomic system: see above list. The available choices for effects are: beneficial; adverse; undecided. These refer to effects on the fishing methods, catch per effort, fish consumption, work distribution (equity, gender), income, etc.

Remarks: This field accommodates additional information not found anywhere in the INTRODUCTIONS table. These include data on reintroductions and species that have been affected by the introductions, among others.

Reports

Two types of lists can be generated from the INTRODUCTIONS table:

- a list of all countries or localities to which a given species was introduced, in chronological order (accessed through the **Introductions** button in Stocks Range window); and
- a list of all species that have been introduced to a given country, with ancillary information (accessed through the **Different Checklists by Country** button in the Predefined Reports Menu).

Maps

If you click on the **Map** button in the 'Introductions as Compiled by FAO window', FishBase will generate a map that shows the native countries with small dark green boxes and the countries where they have been introduced marked with small light green boxes. Each introduction from one country to another is shown by a straight red line linking central locations in the two countries. Details on the introduction represented by a red line may be obtained by double-clicking on the the small light green boxes at the end of the line, which opens a small window with key information on the introduction.

Status

Many aquarium fishes have established themselves in the wild

The INTRODUCTIONS table is, to our knowledge, the largest global database on international movements of fish by humans, including about 2,900 introductions and transfers of over 530 species which were moved for aquaculture (>1,000 records), angling/sport fishing (>200 records) and for the ornamental trade (>300 records). A large number have unknown reasons for the transfer (>400 records). Over half of the documented introductions have established themselves in the wild.

Note that the INTRODUCTIONS table includes records of the *first* introduction of a species into a country, but not those that may have followed. Species found in aquarium shops are not considered to be 'introduced' into a given country unless they subsequently escaped to and established themselves in the wild (as often happens).

Graphs

Graphs can be accessed through the **Environ. factors & biodiversity** button in the graph menu. These are:

- the cumulative number of freshwater introductions from pre-18th century to the present showing the FAO areas to where they have been introduced (see Fig. 10);
- the cumulative number of marine introductions from pre-18th century to the present, showing the magnitude of Lessepsian introductions compared to all other marine introductions; and
- the cumulative number of freshwater introductions from pre-18th century to the present showing the different reasons for the introductions.

The first two graphs can also be accessed from the INTRODUCTIONS table, highlighting individual species.

Sources

Information was derived from more than 150 references, e.g., Courtenay and Stauffer (1984), Silva (1989), Crossman (1991), Holcik (1991), Nelson and Eldredge (1991), Ogutu-Ohwayo (1991), Eldredge (1994), Thys van den Audenaerde (1994) and those mentioned elsewhere in this chapter.

Harald Rosenthal of the Marine Science Institute, Kiel, Germany also has a large database with annotated references of transfers of aquatic organisms. We intend to collaborate with him to make this database available through FishBase.

How to get there

Clicking on the **Range** button in the SPECIES window, then the **Introductions** button in the RANGE window will give a list of introductions and clicking on a particular item brings you to a specific INTRODUCTION record. Alternatively, select **Species** from the Main Menu, **Topic** in the SEARCH BY window, and **Introductions** in the SEARCH SPECIES BY TOPIC window will give you a list of species with introduction record(s). Double-clicking on a particular species brings you to the SPECIES window. The internal name of this table is INTRCASE table.

Internet

On the Internet, click on **Introductions** in the 'More information' section of the 'Species Summary' page. Alternatively, you can select a country and the **Introductions** radio button in the 'Information by Country/Island' section of the 'Search FishBase' page, to get a list of all species introduced in the respective country. Or you can select the **Introductions** radio button in the 'Information by Topic' section of this page to create a list of all fishes known to be introduced somewhere.

Acknowledgments

We thank Robin Welcomme of FAO for providing us with the original INTRO database. We thank former FishBase Team member Liza Agustin for her contributions to this table and to a previous version of this chapter.

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The OCCURRENCES Table

Our knowledge of fish distribution is ultimately based on and restricted to reported encounters between humans and fishes. It is the traditional task of taxonomists to collect, as thoroughly as possible, the species occurring in a certain area, to preserve specimens in a suitable manner, to properly identify known species, to formally describe species that are new to science, to deposit the collected specimens in a museum for reference, and to publish the results of this exercise. The continuing importance of such work as a precondition to our understanding of biodiversity has been recently stressed (e.g., di Castri and Younès 1994; Froese and Pauly 1994; Froese and Palomares 1995).

***Underwater photos
are acceptable
occurrence records***

However, other types of encounters are also acceptable for occurrence records if they can be or have been verified, or if the chance of a misidentification is remote. Such encounters are underwater observations by divers, verified by an identifiable photograph or a video sequence; angling records verified by local experts and supported by a photo; research vessel surveys where the catch was identified by experts; industrial catches of species that are not easily misidentified; or tagging experiments with well-known species. The OCCURRENCES table is designed to accommodate information from these different sources in a standardized form. The FishWatcher database (see 'National Databases', this vol.) is a tool to report such encounters and to make them available to FishBase.

Ultimately, we believe that all reported occurrences of fish, old and new, should be accessible to researchers through FishBase. We believe that the analysis of such a dataset will lead to important insights about fish zoogeography. It will help in the conservation of fish by identifying areas of high diversity or high endemism. At the national level, it will repatriate data stored in other places, assist in resource assessment, and help in establishing protected areas (Froese and Pauly 1994).

Status

In November 2000, the OCCURRENCES table contained over 630,000 records for over 19,600 species (see Fig. 11). These were drawn from twelve museum collection databases, and over 200 references.

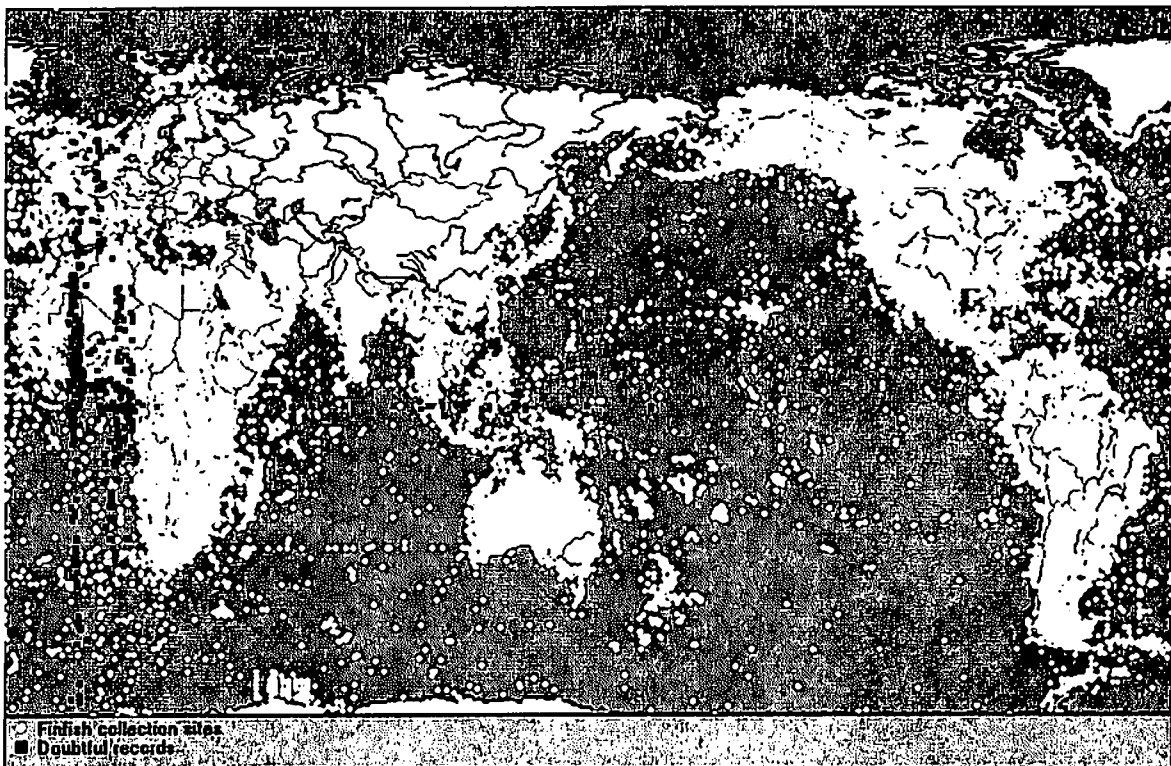


Fig. 11. World map of fish collection sites as currently contained in FishBase. Note limited coverage of North-Central Asia and Amazonia.

We have also drawn occurrence records from other databases such as the fish collection records of the Zoology Department, University of British Columbia, and regional and national surveys, e.g., those documented in Vakily (1994), Künzel et al. (1996) and Pauly and Martosubroto (1996).

The sources mentioned above, although a good source of occurrence records in principle, require a considerable amount of quality checking. Museum collection records, for example, often

***Occurrence datasets
contributed to FishBase go
through a process of
checking and validation***

***A 9-step procedure
to verify occurrence records***

***Occurrence data are
compared with known
distributional ranges***

contain misspellings and names that are no longer valid and, therefore, would need to be matched with and attached to current valid names.

Occurrence datasets contributed to FishBase go through a process of checking and validation outlined below before they are incorporated into the database. The amount of work required varies between datasets, and depends mostly on the number of records and the format used.

Here is our nine-step procedure for incorporating occurrence data of fishes:

1. Import dataset into MS Access format;
2. Match scientific names against FishBase, using the Check-Names procedure (this vol.). Assign names automatically to valid FishBase species, where possible. Send report of synonyms and misspellings to data provider. Ask for references for species not yet in FishBase.

For records that could be automatically assigned to a valid species in FishBase:

3. Match provided country names against FishBase country names (UN standard); assign provided names automatically to FishBase country names, where possible. Send report of misspelled, unknown or missing country names to data provider.
4. Match geographic names with FAO statistical areas; assign provided areas automatically to FishBase FAO areas, where possible. Send report of misspelled, unknown or missing geographic names to data provider.
5. Verify occurrence of species in assigned FAO areas by a) comparison with FAO areas recorded for that species in FishBase, b) if a country was assigned, ensuring that the country actually lies within the assigned FAO area, and c) if coordinates are given, that these actually fall within the indicated FAO area. Send report of doubtful and erroneous records to data provider; ask for references on range extensions.
6. If a country was assigned, verify the occurrence of that species in the country by a) comparison with countries recorded for that species in FishBase, and b) if coordinates are given, that these actually fall within (freshwater) or close (marine) to the country boundaries. Send report of erroneous or doubtful country assignments to data provider; ask for references on range extensions.
7. Based on the outcome of steps 2 to 6, assign a quality indicator to each record (see choices in the Validity field below);
8. Delete all previously contributed records from this source;

9. Transfer data into the FishBase OCCURRENCES table, with indication of source, contact person of the data provider, and date of transfer attached to each record.

Fields

The fields in the OCCURRENCES table are described below:

The **Name Used** in the publication or, in the case of a museum specimen, the name written on the label or in the catalog is given for reference purposes. This name may be different (synonym, misspelling or misidentification) from the valid FishBase name.

A **Catalog No.** or collection number is given, if available (default is 'n.a.'). Where museum names are abbreviated, the full name and address may be found in the GLOSSARY table.

The **Picture** field is used when the record is documented through a fish picture. This can be secured by double-clicking on the field.

Information on the locality where the specimen has been collected is organized in several fields:

The **Locality** states the name of the place or water body as given on the label or in the catalog.

The **Station** field gives the name or code number such as is often used in research vessel surveys (see also the 'EXPEDITION table', this vol.).

A gazetteer links locality names with geographic coordinates. The **Gazetteer** field is a first attempt to standardize locality names in the OCCURRENCES table. So far, it has only been filled for 2,000 locality records. We are looking for existing gazetteers, preferably in digitized format, that could be used for this purpose.

***Latitude and longitude
are the best method to
pinpoint a locality***

Latitude and Longitude are certainly the best method to describe a locality and are given whenever available. Coordinates are particularly useful because they allow plotting of occurrence points (see 'The WinMap Software', this vol).

Country, FAO area and sea or river basin are given as an additional way to classify and access the locality. Assigning historical localities to modern countries is a particularly challenging task.

Altitude, Water depth, Salinity and Temperature describe environmental parameters.

Date, Year and Time of collection are given.

Information on the collected specimen(s) is stated in the following fields: **Length and length type** used (in case of more than one specimen, the **Range** is given), **Weight** in g (in case of more than one specimen, the mean weight is given), **Number** (of specimens

collected or sighted), **Life stage** (egg; larvae; juvenile; adult; juveniles and adults); and **Sex** (females; males; mixed).

Representation of the species in the catch as **Percent of catch** in wet weight is given.

***Abundance of a species
in a certain locality
is reported***

Abundance is classified by five choices derived from those used by birdwatchers: abundant (always seen in some numbers); common (usually seen); fairly common (chances are about 50%); occasional (usually not seen); scarce (very unlikely).

The **Bottom** and **Gear** fields record the type of substrate in the collection area and the gear used, respectively. Additional information pertaining to the collection can be given in the **Remark** field.

Fields identifying the collectors are: **Vessel** (name of the research vessel used in the expedition), **Collector** (person who collected the specimen), and **Identifier** (person who identified the specimen).

The **Type** field gives the taxonomic status of the specimen(s), i.e., holotype; syntype; paratype; lectotype; cotype; paralectotype; neotype; paratopotype. Type of storage used for the specimen is also identified in the **Storage** field.

The **Record Type** field distinguishes between the different sources of information. It has the following choices: trawl survey; other survey; museum record; type locality; tag/recapture; literature; recapture; fishery; angling record; other survey. Also, a multiple choice field is used to identify the Expedition that generated a record (see also the 'EXPEDITIONS table', this vol.).

The **Validity** field refers to the reliability of the occurrence record with the following choices: requires matching against distributional range; compatible with distributional range; doubtful, outside of distributional range; introduced; aquaculture or aquarium specimen(s).

***We plan to include
ex-situ occurrences***

We plan to add to the OCCURRENCES table fields for the coordinates of museum and show aquaria holding fish *ex-situ*, and to link these records with WinMap (see 'The WinMap Software', this vol.).

***Tag/recapture data
can also be accommodated***

When a record refers to a fish that has been 'tagged' (or otherwise 'marked') and released, then recaptured, it can be entered into the OCCURRENCES table as a 'Tag/recapture' record. In this case, the body of the table, as described above is used for the information relating to the tagging site (location, time), and to the released fish (in which case the field for the 'Catalogue number' is used for the tag number).

Information on the recaptured fish (location, time, length) is then entered in the appropriate fields, along with the straight line distance between the tagging under the heading **Recovery** and

recovery sites (in km), if available [this distance is also calculated by a built-in routine, using spherical geometry, from the two locations, if both were entered]. Using the straight line distance, the (minimum) swimming speed (in km/day) is then computed, given the number of days between tagging and recapture.

Tag/recapture data for only a few species (see e.g., *Scomber australasicus*) have been entered so far, mainly to test the ability of the design to accommodate diverse sets of tag/recapture data. Here again, we invite interested colleagues to share suitable data, and to work with us in extracting a maximum amount of insights from them.

How to get there

You get to the OCCURRENCES form by clicking on the **Range** button in the SPECIES window and the **Occurrences** button in the STOCKS range window. Alternatively, you can click on the **Occurrence** button in the COUNTRY INFORMATION window (accessed by clicking on the **Country** button, then the **CountryInfo** button). You get to the FishWatcher table by clicking on the **National Databases** button in the Main Menu and the **FishWatcher** button in the NATIONAL DATABASES window.

Internet

On the Internet, you can access the OCCURRENCES table by clicking on the **Occurrences** link in the 'More information' section of the 'Species Summary' page. The **Point Map** link in the same section will show all occurrence records for the respective species which have coordinates. In the resulting lists, catalog numbers that are links will open the respective record in the respective museum fish collection. Point maps in the Internet are active, i.e., if you click on an occurrence point it will show the underlying record(s).

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The EXPEDITIONS Table

In the period following publication of the 10th edition of Linnaeus' *Systema Naturae* (1758), shipborne scientific expeditions quickly became the major means of increasing European knowledge and holdings of non-European plants and animals.

Indeed, the past importance of shipborne scientific expeditions cannot be described today without reference to space travel, their contemporary analogues in terms of the technology used, and prestige accruing to the scientists involved.

From the mid-18th to the late 19th century, the navies of major European countries thus always had at least one, or several ships devoted to surveying Oceania, and the coast of the Americas, Africa and Asia, and bringing back to European museums suitably preserved specimens—the more the better—of the strange organisms they encountered.

Captains and naturalists

The task was usually shared between the ships' captains—trained in navigation, and hence good at surveying—and trained 'naturalists', often doubling as ship surgeons, both ably supported by junior officers and crew.

The most famous of these expeditions is the voyage of the *H.M.S. Beagle* (1831 - 1836), with the irascible Fitzroy as captain and Charles Darwin as (*de facto*) naturalist (Jenyns, 1842; see also Box 9). Other such expeditions are those documented in Lesson (1830-31; France), Kner (1865-67; Austria), Peters (1877; Germany), or Vinciguerra (1898; Italy), to provide examples representing the effort of some European powers other than Britain.

With time, these expeditions grew in sophistication, and one of the later ones, that of the *Challenger* (1872 -1876) covered in such depth so many areas of marine sciences that it is often viewed as having marked the beginning of the modern science of oceanography (Bayer 1969).

Shipborne scientific expeditions continued well into the 20th century, especially from the USA (see e.g., Thompson 1916), but with the establishment of modern research institutions in Europe's former colonies, distant, single-ship expeditions were gradually replaced by more local undertakings or, at the opposite end of the spectrum, by complex affairs involving the coordinated activities of dozens of ships from different countries, as e.g., the International Indian Ocean Expedition (1959 - 1965; Zeitschel 1973). In the 1960s, finally, systematic trawl surveys became, and have since remained, major sources of new knowledge on fish biodiversity (Pauly 1996).

The International Indian Ocean Expedition

The early expeditions, to which some predominantly land-based adventures may be added, such e.g., as the Lewis & Clark Expedition (Mooring 1996) were crucial to the growth of

ichthyology and of ichthyological collections. Indeed, we surmise that the majority of the approximately ten million of fish samples held in museums, throughout the world, stem from expeditions of one sort or the other.

Box 9. Darwin in FishBase.

A serious database on fish, or on any other group of organisms for that matter, cannot get around Charles Darwin, who provided the intellectual basis for much of what we do as biologists.

Darwin worked on many groups—corals, barnacles, orchids, earthworms—but did not devote any of his many books or articles exclusively to fishes. On the other hand, he edited the book describing the fish he collected during the voyage of *H.M.S. Beagle* (Jenyns 1842), and used fishes to illustrate many of his new concepts, e.g., that of sexual selection, illustrated in Darwin (1877) by many cases of sexually dimorphic fishes.

Pending an exhaustive treatment of this rich material (Pauly, in prep.) and the incorporation of the voyage of *H.M.S. Beagle* into the EXPEDITIONS table of FishBase, users can see some of 'Darwin's Fishes' through the 'View Picture' menu, by calling for the 45 species drawn by Waterhouse, B. Hawkins and Ford, G.

References

Darwin, C. 1877. *The descent man: selection in relation to sex*. 2nd ed. John Murray, London.

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Pauly, D. *Darwin's fishes: an encyclopedia of ichthyology, ecology and evolution*. (in prep.).

Daniel Pauly

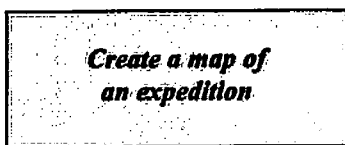
As these fish samples form the core of the occurrence records in FishBase, we assume it will be useful to link these records to the expeditions that generated them. Not only does this allow for a partial reconstruction of these expeditions, but also allows, by providing a 'cut' through thousands of occurrence records, for the emergence of additional criteria with which to 'clean up', complete and then make available such records in ordered fashion.

FishBase 2000 implements these ideas through the EXPEDITIONS table described below, and a Winmap routine which displays the stations covered during an expedition, so far they are represented by FishBase occurrence records. Also, a routine is provided which summarizes and presents the key information gathered during an expedition or survey.

The EXPEDITIONS main table consists of the following fields:

- **Name of expedition:** the (short) name by which the expedition is currently known, irrespective of its (usually long) official name;
- **Names of the Captain,** and of the Chief scientist, so far identified;

- **Name of the vessel** used by the expedition and its **Length** (in m), referring to the main vessel in case of an expedition that may have used auxillary crafts (as was the case with the *H.M.S. Beagle*);
- the **Location** (**Latitude, Longitude and Country**) of the points of departure and arrival of an expedition (or of its first and last stations);
- **Main narrative**, the reference number of a publication providing a narrative of the expedition as a whole;
- **Main ref. on fishes**, the reference number of the publication with most of the ichthyological results from that expedition;
- a choice field **FishBase coverage of Expedition** indicating the depth of coverage in FishBase of the survey in question, with choices (1) complete (or nearly so); (2) incomplete; and (3) fragmentary [note that in any of these cases, 'coverage' refers only to the occurrence records of fishes, not of other organisms, nor of abiotic data];
- a **Remarks** field for items not covered by the above fields, e.g., to indicate that a given expedition may have not been exclusively ship-based, as in the case of the Lewis & Clark Expedition.



Using the items in this table, and those entries in the OCCURRENCES table that have been assigned to a given expedition, FishBase allows at least its partial reconstruction in form of a map which displays sampling sites or stations (accessible from the EXPEDITIONS table by clicking on the **Map** button), and an 'Expedition report' consisting of:

- the contents of the EXPEDITIONS table;
- a list of all the fish species collected, by station;
- a chronological list of all stations, with their position, depth, and other pertinent information.

Access to information regarding the expedition, countries covered, lists of species and stations is through their respective buttons.

How to get there

The EXPEDITIONS table can be accessed by clicking on the **Reports** button in the Main Menu, the **Miscellaneous** button in the PREDEFINED REPORTS window, and the **Expeditions** button in the Miscellaneous Menu.

Only five expeditions (or surveys) are listed as such in FishBase as of November 2000 though the occurrence records herein stem from a far larger number of expeditions.

We anticipate that the assignment of an increasing fraction of the occurrence records in FishBase to the expeditions that generated them will not only contribute to increasing the accuracy of these

records, but also to helping us document many of these expeditions and thereby pay tribute to the astounding, and often heroic work done by their scientists, officers and crew.

We are anxious to collaborate on this with as many colleagues as possible with an interest in the history of ichthyology, and particularly in the reconstruction of major undertakings such as the *Challenger Expedition*. Please do contact us if you are interested.

Internet

As of November 2000, the EXPEDITIONS table was not yet accessible on the Internet. Once we cover a few more expeditions, we will make the related information available from the 'Search FishBase' page, 'Information by Topic' section, **Expeditions** radio button. This will produce a list of expeditions covered so far. A summary page per expedition will contain the fields described in this chapter.

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FAO Statistics

The Food and Agriculture Organization of the United Nations has been one of the most important FishBase collaborators from the very beginning of the project (see 'The Making of FishBase', this vol.). FAO maintains several global databases such as catch statistics, aquaculture production and international introductions (Welcomme 1988). FAO uses FishBase as one of several vehicles to make these data widely available.

FAO Catches

FAO regularly publishes the **Yearbook of Fishery Statistics – Catches and Landings**, which provides annual statistics on nominal catches of fish, crustaceans, mollusks and other aquatic animals, residues and plants (cf. FAO 1995). The statistics comprise reported national data from commercial, industrial and small-scale fisheries, carried out in inland, coastal and high seas fishing areas, but not recreational fishery. They also include statistics for mariculture, aquaculture and other kinds of fish farming. The data summarized by FAO represent the live weight equivalent of the landed quantities caught during the annual period covered (except for marine mammals, which are reported in numbers).

Though FAO makes every effort to gather reliable information on the catches worldwide, it has to be kept in mind that the data presented in its annual statistics are influenced by the abilities of contributing countries to collect accurate and timely information from their respective fishery sector. As the conditions for such an endeavor vary between countries, the catch statistics have to be used with some caution (see Mariott 1984 for an irreverent account of fisheries statisticians' plight).

FAO Aquaculture

Aquaculture production statistics have been compiled by FAO since 1984 and published in the FAO Fisheries Circular No. 815. Now in its 9th revision, this publication summarizes the quantity and value of aquaculture production for the period 1984-1995 (FAO 1997). Data presented are the production by various categories such as species item, country and environment (i.e., brackish water culture, freshwater culture, mariculture). The information originates from national statistics, or—where missing—has been supplemented by information from other sources such as specialist literature, academic reviews and consultants' reports.

In order to properly differentiate catch and landing statistics from aquaculture production data, the following definition of aquaculture and its products should be considered:

“Aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries” (FAO 1997).

Sources

FAO distributes the software packages *FISHSTAT PC* and *AQUACULT PC*, which contain and analyze the reported catch statistics and production figures for the years 1950 to 1998, and 1984 to 1998, respectively. These data were extracted and included in the FishBase FAOCATCH and FAOQUACULT tables.

Box 10. Latitudinal distribution of nominal catches.

There are different ways to visualize the catch data incorporated in FishBase, mainly from FAO statistics. One of these is through our plot of catches vs. latitude (Fig. 12), documenting the relative importance of temperate vs. tropical fish and fisheries. However, its key features and their implications must be understood before the patterns generated by this graph can be interpreted correctly. Only fish for which the catch is reported on a single-species basis, either by FAO (see FAO catches) or as a range of catches in the SPECIES table, and for which a latitudinal range is available in FishBase, are included. The FAO catches used here are the means of the last 5 years for which data are available (generally 1992-1996) and include the 600 finfish for which FAO reports catches on a per species basis.

The data from the SPECIES table are used only for species without FAO catches and consist of geometric midranges (e.g., 3,000 t-year⁻¹ for a range of 1,000 to 10,000 t-year⁻¹). Presently, they refer to only 62 species. However, we expect these numbers to increase as the ‘Catches’ field of the SPECIES table is gradually filled in for more species.

This is important as the FAO catches are based on country reports which usually ignore discarded by-catch (a staggering figure of about 27 million tons per year; see Alverson et al. 1994), and illegal or unreported catches, and which does not identify species for nearly 50% of the world catches, especially at low latitudes.

A correct graph, accounting for these effects, would probably have a bulge in the latitude from 20°N to 20°S, contrary to the present graph, whose maximum occurs at 60°-30°N. We hope that the future development of FishBase will lead to the gradual emergence of such a corrected graph, reflecting the importance of tropical species in world fisheries.

Reference

Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope. 1994. A global assessment of fisheries by catch and discards. FAO Fish. Tech. Pap. 339, 233 p.

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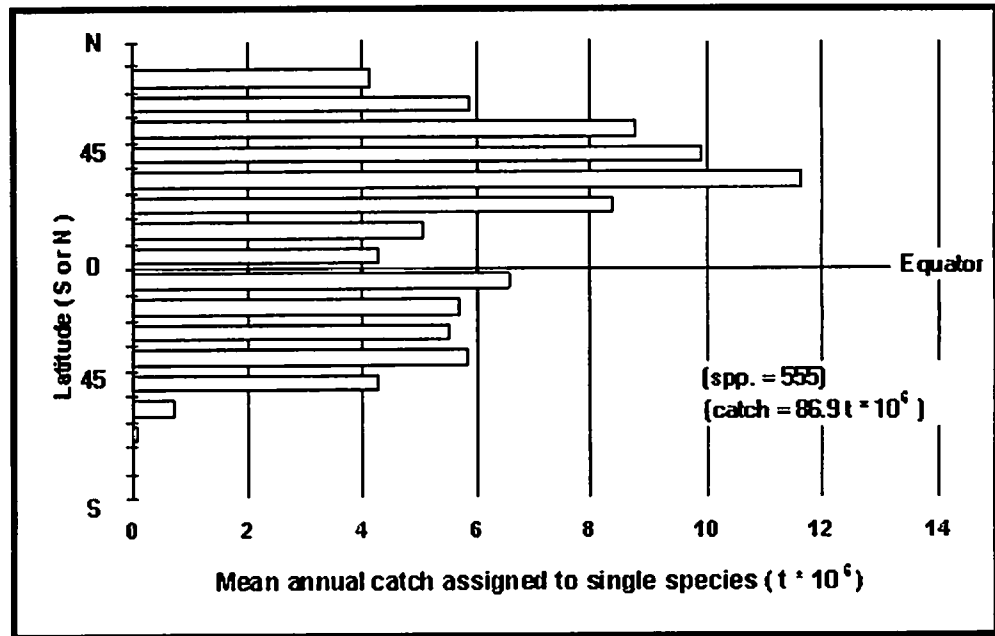


Fig. 12. Latitudinal distribution of nominal catches by species. See Box 10 for interpretation of this graph.

Box 11. Primary production required to sustain fisheries.

The catch taken by a fishery may be seen as a flux ($t \cdot \text{year}^{-1}$). To sustain this flux, another flux must exist, consisting of the food consumed by the fish and invertebrates taken by the fishery; this flux itself must be supported by another flux, consisting of the food consumed by the prey items, and so on down to the primary production which sustains the entire system based on photosynthesis.

Pauly and Christensen (1995) having shown that the transfer efficiency between the trophic levels of marine ecosystem has a mean value of about 10%, the primary production required to sustain the catch of any fishery (PPR) can be estimated, for each species, from

$$\text{PPR} = (\text{catches}) / (9) \cdot 10^{\text{Tr}-1}$$

where Tr is the trophic level of a given species (see Box 22), and where the division of the catch (wet weight) by 9 expresses PPR in carbon units as commonly used in marine biology.

PPR, in Pauly and Christensen (1995) was expressed in % of the observed primary production of various ecosystem types. In contrast, the FishBase output of PPR is expressed in absolute values, implicitly covering the same areas as those from which the catches are extracted. Reexpression of the PPR values shown in FishBase (by pressing the PPR button of the Mean Trophic Level graph) thus requires that the user identifies the reference area and its primary production and converts to %.

Reference

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374:255-257.

Daniel Pauly and Villy Christensen

ISSCAAP

The basic category used in the FAO statistics is the 'species item', which represents an aquatic animal or plant either at the species, genus, family or the suborder level. There are over 1,000 of such statistical categories, arranged in 51 *groups of species* that

constitute the nine divisions of the FAO *International Standard Statistical Classification of Aquatic Animals and Plants* (ISSCAAP).

It should be noted, therefore, that it is only when a 'species item' refers to a single fish species that this category corresponds with a species as defined in FishBase.

Species items can be selected using any of the four choices provided by FAO: scientific, English, French or Spanish name. (For a list of FAO common and scientific names of species see FAO 1996). Information is also available on statistical entities such as FAO Area or definition of ISSCAAP codes, information typically provided in the FAO Fishery Statistics Yearbook.

Box 12. Mean size of fish in fisheries catches.

Much of fisheries research has been devoted, in the last 50 years, to the dynamics of fish species targeted by various fisheries, and particularly to the change in age and size structure resulting from exploitation. If a fishery is to be sustainable, such annual changes in catch composition should have no trend.

However, the exploitation of multispecies communities has the effect of changing the relative abundance of the different functional groups in the ecosystem supporting these communities (Fig. 13). Notably, large long-lived species with high trophic levels tend to be replaced by smaller, short-lived species feeding at lower trophic levels. These trends will ultimately be reflected in catches.

Following a demonstration of worldwide decline in mean trophic levels (Pauly et al. 1998), reproducible as a FishBase routine (see Fig. 4), we have developed a routine which computes the average maximum size of organisms (fish & invertebrates) caught in fisheries, from 1950 to 1998, weighted by the FAO catches, for any country and FAO area or combination thereof. The routine relies on length as measure of 'size' in each group in the ISSCAAP table, consisting of the maximum (standard) length of each species identified as such in the FAO statistics ($n = 744$) and of the mean of the maximum lengths of component species in the case of composite groups ('gadoids', 'perches', etc.). For sharks, the precaudal length and for rays the width were taken as the measure best expressing 'size'. Similarly, for invertebrates, lengths were selected which corresponded best to body length, i.e., excluding antennae or tentacles. Here also for some groups, width was used to represent body size, notably in crabs and most bivalves. References are given for all sources of maximum sizes.

As illustrated by Fig. 14, a decline in average maximum size of organism landed by various countries did occur. Moreover, the trend in Fig. 14 is probably an underestimate, given that it does not consider the reduction of mean length *within* species, i.e., the very trend that single-species analysis has so well documented for major commercial species.

Reference

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torres, Jr. 1998. Fishing down marine food webs. *Science* 279:860-863.

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The FAO catch data can be viewed in tables and graphs, grouped according to:

Country	Nominal catch per species item, reported for a selected country.
FAO area	Nominal catch per species item, per country, reported for a selected FAO statistical area.
Species item	Nominal catch per country, reported for a selected species item.
ISSCAAP code	Nominal catch per country, reported for a selected group of species identified by an ISSCAAP code.

We have added to each ISSCAAP category a fully referenced estimate of trophic level (abbreviated 'troph', see Box 22), used to derive series of mean trophic levels in fisheries catches (Pauly et al. 1998). Also, for each ISSCAAP group, an estimate of maximum length was added (standard length in fish, body length in invertebrates) which allows estimating the mean maximum length in fisheries catches (see Box 12).

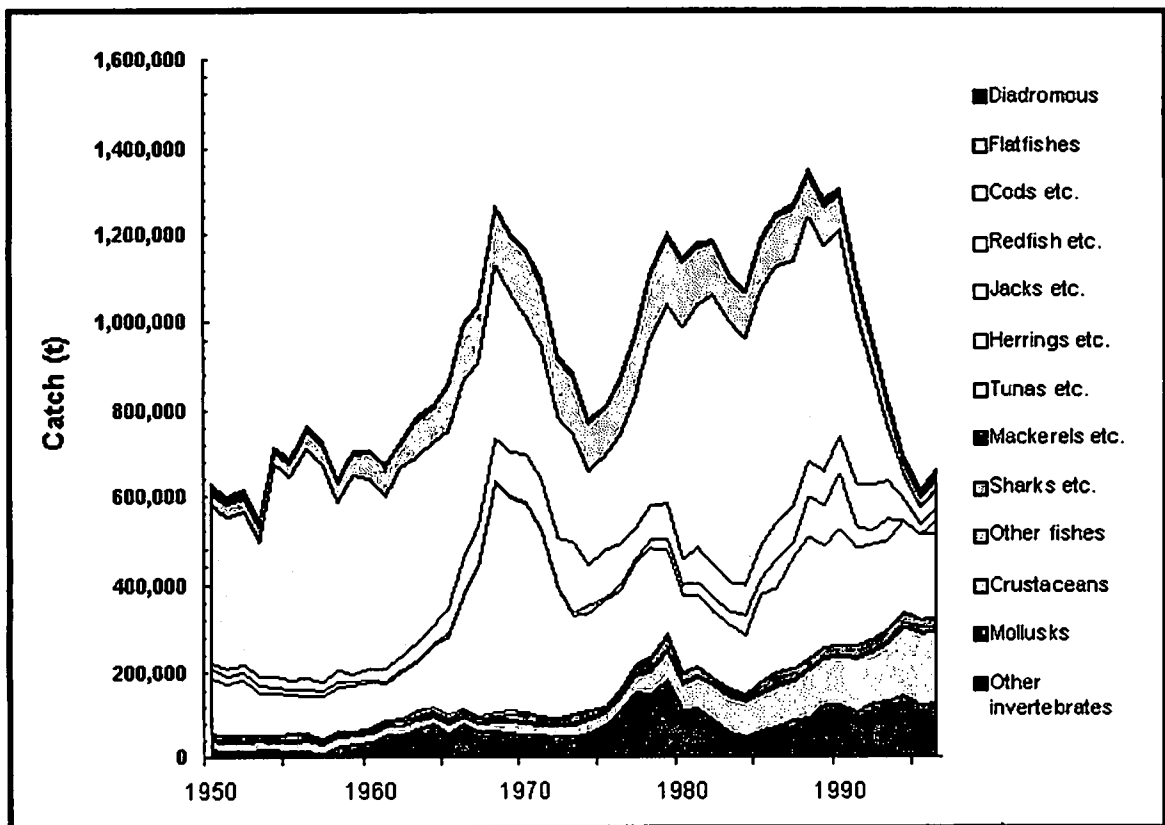


Fig. 13. Time series of catch composition for Canada, Northwest Atlantic. Note collapse of the cod fishery in the early 1990s.

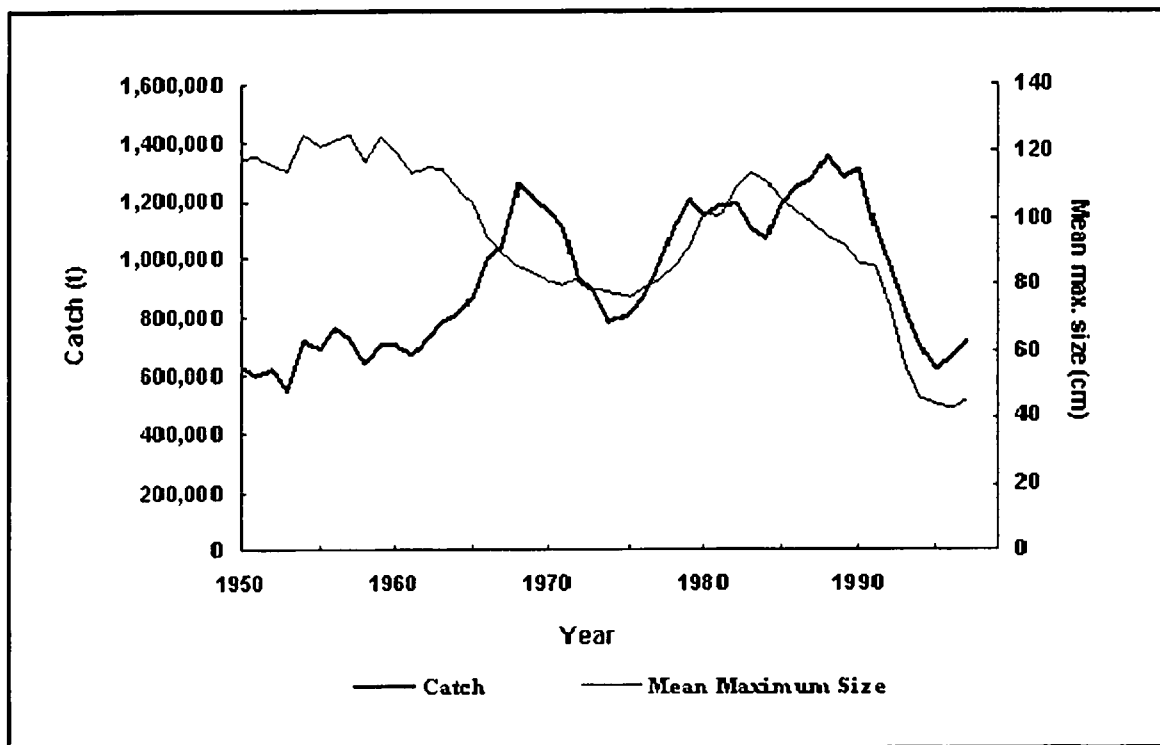


Fig. 14. Time series of total catch and average maximum size of species in catch for Canada, Northwest Atlantic. Note the trend to smaller species in the early 1990s.

Box 13. Analysis of fisheries catches by trophic pyramids.

The FAO fishery catch database hosted by FishBase can be used to show that the composition of these catches has changed much in the last 50 years. Notably, mean sizes have declined (see Box 12), as have the mean trophic levels of the fish landed (Fig. 14). The latter process, described as "Fishing down marine food webs" by Pauly et al. (1998) is also documented by a newly developed routine which outputs, for every time series of multispecies catches (as in Fig. 15) a 'pyramid' of catches per trophic level class, from troph = 2.0 (herbivores) to troph = 5.0 (see Box 23, on "Trophic levels of fishes" for detailed definitions). The routine compares two periods in a time series by plotting them as the left and right side of a trophic pyramid. In a sustainable fishery, the pyramid should be roughly symmetrical, in shape, size and composition (fish vs. invertebrates).

The approach used to construct the pyramids relies on the standard errors of the trophic levels (from the ISSCAAP table, this vol.) to define triangular distributions (base of triangle = mean trophic level of each group \pm 2 s.e.) to assign a catch with a given trophic level (\pm s.e.) to different classes of trophic level. [Note that the trophs used here all comply with $2.0 \leq \text{troph} < 5.0$, and that for very low and very high troph values (i.e., troph - 2 s.e. < 2.0 ; and troph + 2 s.e. ≥ 5), the s.e. is set to zero, these two constraints thus limiting the range of trophs in the resulting graphs from 2.0 to 5.0].

Fig. 15 illustrates the resulting pyramid for the North Atlantic (FAO areas 21 + 27), with the left side (negative scale) documenting catches at the start of the time series (1950), while the right side (positive scale) documents the catches at the end (1996). Note the overall increase of catches in recent years, the relative and absolute decrease of top predators, the strong increase of catches in lower trophic levels, and the development of invertebrate fisheries.

Reference

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torres, Jr. 1998. Fishing down marine food webs. *Science* 279(5352):860-863.

Daniel Pauly and Rainer Froese

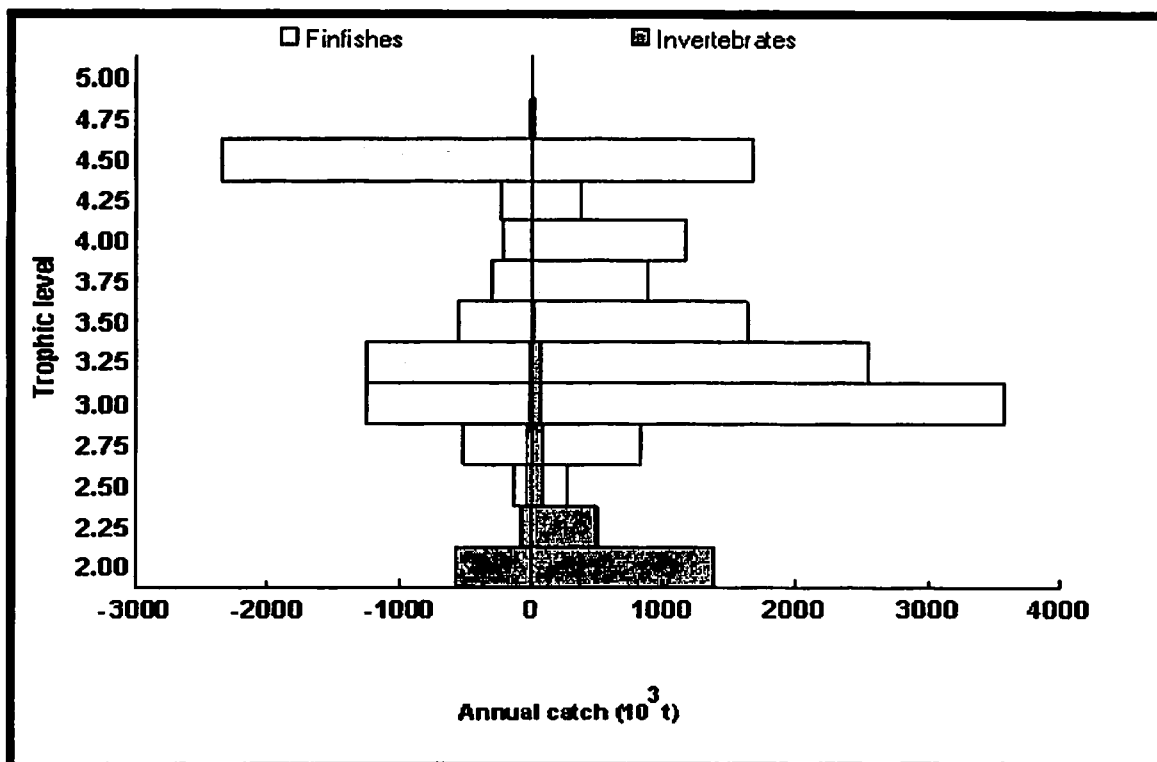


Fig. 15. Trophic pyramid of catches in the North Atlantic (FAO area 21 and 27), for the years 1950 (left) and 1997 (right). Note the decline of fishes with high trophic levels (for example, cod) and the increase of invertebrates in the catches.

How to get there

You get to the FAO Catches, FAO Aquaculture, FAO Areas and ISSCAAP tables by clicking on the Reports button in the Main Menu and the FAO Statistics button in the PREDEFINED REPORTS window. Alternatively, you can access them from the Species, Countries and FAO Areas forms.

Internet

FAO fisheries and aquaculture production statistics are available in the 'Information by Topic' section of the 'Search FishBase' page if you select the FAO statistics radio button. You can also access this information in the 'Species Summary' page, 'Internet sources' section, if you click on the FAO statistics link.

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Jan Michael Vakily

Population Dynamics

Information on the maximum size and age of fish, on their length-weight relationships and estimates of their growth parameters, natural mortality and recruitment variability are crucial for fisheries management purposes.

While maximum age and size, and length-weight relationships are relatively easy to obtain for most fish species, making sure that such information is available wherever and whenever needed—and in the appropriate format—is rather more difficult.

Growth parameters are hard to obtain

This problem is magnified for growth parameters, which are harder to obtain: one set typically corresponds to the work embodied in an MS thesis, or short scientific paper. As for recruitment time series, many years are required for patterns to emerge. Thus, stock assessment research can be considerably accelerated by making available to practitioners growth parameters that have already been estimated, both to replace stock-specific estimates by values from neighboring stocks, and to provide data for reliability checks of one's estimates. Similar considerations apply to natural mortality estimates, and to recruitment time series.

These points are so compelling for tropical fisheries research that they provided, in 1987, the reason for proposing the creation of the database that eventually became FishBase, and which was to include "a summary of growth and mortality information for each species [.....] with the ultimate goal of covering 2,500 species" (Pauly 1988).

We have identified growth parameters for about 1,300 species

This vision underestimated the number of species to be included in FishBase (now ten times more than initially anticipated), but overestimated the number of species for which growth parameters and related information exist: we have now identified published sets of growth parameters for about 1,300 species and there is little prospect that this figure will increase by more than 10-20% in the next years. However, the species presently covered sustain over 95% of the world's fisheries catches, ensuring the relevance of the entries in the tables presented below.

Similarly, the stocks for which over 750 time series of recruitment are included belong to the best-studied, and most important single-species stocks in the world.

A number of precautions were taken to ensure the highest possible accuracy for the entries in the above tables. This included, among other things, rejecting parameter estimates not compatible with related estimates in the same, or closely allied species. However, we are aware that these and related procedures cannot identify all errors, whether in the original papers or as a result of faulty data entry, and all we can hope for is that you will contact us when you find errors or inconsistencies, so that they can be repaired for the

next release of the database. Notably, we will investigate cases labeled 'out-of-range' in the Remarks field, which refer to studies conducted at sites located outside of a given species range, and which thus imply a misidentification.

Reference

Pauly, D. 1988. Resource assessment and management program, p. 47-66. *In* ICLARM five-year plan (1988-1992), Part I. directions and opportunities. International Center for Living Aquatic Resources Management (ICLARM), Manila.

Daniel Pauly and Crispina Binohlan

The POPCHAR Table

This table presents information on maximum length (L_{max}), weight (W_{max}) and age (t_{max}) from various localities where a species occurs. The largest values from this table are also entered in the SPECIES table. The POPCHAR table also indicates whether the L_{max} , W_{max} and t_{max} values or various combinations thereof refer to the same individual fish.

Box 14. The distribution of maximum lengths among fish species.

Plotting histograms of the frequency of species against their maximum length, and interpreting the results seems to be a rather straightforward thing, but it is not. Thus, to be interpretable, histograms must have constant class intervals (here of length), and the number of classes must be neither too low, nor too high (i.e., 15-30, see Sokal and Rohlf 1995). The maximum length of fishes, however ranges from 1 cm (in e.g., gobies) to 14 m (in the whale shark *Rhincodon typus*), and using class intervals of, e.g., 50 cm (which would generate a suitable number of classes) would cause most fish species to occur in the smallest class, with most others being empty. [Note that we multiply maximum lengths by 1.1 when they were expressed as SL, to make them better comparable with FL and TL; the other length types remain unmodified.]

Using $\log(\text{length})$ leads to a graph (see Fig. 16) far more interesting than its linear version: this generates what appears to be normal distributions of $\log(\text{numbers})$ vs. $\log(\text{length})$, with modes characterizing fishes in general (the typical fish species reaches a maximum length of about 25 cm; see peak of upper curve) and any group of interest (bold line).

We have never before seen plots of this kind for fishes, and we look forward to your opinions on their interpretation and potential applications.

Reference

Sokal, R.R. and F.J. Rohlf. 1995. *Biometry*. 3rd ed. W.E. Freeman, San Francisco. 887 p.

Daniel Pauly

***Our answer to the Guinness
Book of World Records***

The table contains over 1,800 records for over 1,000 species extracted from over 500 references.

FishBase users may consider this our answer to the Guinness Book of World Records (Foot 2000). We anticipate many ways for the data in this table to be used, e.g., for testing hypotheses from life-history theory.

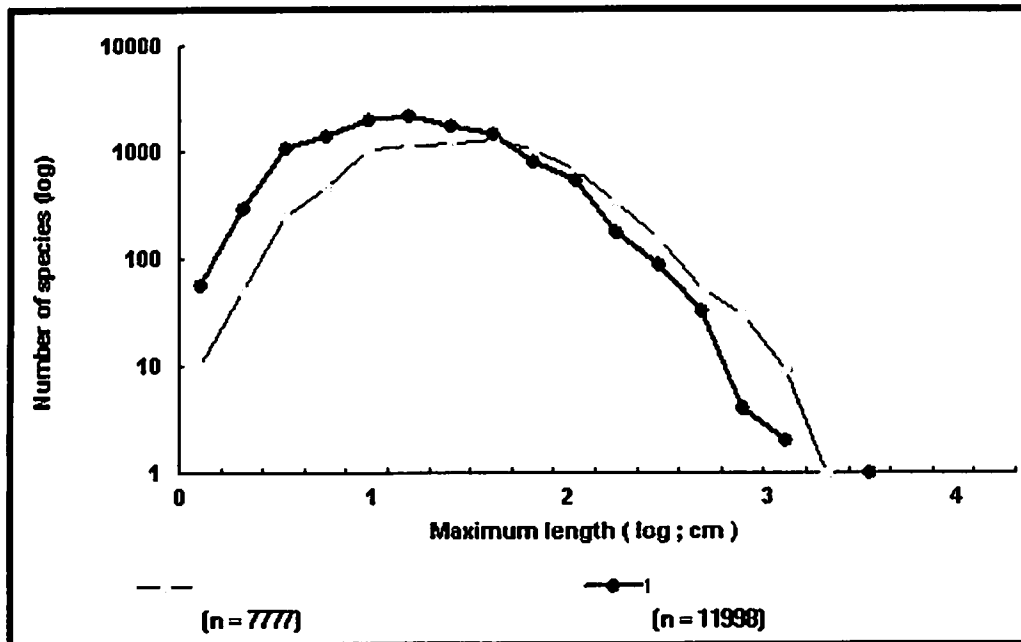


Fig. 16. Length distribution of tropical fishes vs. all other species in FishBase.

How to get there

You get to the POPCHAR table by clicking on the **Population dynamics** button in the **BIOLOGY** window and the **Max. Sizes** button in the **POPULATION DYNAMICS** window.

Internet

On the Internet version of FishBase, click on the **Max. age & size** link in the 'More information' section of the 'Species Summary' page to access the POPCHAR table.

Reference

Foot, T. 2000. Guinness Book of World Records 2001. Guinness World Records Ltd, 284 p.

Crispina Binohlan and Daniel Pauly

The LENGTH-WEIGHT Table

Length-weight relationships are important in fisheries science, notably to raise length-frequency samples to total catch, or to estimate biomass from underwater length observations. The LENGTH-WEIGHT table presents the **a** and **b** values of over 5,000 length-weight relationships of the form $W = a \cdot L^b$, pertaining to about over 2,000 fish species.

However, published length-weight relationships are sometimes difficult to use, as they may be based on a length measurement type (e.g., fork length) different from one's length measurements (expressed e.g., as total length).

Therefore, to facilitate conversion between length types, an additional LENGTH-LENGTH table, presented below, was devised which presents linear regressions or ratios linking length types (e.g., FL vs. TL).

Sources

The length-weight relationships themselves were derived from over 1,000 references, e.g., Carlander (1969, 1977); Cinco (1982); Dorel (1985); Bohnsack and Harper (1988); Coull et al. (1989); Torres (1991); and Kulbicki et al. (1993).

Fields

We included a calculated field with the weight of a 10 cm fish (which should be in the order of 10 g for 'normal', fusiform shaped fish), to allow identification of gross errors, given knowledge of the body form of a species. Also, a graph button in the summary table, when clicked on displays length-weight relationships (Fig. 17). This can be used to identify curves that deviate from the general trend.

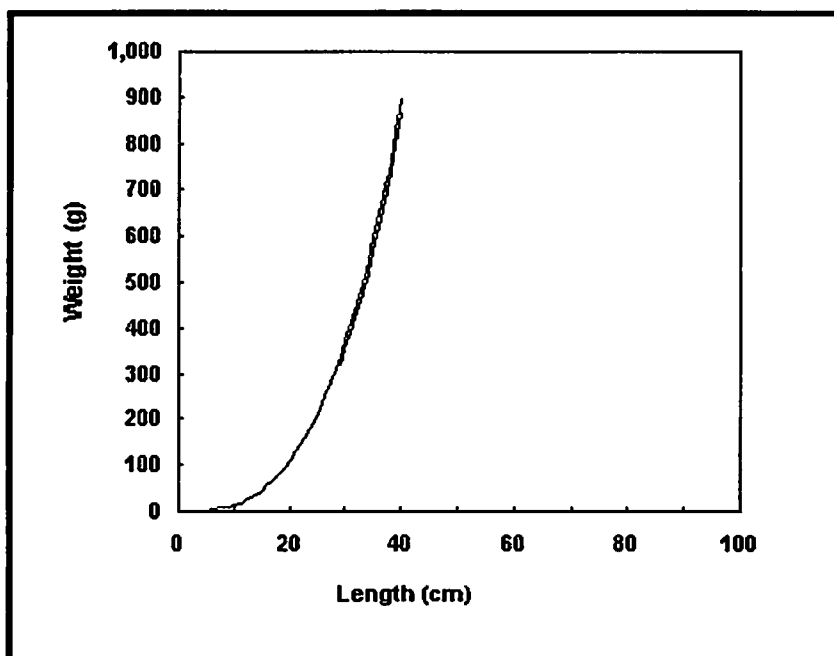


Fig. 17. The two length-weight relationships presently available in FishBase for *Lutjanus bohar*. Note that you can use the graph to estimate weight at a given length.

Different methods can be used to estimate length-weight relationships

A choice field indicating the method used to estimate the parameters a and b of length-weight relationships has been added to this table. These methods are:

1. Type I (or '*predictive*') linear regression of $\log W$ vs. $\log L$ (the method of choice in the overwhelming majority of cases);
2. Type II (or '*functional*') linear regression of $\log W$ vs. $\log L$ (as suggested by Ricker 1975, but rarely used, given that length-weight relationships are generally used to *predict* W from L);
3. Same as (1) or (2), but with correction for bias suggested by Sprugel (1983; see also Vakily et al. 1986);

4. Nonlinear regression of W vs. L , as recommended e.g., by Saita et al. (1988);
5. From length-frequency samples and their bulk weights, using the algorithm of Pauly and Gayanilo (1996);
6. By setting $b = 3$, and using a single pair of L - W values to calculate a ;
7. By setting $b = 3$, and using the geometric mean of L and W values to solve for 'a', or by calculating 'a' for each data pair, then taking the mean of the resulting values of 'a';
8. Any other method (e.g., that of Lenarz 1994; to be specified in the Comment field).

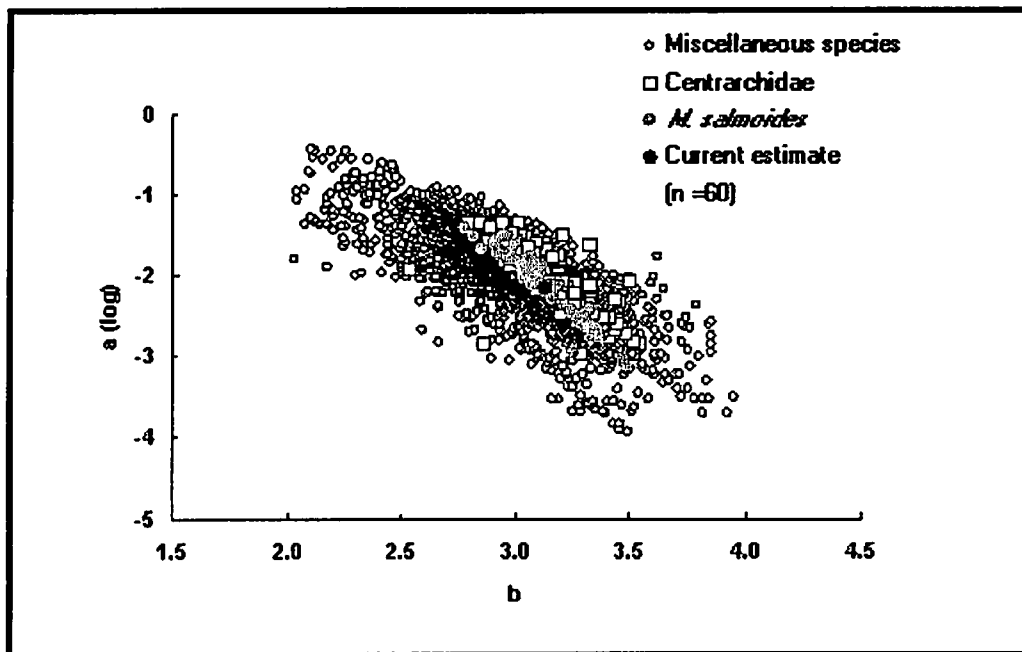


Fig. 18. Plot of length-weight relationships ($\log a$ vs. b) available for *Micropterus salmoides*. Note questionable dot at $a(\log) \approx -3$ and $b \approx 3.25$, which falls below the line formed by the other estimates for the species. Users can enter and plot their own estimate for comparisons.

Box 15. Evaluating length-weight relationships.

Evaluating the quality of length-weight relationships is not easily done, as there are only 'rules of thumb' for what the values of 'a' and 'b' should be. For example, one would expect $a \approx 0.001$ for eel-like fishes and $b > 3$ for fishes that increase more in weight than predicted by their increase in length, such as in many morays. While exploring such relationships, we discovered that a plot of $\log a$ over b forms a straight line for most species with several length-weight relationships available, such as in *Micropterus salmoides* (Fig. 18). Estimates that are clearly below or above that line appear to be questionable. We have added an option to that graph where users can enter their estimates of 'a' and 'b' for the respective species and see how it compares against all other estimates. The graph is also available on the Internet version. We are currently exploring other ramifications of this graph, such as the factors determining the length and the slope of the line formed by the specific dots.

Rainer Froese

How to get there

You get to the LENGTH-WEIGHT table by clicking on the **Biology** button in the SPECIES window, the **Population dynamics** button in the BIOLOGY window and the **L-W relationship** button in the POPULATION DYNAMICS window. The internal name of this table is POPLW table.

Internet

On the Internet, you access this table by clicking on the **L-W relationship** link in the 'More information' section of the 'Species Summary' page. Alternatively, you can click on the **L-W relation** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

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Crispina Binohlan and Daniel Pauly

The LENGTH-FREQUENCY Table

Length-frequency data are widely used to derive growth estimates, especially in small tropical fishes (see the POPGROWTH table, this vol.). Froese and Binohlan (2000) have shown that length-frequency curves can also be used to get a first assessment of the status of a stock (see Fig. 33) if the data are plotted in a framework of asymptotic length, length at optimum yield, and length at first maturity (see Key Facts, this vol.). With this new table, we try to collect and preserve historical data from unfished or still lightly fished populations, to be contrasted with the curves typically

**Large fish are
'Mega-spawners'**

Sources

produced from overexploited stocks, where the large, highly fecund fish (the 'Mega-spawners') have disappeared and the bulk of the catch is made up of juveniles which had no chance to reproduce.

Over 300 publications with length-frequency distributions were used to extract data for the LENGTH-FREQUENCY table. About a quarter of the available LF data were extracted from growth 'atlases', e.g., Ingles and Pauly (1984); Lavapie-Gonzales et al. (1997); Moreau et al. (1995); Dwiponggo et al. (1986); Anon. (1988a); Uosaki and Bayliff (1999). Another quarter are cruise reports, surveys and published chronicles of raw data, e.g., Anon. (1976, 1983, 1984, 1988a, 1988b); Dalzell (1983); Godo and Nedreaas (1986); and Rijavec (1980).

Status

In November 2000, the table contained over 1,500 length-frequency studies with more than 9,600 length-frequencies in the linked LFDATA table. This covers more than 500 species in 136 families, 150 of which are freshwater, 184 brackish water and 441 saltwater species from 95 countries. Over one-third of the species so far covered belong to unexploited stocks. The coverage (i.e., in number of species) of related parameters pertinent to fisheries management in the current dataset is as follows: asymptotic length, L_{∞} (42%); constants of the length-weight relationship, a and b (32%); length at which yield is at its optimum, L_{opt} (30%); total mortality, Z (29%); natural mortality, M (26%); length at first capture, L_c (14%); fishing mortality, F (8%); length at first maturity, L_m (5%).

Fields

Main Ref.: Numeric field referring to the published source of frequency distribution data. Double-clicking on this field opens the REFERENCES INFORMATION window, which gives the bibliographic details, i.e., author, year, title and source.

Locality/Country: Text field specifying the locality and country of the sampling station or area. Double-clicking on the **Country** field opens the COUNTRY REFERENCE window, which gives further details on the country in question.

Latitude, Longitude and Accuracy: Numeric fields referring to the coordinates of sampling station or area obtained either from a geographic positioning system (GPS) or specified from a map and include their level of accuracy (see OCCURRENCES table, this volume).

Depth and Temperature: Numeric fields specifying the depth range (m) and temperature ($^{\circ}\text{C}$) of the water column sampled.

Gear: Choice field indicating the type of gear used and consists of the following options: seines; trawls; dredges; liftnets; castnets; gillnets; traps; hooks and lines; various gears; other.

Sex: Choice field indicating the sex of the fish sampled and consists of the following options: females; males; unsexed/mixed fish.

Lm: Numeric field, which gives the value of length at first maturity obtained by or cited in the study.

L_∞: Numeric field, which gives the value of the asymptotic length of the fish population. Further categorization is provided to indicate if this value is a calculated result from the study or a value obtained from the Key Facts page of FishBase.

Length type: Length of fish measured, e.g., total length.

Length range: Numeric fields specifying the range of lengths (cm), from smallest fish to largest fish sampled, of all frequency distribution samples in the study.

Length/weight parameters: Numeric fields **a** and **b** indicating the constants of the length-weight relationship obtained or calculated directly from the samples.

Frequency type: Choice field describing the type of the frequency distribution and includes four options: absolute number measured (i.e., raw data); % of sample (i.e., frequency expressed as a fraction of the total number of fishes sampled); raised to the catch (i.e., frequency weighted by the total catch); other.

Year: Numeric fields indicating the period of sampling.

Comments: Text field providing further descriptions on locality or sampling conditions, gear type (if the 'other' option is ticked), frequency type (if the 'other' option is ticked), and other pertinent information.

LF code: Numeric field used internally to link each sample to the specific study.

Date of sampling: Numeric field indicating the exact date of sampling with the format dd/mm/yy. Note that in cases where the exact day of sampling is not available or where several samples (or sampling days) were lumped into a month, date of sampling is fixed at the 15th of the month in question.

L/F data: Numeric fields indicating the mid-length and the number of fish sampled in that length class.

How to get there

You get to view length-frequency data by clicking on the **Population dynamics** button in the **BIOLOGY** window and the **Length-frequency** button in the **POPULATION DYNAMICS** window. Double-click on any row in the **LIST OF FREQUENCY STUDIES** window, then on the **LF data** button in the **LENGTH-FREQUENCY** window. The **graph** button in the **LENGTH-**

FREQUENCY window displays a frequency distribution graph of all samples for a particular locality or study. On the other hand, the **Graph** button in FREQUENCY DISTRIBUTION window displays the frequency distribution graph for a single sample in the study.

Internet

The LENGTH-FREQUENCY table was not yet available in the Internet in November 2000.

References

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Maria Lourdes Palomares, Arlene Sampang and Rainer Froese

The LENGTH-LENGTH Table

This table contains relationships for the conversion of one length type to another for over 2,000 species of fish, derived from different publications, or from fish pictures. The relationships, which always refer to centimeters, may consist either of a regression linking two length types, of the form:

*Fish lengths come
in different types*

$$\text{Length type (2)} = a + b \cdot \text{Length type (1)} \quad \dots 1$$

or of ratio b' , viz

$$\text{Length type (2)} = b' \cdot \text{Length type (1)} \quad \dots 2$$

The available length types are, as elsewhere in FishBase,

TL = total length;

FL = fork length;

SL = standard length;

WD = width (in rays);

OT = other type (to be specified in the **Comment** field).

When a version of equation (1) is presented, the length range, the number of fish used in the regression, the sex and the correlation coefficient are presented, if available.

When a version of equation (2) is presented, the range and the correlation coefficient are omitted, as the ratio in (2) will usually be estimated from a single specimen, or a few fish covering a narrow range of lengths.

Sources are presented in either case, through a MainRef or, for ratios, by reference to one or several fish pictures.

How to get there

You get to the LENGTH-LENGTH table by clicking on the **Biology** button in the SPECIES window, the **Population Dynamics** button in the BIOLOGY window, and the **L-L relation** button in the POPULATION DYNAMICS window. The internal name of this table is POPLL table.

Internet

On the Internet, you can access this table by clicking on the L-L relationship link in the 'More information' section in the 'Species Summary' page.

Crispina Binohlan, Rainer Froese and Daniel Pauly

The POPGROWTH Table

*The data in this
table are required for
stock assessment models*

This table contains information on growth, natural mortality and length at first maturity, which serve as inputs to many fish stock assessment models. The data can also be used to generate empirical relationships between growth parameters or natural mortality estimates, and their correlates (e.g., body shape, temperature, etc.), a line of research that is useful both for stock assessment and for increasing understanding of the evolution of life-history strategies (see Fig. 19).

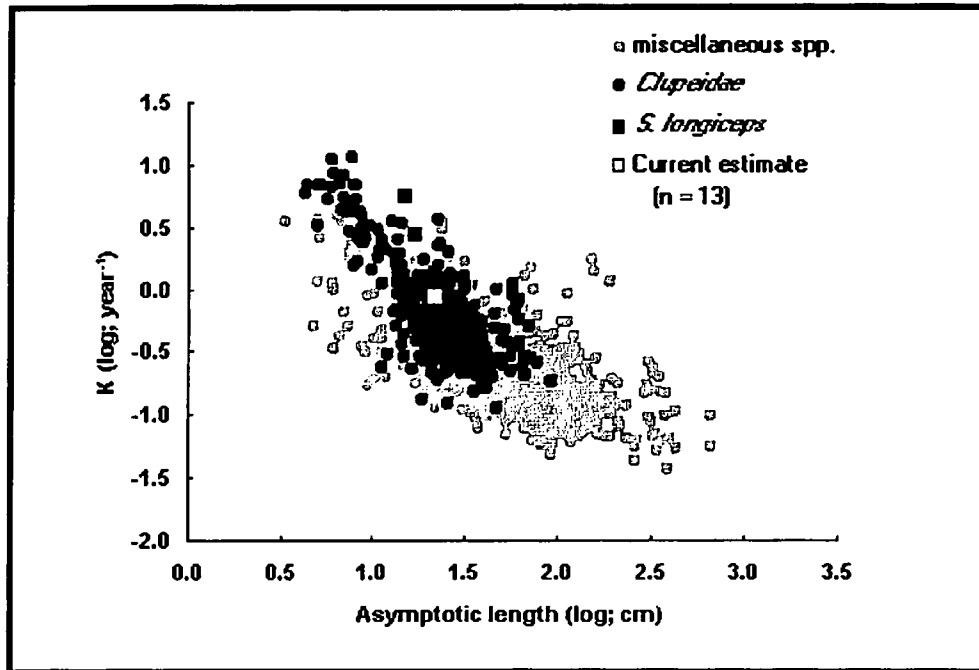


Fig. 19. Auximetric plot for *Sardinella longiceps* and of 20% of the data points for other species.

The growth parameters included in this table are those of the von Bertalanffy Growth Function (VBGF; von Bertalanffy 1938), which takes for growth in length the form

$$L_t = L_\infty \left(1 - e^{-K(t-t_0)} \right) \quad \dots 1)$$

where L_t is the predicted mean length of the fish of a given population at age t , L_∞ is their mean asymptotic length, i.e., the length they would reach at an infinitely high age, K is a factor of dimension time^{-1} , and t_0 is the theoretical (and generally negative) 'age' the fish would have at length zero had they always grown as described by their VBGF.

Similarly, the VBGF for growth in weight takes the form

$$W_t = W_\infty \left(1 - e^{-K(t-t_0)} \right)^b \quad \dots 2)$$

where W_t and W_∞ are the weights corresponding to L_t and L_∞ , respectively, and b is the exponent of a length-weight relationship of the form

$$W = a \cdot L^b \quad \dots 3)$$

POPGROWTH includes records for which at least L_∞ and K are available, i.e., t_0 may be absent (this non-biological parameter is not required for most stock assessment models).

Sources

The table presently contains over 5,000 sets of growth parameter estimates for over 1,300 species, extracted from about 2,000 primary and secondary sources. The compilations of Pauly (1978, 1980) contributed about 1/4 of the entries.

Fields

In addition to the MainRef., a data Ref. is given for each set of growth parameters, as these are often presented in papers that do not include the data from which the estimates were derived. The 'source data', as indicated by a choice field, may consist of: otolith annuli; scale annuli; other annual rings; daily otolith rings; tagging/recaptures; length-frequencies; direct observations; several data types; others.

Also, the method used to estimate a given set of growth parameters is recorded, through selection from a choice list consisting of the following items: Ford-Walford plot; von Bertalanffy/Beverton plot; Gulland and Holt plot; Nonlinear regression; ELEFAN I; other method(s).

Accounts of these methods and their assumptions and biases, and of their data requirements may be found in Ricker (1975), Gulland (1983), Pauly (1984), Gayanilo and Pauly (1997), and other fisheries science texts.

To verify the gross accuracy of growth parameters we included the following:



- a. a calculated field with the growth performance index $\theta' = \log_{10}K + 2\log_{10}L_{\infty}$ (Pauly 1979; Pauly and Munro 1984 and see 'Auximetric Analyses', this vol.), which can be compared with θ' values for other stocks of the same, or closely allied species;
- b. a multiple choice field describing how L_{∞} was converted into W_{∞} , with choices as follows:
 1. As given in MainRef. or Ref. for growth;
 2. Computed using L/W rel. of same stock;
 3. Using L/W rel. of other stock of same species;
 4. Computed using L/W rel. of similar species;
 5. Other (see Comments).
- c. a yes/no field is used to identify cases in which L_{∞} differs from L_{max} (in the SPECIES table) by more than 30% of L_{max} ;
- d. a yes/no field indicating, when $n \geq 4$ records are available, whether a given pair of W_{∞} , K values fall outside of the auximetric ellipse (see 'Auximetric Analyses', this vol.) defined by the other W_{∞} , K records for the species in question;

- e. a graph button in the summary table which, upon clicking, displays plots of body length on relative age (Fig. 20), and which can be used to identify growth curves that deviate from the general trend;

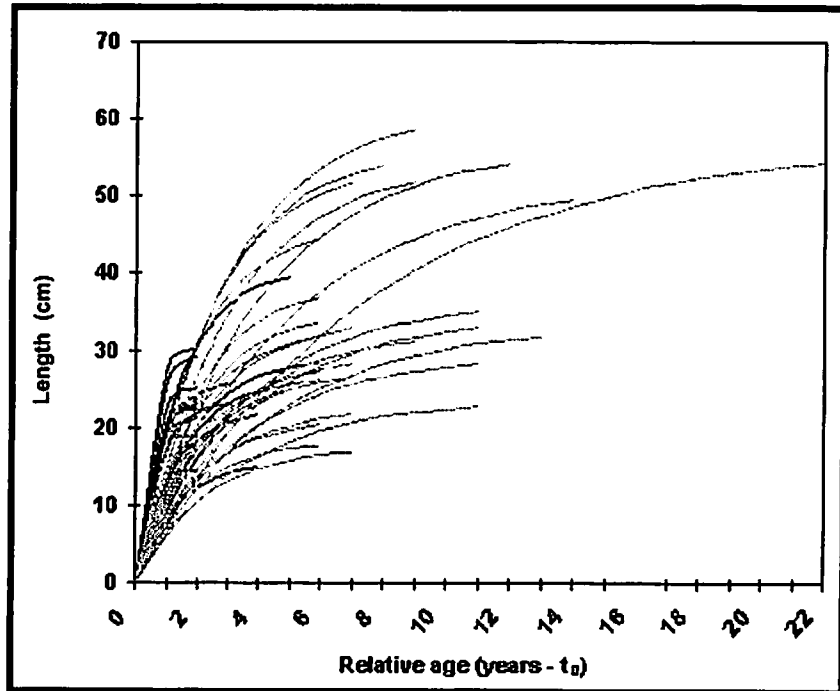


Fig. 20. Body length vs. relative age ($t-t_0$) in *Oreochromis niloticus niloticus*. These curves are based on the parameters L_∞ and K in the POPGROWTH table, and the VBGF (Equation 1). The growth curves with low asymptotes tend to reflect growth in captivity (see Box 16 and Fig. 21).

- f. graph buttons to display auximetric plots, i.e., plots of $\log K$ vs. $\log L_\infty$ (see Fig. 19) or W_∞ (see 'Auximetric Analyses', this vol.);
- g. a field to indicate whether a set of growth parameters originate from fish in 'open waters' or in 'captivity' (see Box 16).

Information on length at first maturity, which also appears in a separate table (MATURITY), is used here in conjunction with L_∞ to compute the 'reproductive load' (Cushing 1981) of the population, i.e., the ratio L_m/L_∞ . Most of the L_m values refer to mean length or the length at which 50% of the population become mature, but when such estimates were not given, or could not be derived from the data, L_m was taken as the midrange of published values.

Box 16. Growth in captive fishes.

In open waters, environmental conditions (e.g., temperature, but also the presence of predators), cause fish to either grow rapidly toward a small size (high K , low L_{∞}), or leisurely toward a large size (low K , high L_{∞}). This leads to their growth performance index ($\phi' = \log K + 2 \log L_{\infty}$) remaining nearly constant among different populations of the same species (Pauly 1994). The reasons for this near constancy of ϕ' , which is ultimately due to the way fish allocate the scarce oxygen diffusing through their gills, are discussed in Pauly (1981, 1994).

For most captive fish, the absence of predators and sexual competitors allows the allocation of more oxygen to feeding and growth, and away from behaviors that are costly in terms of oxygen demand, such as darting about to evade predators, or fighting against sexual competitors.

This results in captive fish usually having ϕ' values higher than those predicted from the growth performance of free-living populations. Moreover, the strength of this effect increases with the sophistication of the culture system (Pauly et al. 1988). Obviously, this effect will be strengthened by genetic enhancement for fast growth, e.g., in Nile tilapia (Pullin 1988) or Atlantic salmon (Gjedrem 1985), which, if often unwittingly, selects for the calm behavior that allows optimal allocation of oxygen to growth (Jones 1996; Bozynski 1998).

Combined, these effects cause the ϕ' values of fish in intensive culture systems to be much higher than for their conspecifics in open waters. A graph making this combination of effects clearly visible is included in FishBase 2000 which distinguishes fish which grow in open waters from those grown in captivity (based on the corresponding field of the POPGROWTH table).

As might be seen on the auximetric plot in Fig 21, the dots pertaining to captive fish form a cluster that deviates strongly from a cluster representing their wild conspecifics, especially for L_{∞} values between 10 and 30 cm, mostly representing Nile tilapia in intensive systems.

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For some records, the estimates of L_{∞} have yet to be checked against the recorded maximum length (L_{max}) to which, we believe, L_{∞} should be reasonably close (see above).

Data in this table have contributed to a recent study on empirical equations for important parameters such as L_{∞} , length at first maturity, and length at optimum yield (Froese and Binohlan 2000).

We look forward to users' comments on the contents and/or utility of the POPGROWTH table.

Box 17. Using FishBase to test life-history hypotheses.

Life-history theory, which is of high importance to both theoretical ecology and resource management, is based on the concept of trade-offs between different energy-consuming functions, and the resulting balance tends to maximize fitness (i.e., total reproductive output; e.g., Beverton 1963, Roff 1992, Stearns 1992, Charnov 1993). FishBase can be very useful for testing life-history hypotheses and identifying patterns at a large geographical scale (e.g., Natural Mortality, this vol.). An example of such a use at a small geographical scale is presented here. Stergiou et al. (1997) reviewed the available quantitative information on the physics, chemistry, biology and fisheries of the Greek Seas. The available data clearly indicate the highly oligotrophic nature of the subtropical Greek waters, with large areas being directly comparable, in terms of trophic potential, to open oceans. Since temperature and the quality and quantity of food are among the most important factors affecting phenotypic responses in fishes (e.g., Wootton 1990, Roff 1992), one may predict, that the fish stocks and/or species inhabiting Greek waters will be generally smaller in size, have lower longevity, mature at an earlier age and size, and probably suffer higher adult mortality rate than their counterparts in other areas of the world (for a discussion on the relationship between trophic potential, temperature, growth rates, body sizes, predatory fields and adult natural mortality rates, and length at maturity see, Pauly 1980, and Natural Mortality, this vol.).

To test the prediction of smaller sizes, the relationship between the VBGF parameters K and L_{∞} of the various fish stocks reviewed by Stergiou et al. (1997) was estimated, and L_{∞} - K pairs were plotted against those of all stocks included in FishBase 98 (Fig. 22). The following relationship was established: $\text{Log}L_{\infty}=1.34-0.32\text{Log}K$ (SE-slope = 0.12, $r = -0.25$, $n = 99$, $P<0.05$). The slope of the $\text{Log}L_{\infty}$ - $\text{Log}K$ relationship in Greek waters was significantly (ANCOVA, $P<0.05$) smaller than that for all records included in FishBase 98, excluding those which refer to fish in captivity, and for which von Bertalanffy estimates are available: $\text{Log}L_{\infty}=1.33-0.61\text{Log}K$ (SE-slope = 0.009, $r = -0.70$, $n = 4,618$, $P<0.001$; Fig. 22). From Fig. 22, it is evident that the Greek stocks are characterized, for the same K values, by smaller L_{∞} values (i.e., the vast majority of the points are positioned below the 'global' FishBase regression line), for lengths up to 100 cm (i.e., $\text{Log}L_{\infty}$ about 2). The only notable exceptions were the seven *Xiphias gladius* stocks to the right (Fig. 22), the removal of which did not affect the slope of the 'Greek' regression line (i.e., $\text{Log}L_{\infty}=1.29-0.30\text{Log}K$, SE-slope=0.09, $r=-0.32$, $n=92$, $P<0.05$). *X. gladius* does not follow the general trend mentioned above because it is a highly migratory species and thus its growth is most probably less affected by local environmental (i.e., food, temperature) conditions.

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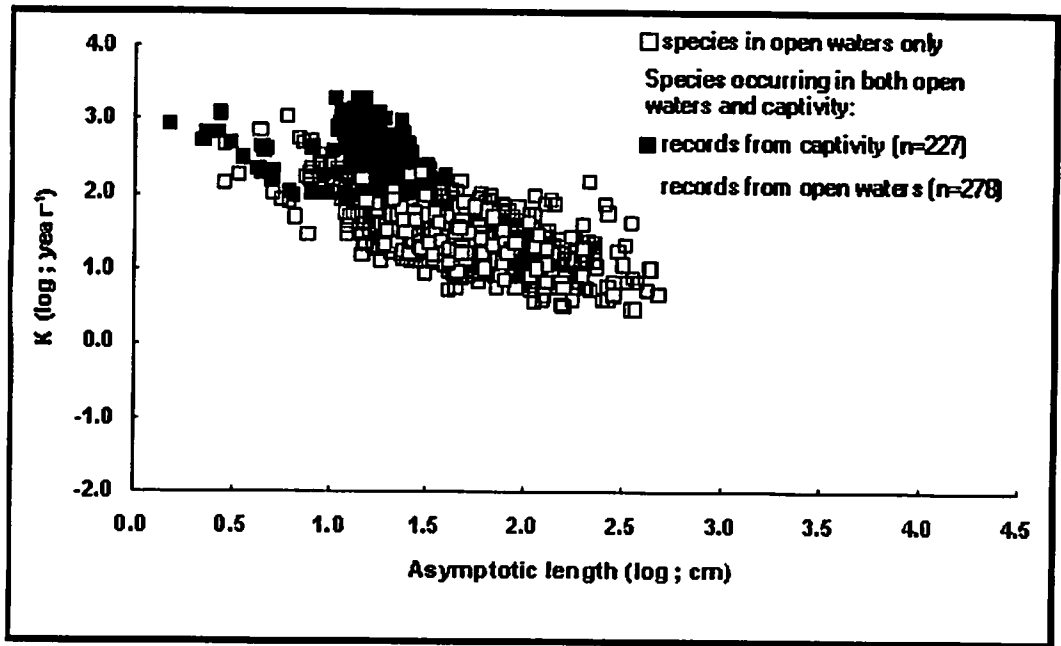


Fig. 21. Auximetric grid, emphasizing the growth of captive fishes. The cluster of black squares between $\log(L_{\infty}) = 1.0-1.5$ refers mainly to Nile tilapia in semi-intensive and intensive systems (see Box 16).

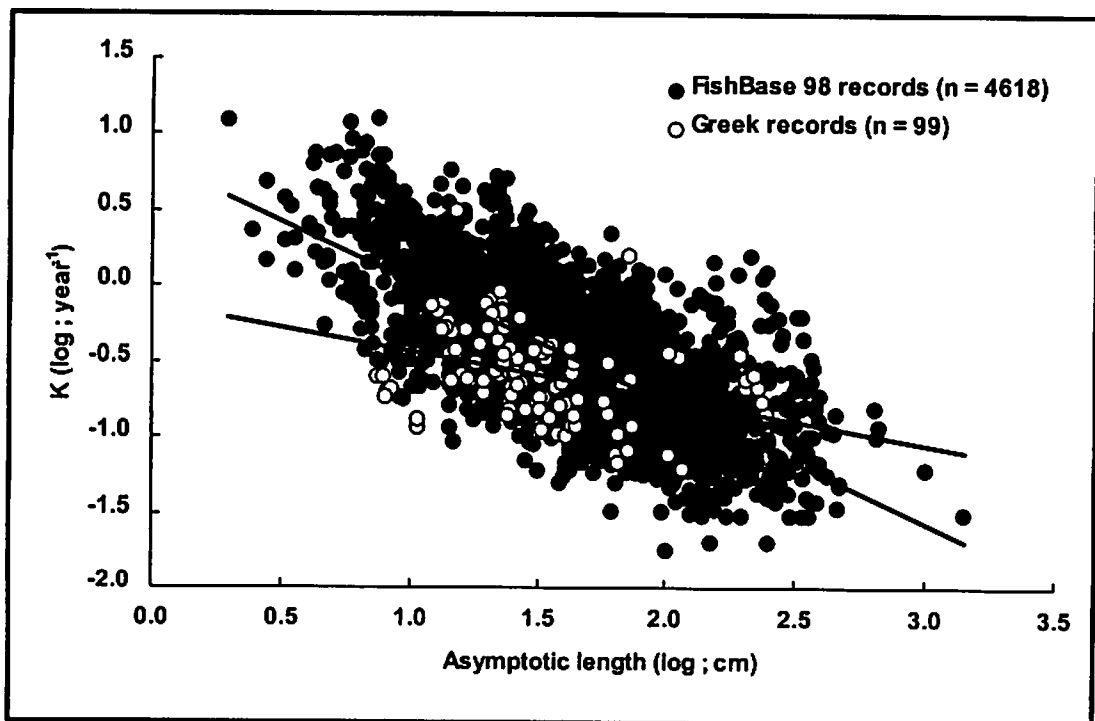


Fig. 22. Relationship between the von Bertalanffy parameters K and L_{∞} for a variety of fish stocks in Greek waters and for records available in FishBase 98 (excluding those which refer to fish in captivity). The two slopes differ significantly (ANCOVA, $P < 0.05$).

How to get there

You get to this table by clicking on the **Biology** button in the SPECIES window, **Population dynamics** button in the BIOLOGY window, and **Growth** button in the POPULATION DYNAMICS window. Fig. 21, emphasizing the growth of captive fishes (e.g., in aquaculture experiments) may also be accessed through the **Population dynamics** button of the Graphs Menu accessed via the Reports button of the FishBase Main Menu.

Internet

On the Internet, you get to the POPGROWTH table by clicking on the **Growth** link in the 'More information' section of the 'Species Summary' page. Alternatively, you can create a list of all species for which growth information is available by selecting the **Growth** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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- Crispina Binohlan and Daniel Pauly**

Auximetric Analyses



**Comparing growth is not
straightforward**

The growth of fishes is a process through which size (weight or length) changes with time, and any attempt to depict or compare growth must deal with *both* of these dimensions. However, comparing growth curves, which link size and time, is not straightforward. Indeed, depending on one's definition of 'slow' or 'fast' growth, one can get into serious contradictions when growth curves cross one another. Thus, Kinne (1960) wrote that "the difference in growth rate established in young fish does not persist throughout life. Initially slow-growing fishes may surpass initially fast-growing fishes, and finally reach a greater length-at-age." (This phenomenon is nicely illustrated in Fig. 20).

In FishBase, we use the parameters of the von Bertalanffy Growth Function or VBGF (see the 'POPGROWTH table', this vol.) to

describe the growth of fishes. However, this does not, by itself, resolve the problem addressed by Kinne (1960), as none of these parameters has the dimensions of growth (i.e., length vs. time or weight vs. time). L_{∞} and W_{∞} represent size alone, and K and t_0 have the dimensions time^{-1} and time, respectively. However, various combinations of these parameters, e.g., $L_{\infty} \cdot K$ have a suitable dimension (here: $\text{length} \cdot \text{time}^{-1}$), i.e., that of a growth rate (Gallucci and Quinn 1979). Put on a logarithmic basis, the indices of growth performance:

$$\phi' = \log K + 2 \log L_{\infty} \quad \dots 1)$$

and

$$\phi = \log K + (2/3) \log W_{\infty} \quad \dots 2)$$

also have the correct dimension of a growth rate, and are now widely used to compare the growth performance of different fishes and invertebrates, owing to their being normally (and narrowly) distributed for different populations of the same species (see, e.g., Moreau et al. 1986). The latter feature also allows estimation of K from L_{∞} or W_{∞} when their (mean) ϕ' or ϕ is known from a (number of) population(s) (Munro and Pauly 1983; Pauly and Munro 1984).

The slopes of 2 and 2/3 in equations (1) and (2), respectively, which make these indices perform as they do, were estimated by Pauly (1979) from a dataset documented in Pauly (1978, 1979) and now included in FishBase. Equation (1) implies that plots of $\log K$ vs. $\log L_{\infty}$ will have, on average, a slope of 2. Correspondingly, equation (2) implies that plots of $\log K$ vs. $\log W_{\infty}$ will have, on average, a slope of 2/3.

An 'auximetric' plot (from the Greek words for 'growth' and 'measure') is a double logarithmic plot of the parameter K of the VBGF vs. asymptotic size (L_{∞} or W_{∞}). Herein, a population with a given set of growth parameters (L_{∞} , K or W_{∞} , K) is represented by a single point, and different populations of the same species will tend to form a cluster of points. Since equations (1) and (2) imply that these clusters can be fitted with regression lines of known slope, the clustering also implies that ellipses can be superimposed on the clusters of points, with long axes having slopes of 2, or 2/3, respectively, with intercepts equal to ϕ' or ϕ , and surface areas related to the variance of the datasets that are represented.

Thus ellipses with circumference containing the 95% confidence area (S_{95}) of a cluster of L_{∞} , K (or W_{∞} , K) values, can be readily estimated, and a software (AUXIM), documented in Pauly et al. (1996), was developed to perform this and related functions, for files with at least 4 pairs of L_{∞} , K or W_{∞} , K values.

As AUXIM is tedious to use as a stand-alone application, a subset of its routines is included in FishBase 2000, to enable analyses of the many growth parameters therein. However, to allow comparisons among fishes of widely different shapes, only

AUXIM estimates the 95% confidence area for growth parameters

routines pertaining to growth in weight (and to \emptyset , not \emptyset') are included here. Also, only fishes from 'open waters' (and not from 'captive') can be included in analyses (the reason is given in Box 16).

How to get there

The auximetric analyses that can be performed within FishBase depend on one's location in the database when invoking these analyses:

- 1) when the auximetric routines are called from within the POPULATION GROWTH INFORMATION window, all that is shown is a plot of $\log K$ vs. $\log W_{\infty}$ for all species in FishBase with such values (in yellow), the point(s) for the species from where the routine was invoked (in red), and an ellipse defining S_{95} (if the number of cases $n \geq 4$; see Box 18). Also, if $n \geq 4$, a table will be output with details on the ellipse (mean W_{∞} and K);
- 2) when the auximetric routines are called from the REPORTS menu, and a group of species by environment, or an order, or a family or a genus has been identified, a complete auximetric analysis can be performed, involving:
 - a) drawing of one ellipse per selected species (see Fig. 23; Box 18) and estimation of its mean K and W_{∞} (in cases where $n < 4$, the means are taken without ellipses being drawn), and display of a graph showing the ellipses and/or the means for all selected species;

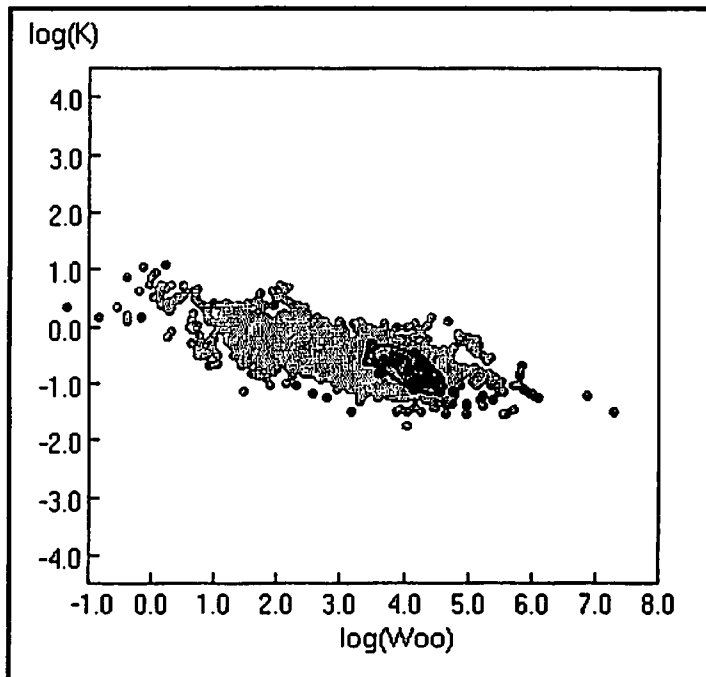


Fig. 23. Plot of K vs. W_{∞} . Light dots represent all species for which W_{∞} is available in FishBase, dark dots represent entries for *Gadus morhua*. The ellipse with a black dot at its center represents the 95% confidence limits. See Box 18 for details.

Box 18. Background and use of AUXIM.

This box, the first part of which is adapted from Pauly et al. (1996) summarizes the essential features of the approach used by AUXIM to draw ellipses. Given the VBGF weight, and the definition of \emptyset , we have

$$\log K = \emptyset - 2/3 \log W_{\infty}$$

which is the equation of the major axis of the ellipse, with \emptyset as the intercept with the ordinate.

Simultaneously, and because it is perpendicular, the equation for the ellipse's minor axis is

$$\log K = Y_0 + 3/2 \log W_{\infty}$$

where Y_0 is the ordinate at the intercept with the ordinate axis. The abscissa of the intercept of the minor axis with the abscissa axis is

$$X_0 = \log W_{\infty} - 2/3 \log K$$

If an ellipse is to refer to the 95% confidence interval of a cloud of points, the length ($2 \cdot a$) of the major axis must be related to the standard deviation of X_0 ; at the same time, the length of the minor axis ($2 \cdot b$) must be related to the standard deviation of \emptyset , or

$$2 \cdot a = 2 \cdot t \cdot sd_{(X_0)} \cdot 3/2 \cdot 3/2 \cdot (1 / ((1 + (3/2)^2)^{1/2}))$$

$$2 \cdot b = 2 \cdot t \cdot sd_{(\emptyset)} \cdot 3/2 \cdot 3/2 \cdot (1 / ((1 + (3/2)^2)^{1/2}))$$

where the value of the t-statistic is related to the number of points (n), with $t = 1.96$ when $n = \infty$ (Sokal and Rohlf 1995), and where the factor $3/2 \cdot 3/2 \cdot (1 / ((1 + (3/2)^2)^{1/2}))$ takes into account the fact that the axes of the ellipses are not parallel to the axes of the coordinate system.

When the ellipses refer to the standard deviation of the average values of $\log W_{\infty}$ and $\log K$, $sd_{(X_0)}$ and $sd_{(\emptyset)}$ are replaced by standard errors, i.e., by $se_{(X_0)}$ and $se_{(\emptyset)}$, respectively.

How to use AUXIM:

The user interface of AUXIM has four parts:

1. 'Command buttons' in the upper left corner of the display with functions to: (i) increase or decrease the size of the auximetric plot (i.e., zoom-in or out); (ii) open the list of species selected prior to activating the AUXIM routine proper (available only if AUXIM was opened from the Reports Menu); and (iii) open the table of growth parameters for the current species;
2. Display of currently selected species and of command buttons enabling scrolling through the list (upper right corner of display);
3. Display tab, showing the auximetric plot, and also allowing to view the distance and overlap table, as well as the dendrogram; and
4. System command buttons to: (i) select or deselect a species from the list; (ii) print the current display to a printer or a file; (iii) open the help file; or (iv) close the form and return control to FishBase.

Note that functions associated with the command buttons for utilities may also be accessed by clicking the right button of the mouse. Also, the selection and deselection of species may be done through the list of species by either double-clicking on the species or by pressing the <Space Bar> to toggle the status.

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- b) estimating the distances and overlaps between species (for a minimum of 4 species), and output of these in table form; and
- c) using the distances in (b) and the clustering algorithm in McCammon and Wenninger (1970) to construct a dendrogram of distances in 'growth space', i.e., showing the similarity of species (within the group selected) in terms of their growth (Fig. 24).

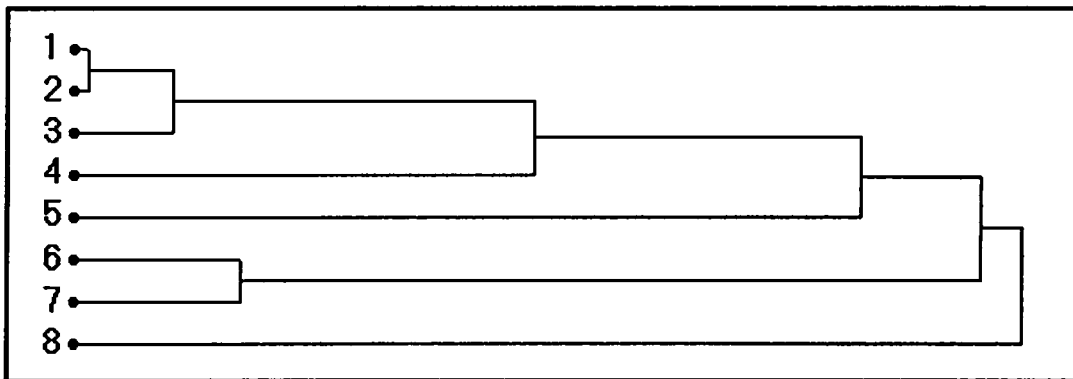


Fig. 24. Dendrogram of similarities (X-axis: arbitrary units) in 'growth space' as output by AUXIM for Gadidae, with 1 = *Theragra chalcogramma*; 2 = *Trisopterus luscus*; 3 = *Merlangius merlangus*; 4 = *Micromesistius poutassou*; 5 = *Melanogrammus aeglefinus*; 6 = *Gadus morhua*; 7 = *Pollachius virens*; 8 = *Trisopterus minutus*. As can be seen, two pairs of species (*T. chalcogramma* and *T. luscus*; *G. morhua* and *P. virens*) form the closest clusters, with subsequent clusters formed by links with other species.

Analyses such as these have been performed for tilapias, Fam. Cichlidae (Pauly et al. 1996) and snappers, Fam. Lutjanidae (Pauly and Binohlan 1996), but their potential still needs to be fully explored. We are confident that such analyses will considerably expand our understanding of the growth, and generally, of the biology of fishes, and we look forward to users' feedback on this.

Internet

An auximetric graph—albeit without ellipse—can be created by clicking on the **Auximetric graph** link in the list of growth parameters for a given species, which is created by clicking on the **Growth** link in the 'More information' section of the 'Species Summary' page.

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Seasonal Growth

That the growth of fishes displays seasonal oscillations was well known to the pioneers of fishery biology, notably to T.W. Fulton (1901, 1904), who along with C.G.J. Petersen, invented length-frequency analysis.

This awareness faded away, however, when fishery scientists gradually switched away from the analysis of length data and used 'annuli' (on otoliths, scales and other bones) to estimate growth rate and draw growth curves (Went 1972). Thus, Beverton and Holt, in their classic of 1957, did not consider seasonal growth oscillations in more than cursory manner, and particularly, saw no point in modifying the basic von Bertalanffy growth function (VBGF) to express such oscillations, although they occur in all the fishes they studied.

***Seasonal growth oscillations
occur in tropical
and temperate fishes***

Following a discussion of seasonal growth by von Bertalanffy and Müller (1943), the first published version of the VBGF allowing for such oscillation was that of Ursin (1963a, 1963b). Other modifications of the VBGF were those of Pitcher and MacDonald (1973) and Daget and Ecoutin (1976). Improvements of these earlier models and various approaches for fitting them followed in quick successions (Cloern and Nichols 1978; Pauly and Gaschütz 1979; Appeldoorn 1987; Somer 1988; Soriano and Pauly 1989). The application examples presented by these authors made it quite obvious that growth models which do not explicitly consider seasonal oscillations fail to capture an essential aspect of the growth process (Pauly 1990).

This is also true for tropical fishes, since winter-summer temperature differences as small as 2°C are sufficient to induce seasonal growth oscillations which, while not detectable visually, are still statistically significant (Pauly and Ingles 1981; Longhurst and Pauly 1987).

The growth model which best accounts for seasonal growth oscillation is probably that of Somer (1988), of the form

$$L_t = L_\infty \{1 - \exp - [K(t - t_0) + S(t) - S(t_0)]\} \quad \dots 1)$$

where

L_∞ , K and t_0 are defined as in the standard VBGF;

$S(t) = (CK/2\pi) \sin \pi (t - t_s)$; and

$S(t_0) = (CK/2\pi) \sin \pi (t_0 - t_s)$.

Equation (1) has two parameters more than the standard VBGF: C and t_s . Of these, the former is easiest to visualize, as it expresses the amplitude of the growth oscillations. When $C = 0$, equation (1) reverts to the standard VBGF. When $C = 0.5$, the seasonal growth oscillations are such that growth is increased by 50% at the peak of the 'growth season', i.e., in 'summer', and, briefly, reduced by 50% in 'winter'. When $C = 1$, growth increases by 100%, i.e., doubles during 'summer', and becomes zero in the depth of 'winter' (see Fig. 25).



The second new parameter, t_s , expresses the time between $t = 0$ and the start of a sinusoid growth oscillation. For visualization, it helps to define $t_s + 0.5 = WP$, which expresses, as a fraction of the year, the period when growth is slowest. WP is often near 0.1 (i.e., mid-February) in the northern and 0.6 (mid-August) in the southern hemisphere, hence the name. [Note that it is not necessarily the alternation of high summer and low winter temperatures which causes the seasonal oscillations of growth; in freshwater fishes, e.g., of the Amazon, such oscillations are due to the alternation of flood and dry seasons. Note also that equation (1) cannot describe long periods of zero growth (and values of $C > 1$), a problem discussed in Pauly et al. (1992)].

As this model and its predecessors (notably the model of Pauly and Gaschütz 1979) have been fitted to numerous sets of seasonally oscillating growth data, a number of estimates of C exist, covering a wide range of fish species and habitats.

The POPGROWTH table of FishBase includes most of the estimates of C so far published for fish, along with matching estimates of the summer-winter temperature difference (ΔT ; difference of mean monthly values, in °C). As might be seen on Fig. 26, these C values are linearly related to ΔT , with C near 1 when ΔT is about 10°C.

Some of the physiological implications of this relationship, known since the early 1980s (see e.g., Pauly and Ingles 1981), are discussed in Longhurst and Pauly (1987).

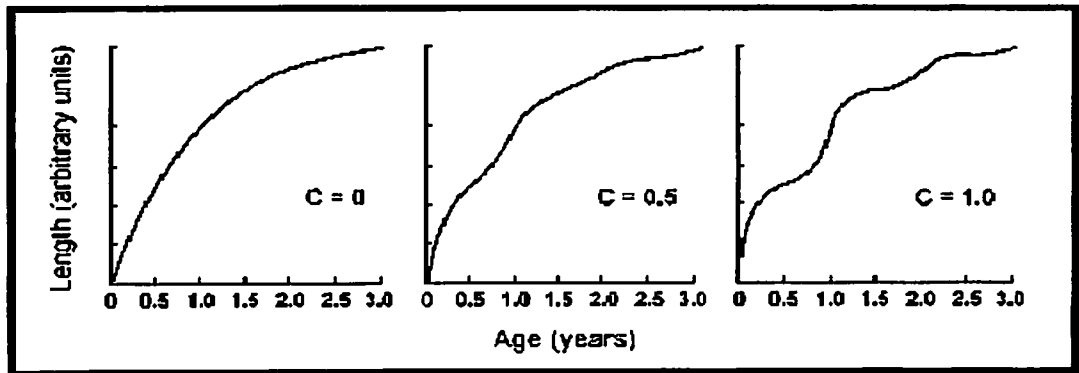


Fig. 25. The effect of the amplitude parameter C on a von Bertalanffy growth curve with $L_{\infty} = 25$ units; $K = 1\text{year}^{-1}$, $t_0 = 0$ and $t_1 = 0$.

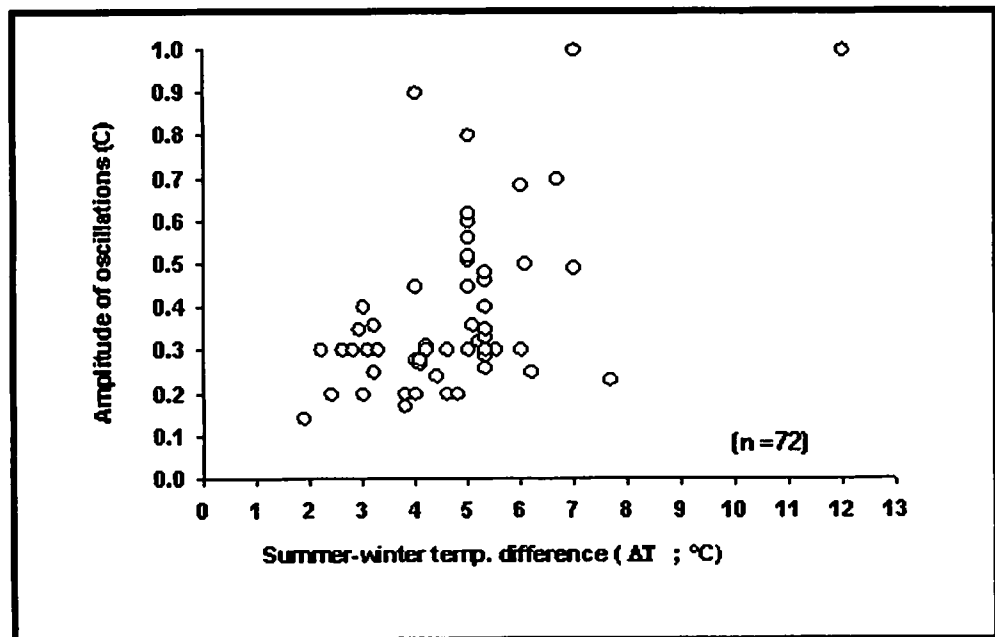


Fig. 26. The relationship between the parameter C , expressing the amplitude of seasonal growth oscillations in 72 fish populations and the summer-winter temperature differences of their habitat (ΔT ; °C).

How to get there

You get to the graph corresponding to Fig. 26 from the GRAPHS menu, under the Report button of the Main Menu.

Internet

The parameters of seasonal growth (C , WP) are available in the POPGROWTH table which can be accessed on the Internet by clicking on the Growth link in the 'More information' section of the 'Species Summary' page.

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Natural Mortality

In fisheries science, mortalities are usually expressed as instantaneous rates, viz.:

$$N_0 = N_1 \cdot e^{(-Z \cdot \Delta t)} \quad \dots 1)$$

where N_0 and N_1 are successive numbers in a population, affected by a (total) mortality rate Z during a time interval Δt .

This allows defining

$$Z = F + M \quad \dots 2)$$

where F is the fishing mortality and M is the natural mortality, caused by any factor other than fishing (in an unexploited stock, we obviously have $Z = M$).

Natural mortality estimates are usually hard to obtain (except in unexploited populations, which tend to be inaccessible for study and are becoming scarcer). Thus, every well-documented estimate of M so far encountered in the literature has been incorporated in the POPGROWTH table, which now includes over 400 estimates of natural mortality, for over 200 species (see Box 19). About 42% of these are from Pauly (1980; see also Yield-per-recruit Analyses) while 20% are from Beverton and Holt (1959) and Djabali et al. (1993).

Every well-documented estimate of natural mortality has been incorporated

Box 19. The natural mortality of fishes.

The FishBase graphs of natural mortality are based on what is surely the largest compilation of independently derived natural mortality estimates of fish in the world, i.e., similar, but independent data do not exist which could be used to verify the generalizations derived from this dataset. Thus, since independent replication of our results is difficult, we must be very careful in presenting generalizations based on this dataset.

Here, we have therefore limited ourselves to two graphs testing earlier generalizations of Beverton and Holt (1959) and Pauly (1980). The first of these graphs (Fig. 27) is a plot of $\log M$ vs. $\log K$, the curvature parameters of the von Bertalanffy growth function. As might be seen, this confirms that K , which is related to longevity, is a good predictor of M . The variance is high, however, suggesting that other factors also influence M .

Our second graph (Fig. 28) documents two of the factors influencing M , size and environmental temperature. The dots are estimates of $\log M$ vs. the corresponding estimates of $\log L_{\infty}$, with open dots for estimates from waters below 20°C (about 2/3 of all cases), and full dots for the rest, referring to tropical fishes.

As might be seen, M is not only related to L_{∞} (and to K ; see Fig. 27), but also to temperature, notwithstanding Charnov (1993), whose concepts of 'Beverton and Holt invariants', of which M/K is supposed to be one, do not allow for the temperature effect so evident in the data at hand.

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Note that except in a few cases explicitly listed as such, these estimates are *independent*, i.e., were not estimated using rules of thumbs, or empirical models linking values of M with some predictor variable(s), as presented by Pauly (1980) or Hoernig

(1984). Thus, the estimates of M presented here may be used to derive new empirical models (Froese et al. in prep.).

Hoenig's (1984) model takes:

$$l_n = 1.44 - 0.984 l_n(t_{\max})$$

where t_{\max} is the longevity of the fish in question, in years. Combined with the highest t_{\max} values on record (in the SPECIES table), this yields approximate values of M in species for which there is little hope that more precise estimates will ever become available. These values (and a few other, non-independent estimates of M) are identifiable as such by the method used (see below).

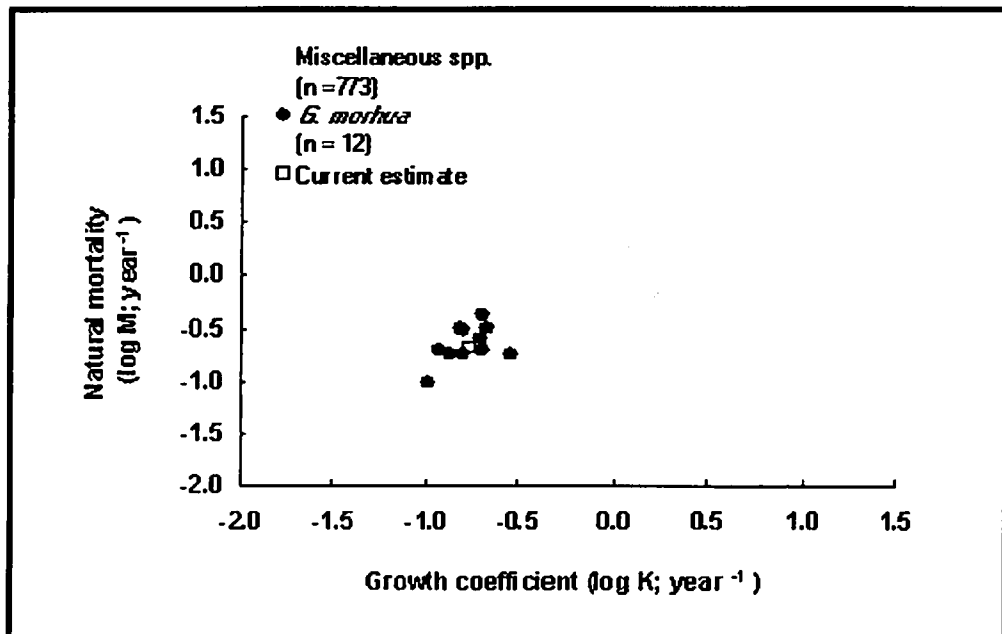


Fig. 27. Natural mortality vs. growth coefficient for various fishes. See Box 19 for details.

An estimate of mean environmental temperature (in °C) was added to every POPGROWTH record that included an estimate of M. Also, the method used to estimate M is recorded, using one of the following choices: length-converted catch curve in unexploited population; age-structured catch curve in unexploited population; mean length in unexploited population; tagging-recapture data; plot of Z on effort; parabolic plot of Z on catch; Ecopath (trophic) model (Christensen and Pauly 1993); from t_{\max} and Hoenig's model; other non-independent estimate; and other method. In the last two cases, a comment is provided in the Remarks field.

These methods are described in the textbooks cited in the POPGROWTH table, except for that involving the Ecopath model, briefly described in Box 21.

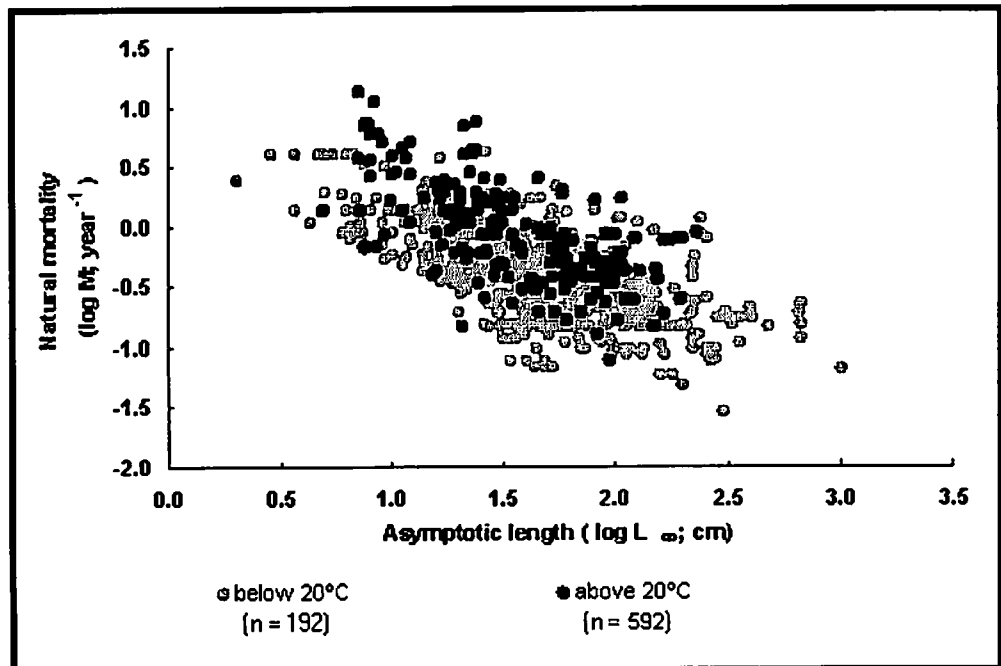


Fig. 28. Natural mortality vs. asymptotic length for tropical fishes and other fishes. Note temperature effect, and see Box 19 for details.

References

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Daniel Pauly and Crispina Binohlan

Yield-per-recruit Analyses

One major reason why fisheries scientists study fish growth, and describe it by means of the von Bertalanffy growth function (VBGF), is to perform stock assessments using the yield-per-

recruit (Y/R) model of Beverton and Holt (1957), or one of its variants.

Thus, to optimize the use of the VBGF parameters, we have included a Y/R button to the POPGROWTH table which, when clicked on, leads to different forms of yield-per-recruit analyses being performed, depending on the entries in the table, and user's choices. For definitions of some of the terms used below, see the section on POPGROWTH, 'Natural Mortality' and the LENGTH-WEIGHT tables.

Recruits are young fish entering the fishing grounds

However, before the available options are presented, the terms 'recruit' and 'yield-per-recruit' must be defined. Although the definition may vary between authors and between fisheries, we may here visualize recruits as fully metamorphosed young fish, whose growth is described adequately by the VBGF, and whose instantaneous rate of natural mortality is assumed similar to that of the adults. Such recruits have an average age t_r , an average length L_r and an average weight W_r . Upon reaching age t_r the recruits may be caught immediately, in which case the mean age at first capture t_c is equal to the age at recruitment ($t_c = t_r$). Alternatively, the recruits may be caught at a more advanced age (and correspondingly larger sizes, L_c and W_c). In such case, because of natural mortality, the number of recruits actually entering the fishery R_c will be less than the initial number of recruits R_r or

$$R_c = R_r \cdot e^{-M(t_c - t_r)} \quad \dots 1)$$

Thus, there is, for each combination of t_c and F values, a yield-per-recruit (Y/R = catch in weight, per recruit), the value of which can be estimated from various equations whose exact form depends mainly on the model used to describe the growth of the fish. In the following paragraphs, equations for the estimation of Y/R are given for three forms of the VBGF, i.e.,

$$\text{Case I: } W_t = W_\infty \left(1 - e^{-K(t-t_0)}\right)^3 \quad \dots 2)$$

or standard VBGF (Beverton and Holt 1957), based on conversion from length using the isometric length-weight relationship

$$W = (c.f./100)L^3 \quad \dots 3)$$

where c.f. is the condition factor.

$$\text{Case II: } W_t = W_\infty \left(1 - e^{-K(t-t_0)}\right)^b \quad \dots 4)$$

which is a form of the special VBGF (Pauly 1984) where the exponent (b) of the length-weight relationship is allowed to take values other than 3, i.e.,

$$W = a \cdot L^b \quad \dots 5)$$

where $b \neq 3$.

$$\text{Case III: } L_t = L_\infty (1 - e^{-K(t-t_0)}) \quad \dots 6)$$

which is the VBGF for growth in length, and which can be used for *relative* yield-per-recruit analyses when a length-weight relationship is not available.

***The original
Beverton and Holt model***

Estimation of yield-per-recruit

Case I is the original model of Beverton and Holt (1957), which has the form:

$$Y / R = F \cdot e^{-Mr_2} W_\infty \left\{ \frac{1 - e^{-Zr_3}}{Z} - \frac{3e^{-Kr_1} (1 - e^{-(Z-K)r_3})}{Z + K} \right. \\ \left. + \frac{3e^{-2Kr_1} (1 - e^{-(Z-2K)r_3})}{Z + 2K} - \frac{e^{-3Kr_1} (1 - e^{-(Z+3K)r_3})}{Z + 3K} \right\} \quad \dots 7)$$

where $Z = F + M$;

$$r_1 = t_c - t_0 ;$$

$$r_2 = t_c - t_r ;$$

$$r_3 = t_{\max} - t_c ; \text{ and}$$

where W_∞ , K and t_0 are growth parameters (see 'POPGROWTH table', this vol.), t_c and t_r are as defined above and t_{\max} is "the maximum age of significant contribution to the fishery" (Ricker 1975) or more simply, the longevity, in open waters, of the fish in question (as given in the SPECIES table). The effect of the exact value of t_{\max} is generally very small, and thus, when a suitably high value of t_{\max} is not available, equation (7) can be considerably simplified by setting $t_{\max} = \infty$, in which case equation (7) becomes:

$$Y / R = F \cdot e^{-Mr_2} W_\infty \left\{ \frac{1}{Z} - \frac{3e^{-Kr_1}}{Z + K} + \frac{3e^{2Kr_1}}{Z + 2K} - \frac{e^{-3Kr_1}}{Z + 3K} \right\} \quad \dots 8)$$

whose parameters are defined as in Equation (7).

Both equations (7) and (8) can be used to assess the effect on yield-per-recruit of different values of t_c , corresponding to

different values of L_c , as generated, e.g., by different mesh sizes, and of F , corresponding to different levels of fishing effort.

The graphic routine included here allows viewing and printing two types of graphs: (a) plots of Y/R (always in $g \cdot year^{-1}$) vs. F ($year^{-1}$), for values of L_c selected by the user (Fig. 29), or (b) complete 'yield isopleth diagrams', presenting yield-per-recruit contours for L_c/L_∞ values ranging from 5 to 95% of L_∞ , and values of F ranging from zero to an upper limit (default $5 year^{-1}$; max. = $20 year^{-1}$) set by the user (see Fig. 30, and Box 20).

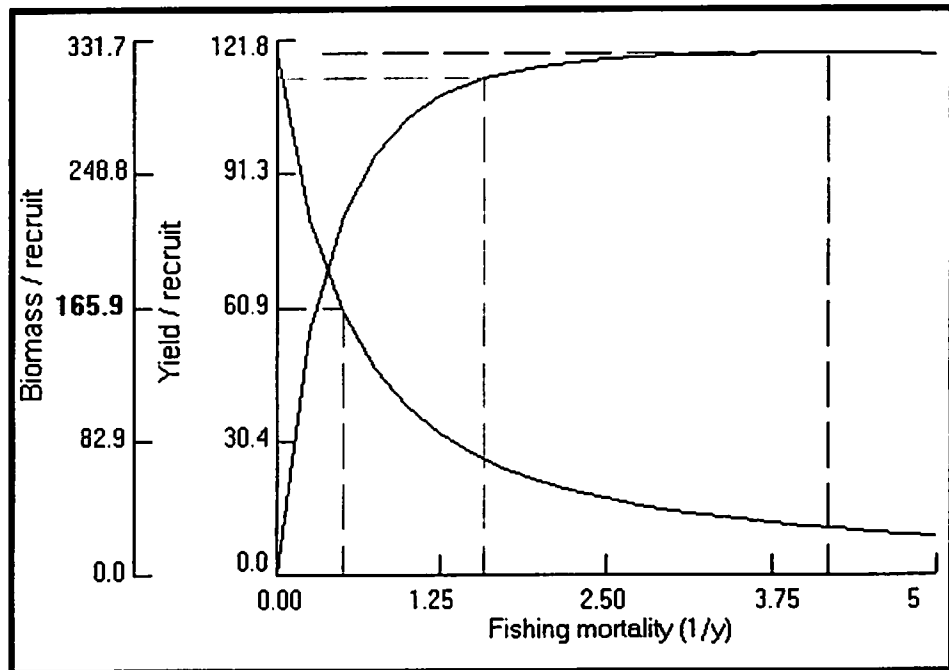


Fig. 29. Two-dimensional yield-per-recruit plot of *Plectropomus leopardus*. The parameters used are: $W_\infty = 2,220 g$; $K = 0.43 year^{-1}$; $t_0 = 0.34 year$; $M = 0.86 year^{-1}$; $b = 3.2$; $t_r = 0.12 year$; and $t_{max} = 26 years$. L_c was set to 20 cm. The descending curve shows the decrease in biomass/recruit as fishing mortality increases. The ascending curve illustrates the small increase in yield when F is increased beyond $F_{0.5} = 1.75 year^{-1}$. The units are g for biomass/recruit and $g \cdot year^{-1}$ for yield/recruit. Dotted lines indicate (from left to right): F value at which B/R is 50% of its original value (i.e., $F_{0.5}$; $F_{0.5}$); and F_{max} , defined in Box 20.

In all these analyses, M is either taken from the POPGROWTH table (see section on 'Natural Mortality'), entered by the user, or generated by the empirical equations of Pauly (1980), which, for length, takes the form

$$\log M = -0.066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T \quad \dots 9)$$

and for weight

$$\log M = -0.2107 - 0.0824 \log W_\infty + 0.6757 \log K + 0.4627 \log T \quad 10)$$

where M and K are expressed on an annual basis, L_∞ and W_∞ are expressed in cm (TL) and g (live weight), respectively, and where T is the mean environmental (water) temperature in °C. [An internal routine converts low values of T (down to -2°C) to their higher physiologically effective equivalent (Pauly 1980); another routine converts values of L_∞ originally expressed as SL or FL into TL, such that they can be used in equation (9); other measures of length (WD, OT or NA) are left unchanged.]

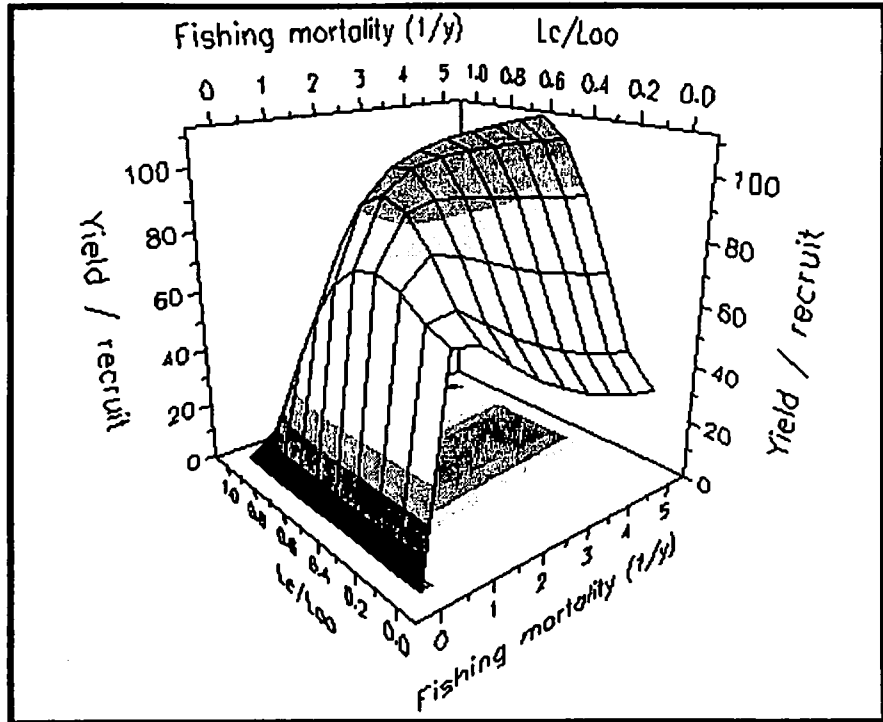


Fig. 30. Three-dimensional yield-per-recruit isopleth for *Plectropomus leopardus* as a function of relative size at entry (L_c/L_∞) in the fishery, and of fishing mortality. The parameters used are: $L_\infty = 45$ cm; $M/K = 2$; $t_c = 0.12$ year; $t_{max} = 26$ years; and $L_c = 20$ cm. Note the small change in $L_c/L_\infty \approx 0.6$ for maximum Y/R and fishing mortality > 1.5 year $^{-1}$. See Box 20 for details.

The parameters W_∞ and K are always taken from the POPGROWTH table, along with t_0 , when available, while an input routine allows entry of values of L_c and t_0 higher than their default of zero (see Box 20); note that L_c must remain $\leq 50\%$ of L_∞ .

Case II

Equations (7) and (8) above assume that growth in weight is isometric (i.e. $b = 3$). This assumption is often not met in reality and the value of b in length-weight relationships generally ranges between 2.5 and 3.5 (see the LENGTH-WEIGHT table, this vol.). One method for dealing with values of $b \neq 3$ is the use of the incomplete β -function, as proposed by Jones (1957); see also Ricker (1975).

Box 20. The yield-per-recruit and biomass-per-recruit graphs.

The Y/R routine included in FishBase is constructed such that Y/R and B/R plots are presented even if only L_∞ and K are available in the POPGROWTH table, i.e., defaults are provided for the missing parameters, as follows:

Case I (see Yield-per-recruit Analyses, this vol.) is used when W_∞ is available and $b = 3$. The initial plot assumes $t_r = 0$, $t_0 = 0$ (unless available in the POPGROWTH table), and $L_c = 0.05 \cdot L_\infty$, while M is treated as in Case III, except that it is equation (10) which is provided for the estimation of M . The parameters t_r and t_0 can be subsequently changed, the former via entry of a value of L_r (changed internally into t_r), the latter by entry of a value of choice, or of a rough estimate, derived using an empirical equation of the form

$$\log(-t_0) \approx -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$$

where L_∞ is in cm (TL), and K in year⁻¹, and which is based on 153 triplets of t_0 , L_∞ and K values selected from Pauly (1978) such as to cover a wide diversity of fish taxa and sizes (Pauly 1979). As equation (7) allows consideration of t_{\max} , such value is taken from the SPECIES table when available; otherwise $t_{\max} = \infty$ and equation (8) is used.

Case II is used when W_∞ is available and $b = 3$; the treatment of t_0 , t_r , L_c and M is as in Case I.

Case III is used when W_∞ is missing and L_∞ has to be used instead. This assumes $b = 3$, $t_0 = 0$, $t_{\max} = \infty$, $t_r = 0$, and $L_c = 0.05 \cdot L_\infty$. Routines are provided for entry of values of M other than the default, set at $M = 2K$ (an estimation routine is provided which uses equation (9), i.e., an input of T , in °C, is required), and for varying L_c .

The B/R plots presented along with the Y/R analyses rely on modified versions of equations (7), (8), and (12), and should be considered when interpreting the Y/R plots (see below).

The plots themselves come in two forms: (1) 2D, with the shapes of the Y/R and B/R lines depending on L_c ; and (2) 3D, i.e., as yield (or biomass) isopleth diagrams. The former plots show three reference points:

- E_{\max} or F_{\max} , i.e., the value of E or F associated with the highest Y/R value that is possible with a given value of L_c ;
- $E_{0.1}$ and $F_{0.1}$, the value of E or F at which the slope of the Y/R is 1/10 of its value at the origin; and
- $E_{0.5}$ and $F_{0.5}$, the value of E or F associated with a 50% reduction of the biomass (per recruit) in the unexploited stock.

These reference points, corresponding to the three broken vertical lines in Fig. 29, are discussed in the concluding section of 'Yield-per-recruit Analyses'.

References

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Here, yield-per-recruit, when $t_{\max} = \infty$, is given by

$$Y/R = F/K \cdot e^{Zt_1 - Mt_2} W_\infty \left\{ \beta[X, P, Q] \right\} \quad \dots 11$$

where $X = e^{-Kr_1}$;

$$P = Z/K;$$

$$Q = b + 1;$$

$\beta =$ is the symbol of the incomplete beta function, while

r_1 and r_2 are defined as in equation (7).

The Y/R routine of FishBase automatically checks whether $b = 3$ or not. If not, equation (11) is used (see Box 20). The parameters used and the displays are otherwise the same as for equation (8).

Case III

When the parameters of a length-weight relationship are not available, Y/R analyses can still be performed, using the relative yield-per-recruit (Y'/R) concept of Beverton and Holt (1964) defined by

$$Y'/R = E(1-c)^{M/K} \cdot \left\{ 1 - \frac{3(1-c)}{1 + \frac{(1-E)}{(M/K)}} + \frac{3(1-c)^2}{1 + \frac{2(1-E)}{(M/K)}} - \frac{(1-c)^3}{1 + \frac{3(1-E)}{(M/K)}} \right\} \quad \dots 12$$

where $c = L_c/L_\infty$, and the exploitation ratio is defined by $E = F/Z$.

Note that the relationship between Y/R and Y'/R is given, other things being equal by

$$(Y/R) = Y'/R \cdot \left(W_\infty \cdot e^{-M(t_r - t_0)} \right) \quad \dots 13$$

while the relationship between F and E is given by

$$F = M \cdot E / (1 - E) \quad \dots 14$$

Also note that the E scale is strongly non-linear, with $E = 1$ corresponding to $F = \infty$. Hence, high values of E indicate effort levels that are always unsustainable, if not outright impossible to even achieve.

The use of the yield-per-recruit models: WARNINGS

Yield-per-recruit models, although elegant and still suited to the management of certain stocks, should be used with caution. Fishers are not interested in an imaginary yield *per recruit*; they are interested in a *physical* yield of fish, and this is the product of the yield-per-recruit *times* the absolute number of recruits produced in the stock. Yield is directly proportional to yield-per-recruit over a wide range of fishing mortalities *only* if it can be

**No stock-recruitment
relationship assumed**

assumed that there is no relationship—over a wide range of F or E values—between the size of the parental stock of fish and its progeny (which is *not* true, see the 'RECRUITMENT table', this vol.).

Because of equilibrium assumption, only long-term effects are predicted

Thus, the values of F or E needed to produce a maximum yield-per-recruit will tend to generate very low yields, because F_{max} and E_{max} usually reduce the parental stock to a level at which few recruits are produced. Moreover, it must be realized that the finding of yield-per-recruit analyses apply to long-term or *equilibrium situations* only. In the short term, an increase of fishing mortality or a decrease in size at first capture always results in higher yields, even when yield-per-recruit analyses predict lower yields. Similarly, a decrease in fishing mortality or an increase in size at first capture always results in lower yields in the short term, although, in the long run, higher yields may be reached. The duration of the transition period can be of several years in fish which have a high longevity and are subjected to exploitation over a number of years, as in a number of temperate stocks such as cod or halibut. In short-lived fish, the transition period will be much shorter; in the case of very short-lived fish, the distinction between short- and long-term effects does not even apply, because the stocks are never at equilibrium.

Y/R analysis for tropical fish can be very misleading

Another important feature of the yield-per-recruit approach is that yield-per-recruit is maximized at low values of F or E only in the case of large, long-lived, low mortality fishes. In small tropical fishes with high values of M, the values of F or E which maximize yield-per-recruit are generally high. Thus, managing a tropical fishery based only on Y/R analysis for a species of small fish (let alone a multi-species fishery) can be very misleading. [This account ignores the additional bias due to the assumption of knife-edge recruitment and selection implicit in equations (7), (8) and (12); see Pauly and Soriano 1986; Silvestre et al. 1991]

For this and related reasons, an (arbitrary) agreement has emerged to generally limit F to the point where the slope of the yield-per-recruit curve has 1/10 of its value at the origin of the curve (Gulland and Boerema 1973). This concept, called $F_{0.1}$, may be viewed as a surrogate for MEY (Maximum Economic Yield), applicable in situations where economic data on the performance of a fishery are lacking. A concept analogous to $F_{0.1}$, but applied to the exploitation ratio E is $E_{0.1}$, is used in conjunction with Case III above.

Another safeguard when performing Y/R analysis is to always examine the corresponding biomass-per-recruit (B/R or B'/R) curve that is computed along with yield-per-recruit (one obtains B/R simply by dividing Y/R by F, see e.g., equation 8). Here, the appropriate reference point is the F (or E) value which reduces B/R (or B'/R) to half its unfished level (when F or E = 0), i.e., to the biomass level which—theoretically—maximizes surplus production and thus generates MSY (see Schaefer 1954, 1957;

Gulland 1983; or Pauly 1984). This level is here referred to as $F_{0.5}$ or $E_{0.5}$.

How to get there

You get to Yield-per-recruit Analyses by clicking on the **Biology** button in the SPECIES window, the **Population Dynamics** button in the BIOLOGY window, the **Growth** button in the POPULATION DYNAMICS window and after selecting a study, the **Y/R** button of the GROWTH table. Alternatively, you can go to REPORTS, GRAPHS, POPULATION DYNAMICS, Y/R ANALYSES.

Internet

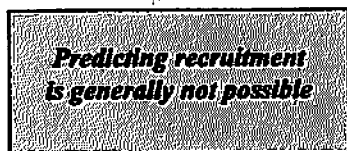
On the Internet, a relative yield-per-recruit analyses as well as an estimation of exploitation rate from length at first capture and average length is available if you click on the **Key Facts** link in the 'More information' section of the 'Species Summary' page.

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- Daniel Pauly and Felimon C. Gayanilo, Jr.**

The RECRUITMENT Table

Recruitment fluctuations and their causes represent one of the main areas of research in fisheries science, which is not surprising since it is these fluctuations which determine the annual catch levels of fisheries.



Precise prediction of future recruitment is not possible. However, broad generalizations are possible (e.g., that depleted stocks produce fewer recruits than healthy stocks, a non-trivial result).

The more recruitment time series are available from various parts of the world, the more precise and reliable will the generalizations be.

Thus, we were delighted when R.A. Myers offered to incorporate into FishBase the comprehensive database of recruitment time series and related information he and his former colleagues at the North West Atlantic Fisheries Center, Science Branch, Department of Fisheries and Oceans, St. John's, Canada, had painstakingly assembled (Myers et al. 1990, 1995). Pending a more comprehensive account by R.A. Myers (now with Dalhousie University, Halifax, Nova Scotia, Canada), the paragraphs below briefly describe the structure created to accommodate these data.

The RECRUITMENT window will first list, for a given species, the stocks for which a recruitment series (and associated series, if any) are available. Double-clicking on one such stock leads to the RECRUITMENT table proper.

Fields

The method used to derive a time series of recruitment (and related series) is shown through a multiple-choice field with the following entries:

1. direct counts;
2. catch/effort data;
3. electro-fishing;
4. mark-recapture;
5. SPA (VPA);
6. stock reconstruction;
7. research survey; and
8. see additional information.

Also presented are the age groups used for estimating fishery mortality, the recruitment lag, i.e., the age at recruitment, t_r (in years), and the locality, together with the latitude/longitude of the midpoint of the stock's range. Finally, the other components of the database supplied by R.A. Myers are shown in form of a concatenated memo field, with all non-empty entries following the (slightly expanded) column headings.

The recruitment time series data and, if available, the corresponding estimates of landings, spawning stock biomass and/or fishery mortality are shown when you click on the **Graph** or **Table** buttons. Note, however, that in the graphs, the series are expressed in relative units (each as percentage of its maximum value) (see Fig. 31). Click on the **Table** button for numeric data in absolute units.

A graph can also be accessed which allows comparing the variability of the available recruitment time series, while another graph (see Fig. 32) illustrates the relationship between parental stock size and subsequent recruitment.

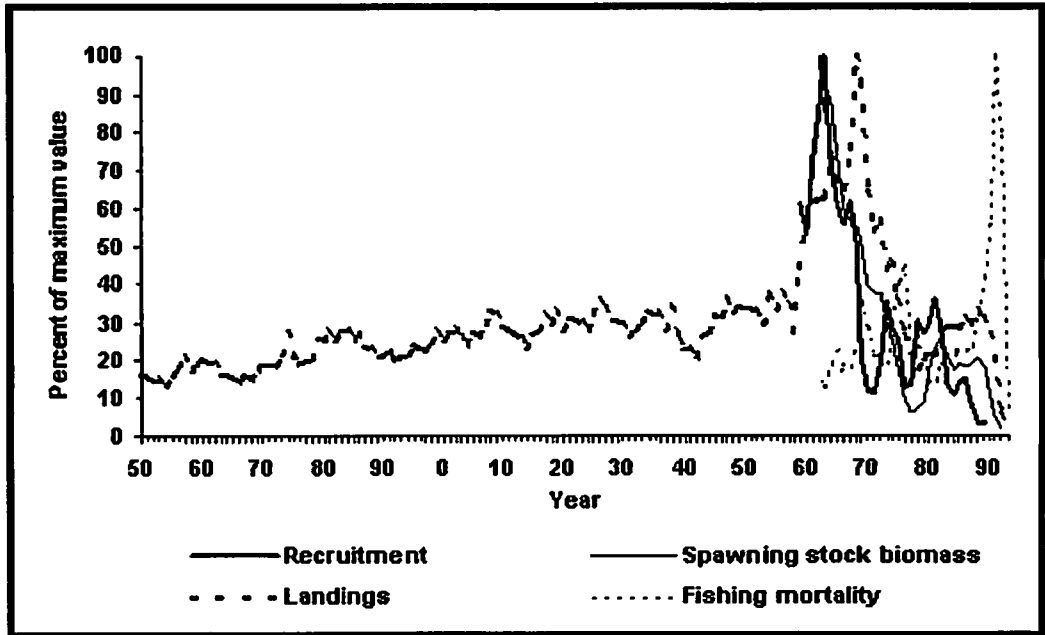


Fig. 31. Time series of landings, spawning stock biomass, recruitment and fishing mortality of Atlantic cod (*Gadus morhua*) around Newfoundland, Canada. Note how modern fisheries development, starting in the 1960s destroyed a fishery that had previously been sustained for a very long time.

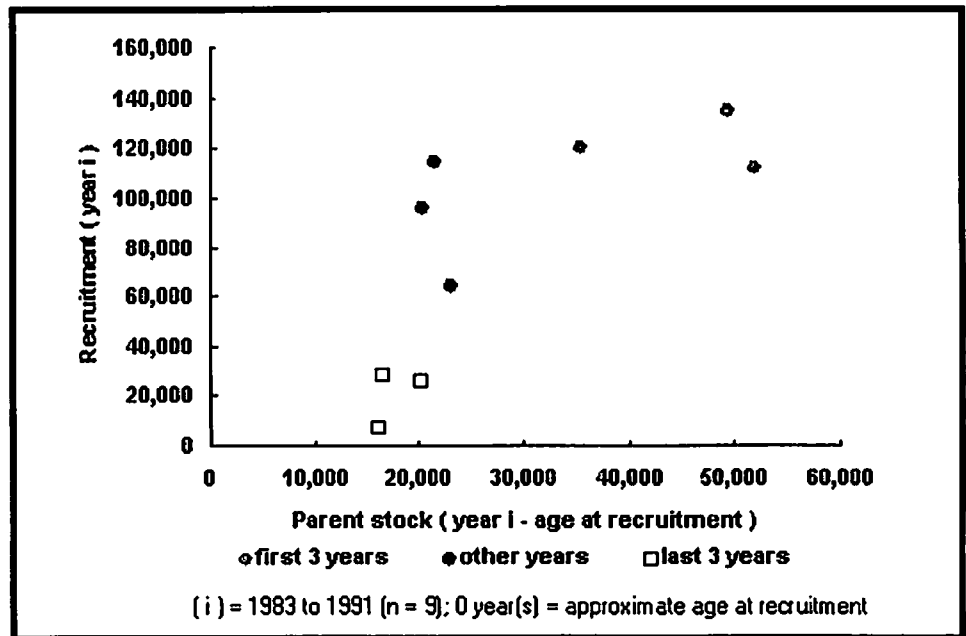


Fig. 32. Example of a relationship between recruitment and parental stock for *Merluccius merluccius* in ICES VIIIc and IXa; note codes used to identify the start and the end of a series.

Over 750 recruitment time series are available

Presently, over 750 recruitment series are available for about 150 species. All updating will be through R.A. Myers, who should be contacted directly by users interested in contributing data (Myers@phys.ocean.dal.ca).

How to get there

You get to the RECRUITMENT Form by clicking on the Recruitment button in the POPULATION DYNAMICS window.

Internet

On the Internet, the RECRUITMENT table as well as the graphs are available if you click on the Recruitment link in the 'More information' section of the 'Species Summary' page. The original version of R.A. Myers' series may also be downloaded from <http://www.mscs.dal.ca/~myers/welcome.html>.

Acknowledgments

We thank R.A. Myers and his colleagues for entrusting the FishBase Project with their valuable database.

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Daniel Pauly and Crispina Binohlan

Estimation of Life-History Key Facts

About 7,000 species of fishes are used by humans for food, sports, the aquarium trade, or are threatened by environmental degradation. However, life history parameters such as growth and size at first maturity, which are important for management, are known for less than 2,000 species. We therefore created a life history 'Key Facts' page that strives to provide estimates with error margins of important life-history parameters for all fishes (select a species and click on the Key facts link). It uses the 'best' available data in FishBase as defaults for various equations, as explained below. Users can replace these defaults with their own estimates and recalculate the parameters. For most parameters, we present the range of the standard error of the estimate, which contains about 2/3 of the range of the observed values. We will gradually replace these with estimates of the 95% confidence limits, derived from the standardized residuals. We hope the Key Facts will prove useful to managers and conservationists in species-rich and data-poor tropical countries.



***Best estimates with
error margin***

Life history parameters

Max. length: The maximum size of an organism is a strong predictor for many life history parameters (e.g., Blueweiss et al. 1978). The default value used here is the maximum length (L_{max}) ever reported for the species in question, which is in principle available for all species of fish. If no other data are available, this value is used to estimate asymptotic length (L_{inf}), length at first maturity (L_m), and length of maximum possible yield (L_{opt}), as defined in more detail below. However, L_{max} may be much higher than the maximum length reached by the fish population being studied by the user, in which case the derived estimates will be unrealistically high. If additional maximum size estimates for different areas are available in FishBase, a click on the **Max. size data** link displays a list that can be used to replace the L_{max} value with more appropriate estimates. If the **Recalculate** button in the **Max. length** row is clicked, L_{inf} , L_m and L_{opt} are recalculated.

*Growth can be estimated
from age and size at
first maturity*

L infinity: This is the length (L_{inf}) that the fish of a population would reach if they were to grow indefinitely (also known as asymptotic length). It is one of the three parameters of the von Bertalanffy growth function: $L_t = L_{inf} (1 - e^{-K(t-t_0)})$; where L_t is the length at age t (see below for definitions of K and t_0). If one or more growth studies are available in FishBase, L_{inf} of the population with the median \emptyset' (see definition below) is taken. Users can click on 'Growth data' to see a list of the different estimates of L_{inf} for different populations, i.e. from different localities, of the species in question. If no growth studies are available, L_{inf} and the corresponding 95% confidence interval are estimated from maximum length using an empirical relationship between L_{inf} and L_{max} (Froese and Binohlan 2000). Users can change the L_{inf} value and click the Recalculate button to update all parameters depending on L_{inf} .

K: This is a parameter of the von Bertalanffy growth function (also known as growth coefficient), expressing the rate (1/year) at which the asymptotic length is approached. The default value of K is calculated using the L_{inf} provided above and a median value of $\emptyset' = \log K + 2 \log L_{inf}$ (see Pauly et al. 1998) from growth studies available in FishBase for the species. Users can click on the 'Growth data' link to see different estimates of K and \emptyset' for different populations. Users can change the value of \emptyset' and click the 'Recalculate' button to update the values of K , t_0 (see below), natural mortality, life span, and generation time. If no growth studies but data on L_m and t_m are available for a species, these are used to estimate K from the approximation: $K = -\ln(1 - L_m / L_{inf}) / (t_m - t_0)$. If there are no available growth and maturity data but an estimate of maximum age (t_{max}) is available, this is used to calculate K from the equation $K = 3 / (t_{max} - t_0)$. If data for maturity or maximum age are not available in FishBase, users can enter their own estimates to calculate growth. Pauly et al. (1998) have shown that closely related species have similar values of \emptyset' , even if their L_{inf} and K values differ. We are working on an option to estimate K , in the absence of data, from the maximum length, and the median \emptyset' of species from the same genus or family and in the same climate zone.

t_0 : This is another parameter of the von Bertalanffy growth function which is defined as the hypothetical age (in years) the fish would have had at zero length, had their early life stages grown in the manner described by the growth equation—which in most fishes is not the case. Its effect is to move the whole growth curve sideways along the X-axis without affecting either L_{inf} or K . Many growth studies use methods that do not provide realistic estimates of t_0 and thus result in 'relative' age at length. To improve the estimation of life span and generation time below, we use an empirical equation (Pauly 1979) to estimate a default value for t_0 from L_{inf} and K . This has the form: $\log(-t_0) = -0.3922 - 0.2752 \log L_{inf} - 1.038 \log K$. Users can replace the default value and recalculate life span and age at first maturity.

Natural mortality can be estimated from maximum length and water temperature

Natural mortality: The instantaneous rate of natural mortality (M ; 1/year) refers to the late juvenile and adult phases of a population and is calculated here from Pauly's (1980) empirical equation based on the parameters of the von Bertalanffy growth function and on the mean annual water temperature (T), using a re-estimated version that analyzes a larger dataset and provides confidence limits. The **Growth data** link shows other estimates of M and water temperature. Users can change the values for L_{inf} , K and annual water temperature and recalculate the value of M . If no estimate of K is available, M is calculated from the preliminary empirical equation: $M = 10^{(0.566 - 0.718 * \log(L_{inf}) + 0.02 * T)}$ (Froese et al. in prep.). Note that the length type for calculating M has to be fork length for scombroids (tuna and tuna-like fishes) and total length for all other fishes. Length is used here mainly as a 'proxy' for weight. Thus, natural mortality will be underestimated in eel-like fishes and overestimated in sphere-shaped fishes.

Life span: This is the approximate maximum age (t_{max}) that fish of a given population would reach. Following Taylor (1958), it is calculated as the age at 95% of L_{inf} , using the parameters of the von Bertalanffy growth function as estimated above, viz.: $t_{max} = t_0 + 3 / K$.

L maturity: This is the average length (L_m) at which fish of a given population mature for the first time. The value and its standard error are calculated from an empirical relationship between length at first maturity and asymptotic length L_{inf} (Froese and Binohlan 2000). Additional information on maturity, when available, can be displayed by clicking on the **Maturity data** link.

Age at first maturity: This is the average age at which fish of a given population mature for the first time. It is calculated from the length at first maturity using the inverse of the von Bertalanffy growth function, viz.: $t_m = t_0 - \ln(1 - L_m / L_{inf}) / K$.

L max. yield: This is the length class (L_{opt}) with the highest biomass in an unfished population, where the number of survivors multiplied with their average weight reaches a maximum (Beverton 1992). A fishery would obtain the maximum possible yield if it were to catch only fish of this size. Thus, fisheries managers should strive to adjust the mean length in their catch towards this value. They can also use L_m and L_{opt} to evaluate length-frequency diagrams for signs of growth overfishing (capturing fish before they have realized most of their growth potential) and recruitment overfishing (reducing the number of parents to a level that is insufficient to maintain the stock and hence the fishery; see Fig. 33). If no growth parameters are available, L_{opt} and its standard error are estimated from an empirical relationship between L_{opt} and L_{inf} (Froese and Binohlan 2000). Otherwise, L_{opt} is estimated from the parameters of the von Bertalanffy growth function and natural mortality as: $L_{opt} = L_{inf} * (3 / (3 + M/K))$ (Beverton 1992).

L_m is the length class giving highest yield

Relative yield-per-recruit: The main reason why fisheries scientists study the growth of fishes and describe it in the form of the von Bertalanffy growth function, is to perform stock assessment using the yield-per-recruit (Y/R) model of Beverton and Holt (1957). We implemented the simplified version that estimates relative yield-per-recruit (Y'/R) as a function of the mean length at first capture (L_c), L_{inf} , M , K and the exploitation rate (E ; see below) (Beverton and Holt 1964). The value for exploitation rate is set at $E = 0.5$ as a default, but see discussion below. The default value for L_c is set equal to 40% of L_{inf} . This is based on a preliminary investigation of the L_c / L_{inf} ratio for 34 stocks ranging in size from 15 to 184 cm maximum length and which give a range of L_c/L_{inf} values between 0.15 and 0.74. Users can enter other values for their respective fisheries and calculate the corresponding relative yield-per-recruit. For the respective L_c the corresponding maximum and optimum exploitation rates and fishing mortalities (F) are shown (see next paragraph for discussion). Relative yield-per-recruit values can be transformed to absolute yield-per-recruit in weight by the relationship: $Y/R = Y'/R * (W_{inf} * e^{-(M(t-t_0))})$; where W_{inf} is the asymptotic weight and t_0 is the mean age at recruitment. The Y'/R function can be used to estimate the proportion by which the relative yield will increase if the mean size at first capture is closer to L_{opt} and the exploitation rate is closer to the one producing an optimum sustainable yield (see discussion of exploitation rate below). Note that yield-per-recruit analysis assumes relatively stable recruitment even at very small stock sizes, which is often not the case (see paragraph on resilience / productivity below).

Exploitation rate: This is the fraction of an age class that is caught during the life span of a population exposed to fishing pressure, i.e., the number caught versus the total number of individuals dying due to fishing and other reasons (e.g., Pauly 1984). In terms of mortality rates, the exploitation rate (E) is defined as: $E = F / (F + M)$; where M is the natural mortality rate and F the rate of fishing mortality. Gulland (1971) suggested that in an optimally exploited stock, fishing mortality should be about equal to natural mortality, resulting in a fixed $E_{opt} = 0.5$. This value is still used widely but has been shown to overestimate potential yields in many stocks by a factor of 3-4 (Beddington and Cooke 1983). For small tropical fishes with high natural mortality the exploitation rates at maximum sustainable yield (E_{MSY}) may be unrealistically high. We therefore provide an estimate of the exploitation rate E_{opt} corresponding to a value that is slightly lower than E_{MSY} and which is the exploitation rate corresponding to a point on the yield-per-recruit curve where the slope is 1/10th of the value at the origin of the curve. Users are able to change the value of L_c and calculate the corresponding values of E_{MSY} and E_{opt} . We also provide the corresponding values of F_{MSY} and F_{opt} through the relationship: $F = M * E / (1 - E)$.

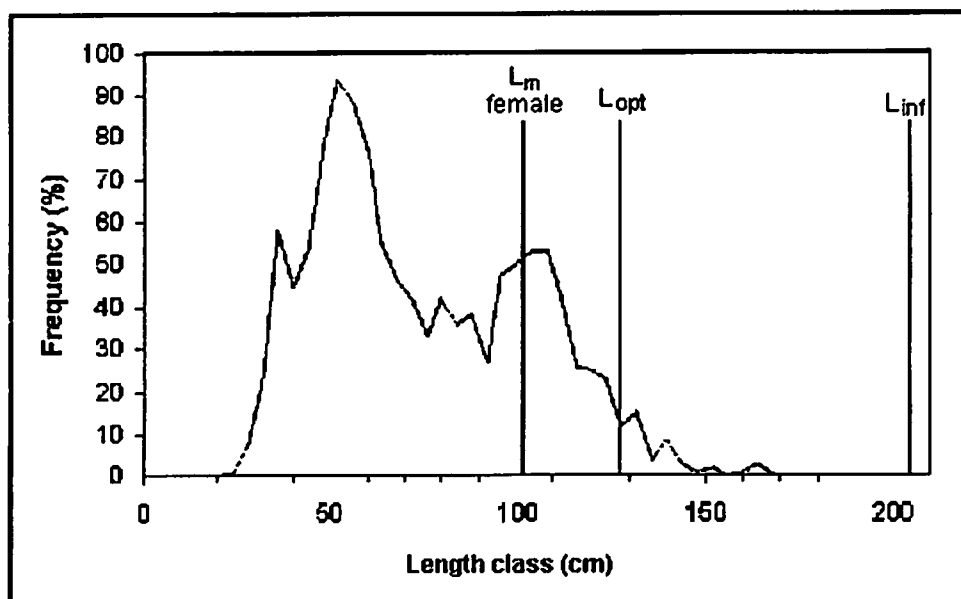


Fig. 33. Length-frequency data of commercial Nile perch catches in Lake Victoria (Asila and Ogari 1988) plotted in a simple framework indicating L_{∞} , L_m and L_{opt} . Note that the length distribution indicates growth and recruitment overfishing. The yield could be increased by a factor of about 2.4 if all fishes smaller than L_{opt} were caught at a length between L_m and L_{opt} .

*Estimate exploitation rate
from mean size in catch*

Estimation of exploitation rate from mean length in catches:

Beverton and Holt (1956) showed that for fish that grow according to the von Bertalanffy growth function, total mortality (Z) can be expressed by: $Z = K * (L_{inf} - L_{mean}) / (L_{mean} - L')$, where L_{mean} is the mean length of all fishes caught at sizes equal or larger than L' , which is the smallest size in the catch and here assumed to be the same as L_c , which is the mean length at entry in the fishery, assuming knife-edge selection, and thus the same as used under Yield per Recruit above. All other parameters are as defined above. Users can enter observed values of L_c and L_{mean} for a given fishery, as may be estimated from length-frequency samples, and calculate total mortality Z , fishing mortality $F = Z - M$, and exploitation rate $E = F / Z$. The estimate of F or E can then be compared with those at maximum sustainable yield and optimum yield as given in the Relative Yield per Recruit section, thus obtaining a preliminary indication of the status of the fishery. Note, however, that the length-frequencies from which L_c and L_{mean} are derived must be to the furthest extent possible representative of the length-structure of the population under equilibrium, as may be obtained by averaging a long time series of length-frequency samples.

*Resilience to
fishing pressure*

Resilience / productivity: The American Fisheries Society (AFS) has suggested values for several biological parameters that allow to classify a fish population or species into categories of high, medium, low and very low resilience or productivity (Musick 1999; Tab. 1). If no reliable estimate of r_m (see below) is available, the assignment is to the lowest category for which any of the

available parameters fits. For each of these categories, AFS has suggested thresholds for decline over the longer of 10 years or three generations. If an observed decline measured in biomass or numbers of mature individuals exceeds the indicated threshold value, the population or species is considered vulnerable to extinction unless explicitly shown otherwise. If one sex strongly limits the reproductive capacity of the species or population, then only the decline in the limiting sex should be considered. We decided to restrict the automatic assignment of resilience categories in the Key Facts page to values of K , t_m and t_{max} and those records of fecundity estimates that referred to minimum number of eggs or pups per female per year, assuming that these were equivalent to average fecundity at first maturity (Musick 1999). Note that many small fishes may spawn several times per year (we exclude these for the time being) and large live bearers such as the coelacanth may have gestation periods of more than one year (we corrected fecundity estimates for those cases reported in the literature). Also, we excluded resilience estimates based on r_m (see below) as we are not yet confident with the reliability of the current method for estimating r_m . If users have independent r_m or fecundity estimates, they can refer to Table 1 for using this information.

Table 1. Values of selected life-history parameters suggested for classifying the resilience / productivity of fish populations or species. See text for definitions and discussion.

Parameter	High	Medium	Low	Very low
Threshold	0.99	0.95	0.85	0.70
r_{max} (1/year)	> 0.5	0.16 – 0.50	0.05 – 0.15	< 0.05
K (1/year)	> 0.3	0.16 – 0.30	0.05 – 0.15	< 0.05
Fecundity (1/year)	> 10,000	100 – 1000	10 – 100	< 10
t_m (years)	< 1	2 – 4	5 – 10	> 10
t_{max} (years)	1 – 3	4 – 10	11 – 30	> 30

r_m is difficult to estimate in fishes

Intrinsic rate of population increase: The intrinsic rate of population growth (r_m ; 1/year) has been suggested as a useful parameter to estimate the capacity of species to withstand exploitation (see above). It also largely simplifies the parametrization of Schaefer models for estimating maximum sustainable yield through the relationship $MSY = r_m * B_{inf} / 4$, where B_{inf} is the maximum biomass of a particular species that a given ecosystem can support (Ricker 1975), often corresponding to the original size of the unfished population. Note that if L_c is close to the average length L_r at which juveniles join the parent stock, then the value of F_{MSY} (above) can be used to estimate r_m

Our approach to estimate generation time

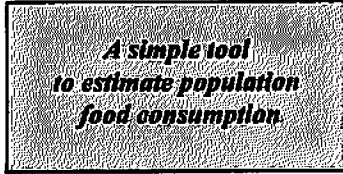
from the relationship $r_m = 2 * F_{MSY}$ (Ricker 1975). It seems that $0.4 * L_{inf}$ is a first approximation of L_r . We are exploring this and other options to estimate r_m . One can calculate the time (t_d) in years that it would take a strongly reduced population to double in numbers if all fishing ends, from $t_d = \ln(2) / r_m$.

Generation time: This is the average age (t_g) of parents at the time their young are born. In most fishes L_{opt} (see above) is the size class with the maximum egg production (Beverton 1992). The corresponding age (t_{opt}) is a good approximation of generation time in fishes. It is calculated using the parameters of the von Bertalanffy growth function as $t_g = t_{opt} = t_0 - \ln(1 - L_{opt} / L_{inf}) / K$. Note that in small fishes (< 10 cm) maturity is often reached at a size larger than L_{opt} and closer to L_{inf} . In these cases, the length class where about 100% (instead of 50%) first reach maturity will contain the highest biomass of spawning fishes, resulting usually in the highest egg production. As an approximation for that length class we assume that most fish will have reached maturity at a length that is slightly longer than L_m , viz.: $L_{m100} = L_m + (L_{inf} - L_m) / 4$, and calculate generation time as the age at L_{m100} . This is applied whenever $L_m \geq L_{opt}$.

Length-weight: This equation can be used to estimate the corresponding wet weight to any given length. The default entry is L_{inf} , thus calculating the asymptotic weight for the fish of the population in question. The parameters 'a' and 'b' are taken from data in FishBase with a median value of 'a' and with the same length type (TL, SL, FL) as L_{inf} . Users can click on the 'Length-weight' link to see additional data. Users can change the length or the values of 'a' and 'b' and recalculate the corresponding weight.

Trophic level: The rank of a species in a food web can be described by its trophic level (troph), which can be estimated as: $Troph = 1 + \text{mean trophs of food items}$; where the mean troph is weighted by the contribution of the various food items (Pauly and Christensen 1998). The default value and its standard error as shown in the Key Facts sheet are derived from the first of the following options that provides an estimate of troph based on: 1) diet information in FishBase, 2) food items in FishBase, and 3) size-adjusted troph estimates from species with relatives for which (1) or (2) are available (see Box 23 where the comparative method for estimating troph is described)].

Food consumption: The amount of food ingested (Q) by an age-structured fish population expressed as a fraction of its biomass (B) is here presented by the parameter Q/B. FishBase contains over 160 independent estimates of Q/B extracted mainly from Palomares (1991) and Palomares and Pauly (1989) and also from Pauly (1989). These estimates were obtained using Pauly's (1986) equation, viz.: $Q/B = [(dW/dt) / K_{1(t)}] / [W_t N_t d_t]$ integrated between the age at which fish recruit (t_r) and the maximum age of the population (t_{max}); where N_t is the number of fishes at age t, W_t their mean individual weight, and $K_{1(t)}$ their gross food conversion efficiency (= growth increment / food ingested). These Q/B estimates are available in FishBase for only 98 species and for



most of these, there is only one Q/B estimate per species. In the few species for which several Q/B values are available, the median Q/B value is taken and a 'Food consumption' link is provided to the user for viewing the details of these studies. For other species, Q/B is estimated from the empirical relationship proposed by Palomares and Pauly (1999), viz.: $\log Q/B = 7.964 - 0.204 \log W_{inf} - 1.965T' + 0.083A + 0.532h + 0.398d$; where W_{inf} (or asymptotic weight) is the mean weight that a population would reach if it were to grow indefinitely, T' is the mean environmental temperature expressed as $1000 / (C + 273.15)$, A is the aspect ratio of the caudal fin indicative of metabolic activity and expressed as the ratio of the square of the height of the caudal fin and its surface area, 'h' and 'd' are dummy variables indicating herbivores (h=1, d=0), detritivores (h=0, d=1) and carnivores (h=0, d=0). The default value for W_{inf} is taken either from L_{inf} and the length-weight relationship (see above) or from W_{max} (maximum weight ever recorded for the species) when an independent estimate of W_{inf} is not available in FishBase. Values of A were assigned, for each of the different shapes of caudal fins considered here, using the median A values based on 125 records in FishBase of species with A and caudal fin shape data (from left to right: lunate, forked, emarginate, truncate, round, pointed, double emarginate and heterocercal). Note that five of these eight shapes share the same median value, that which is used as the default A value for the empirical estimation of Q/B when an independent estimate is not available. We are working on a method that will better separate categories of caudal fins. Values of the feeding type indicators 'd' and 'h' are assigned according to which feeding category the species belongs: detritivore, herbivore, omnivore (default) and carnivore. These categories are determined either from the Main food or the Trophic level (detritivores troph < 2.2; herbivores troph < 2.8; carnivores troph > 2.8). When the default category 'Omnivore' is highlighted, Q/B is estimated as the mean of the Q/B values obtained for herbivores and carnivores. The temperature used in the estimation of M above is applied in the empirical estimation of Q/B. The Q/B estimate is automatically recalculated when the tail fin shape and/or the feeding types are changed. The Recalculate button is provided when values of W_{inf} and A are re-entered, e.g., in cases where no possible/guessed values of W_{inf} are available in FishBase.

Comments

The Key Facts page is still very much evolving and we welcome comments and suggestions for its further improvement to any of the authors.

Acknowledgments

We thank Eli Agbayani for programming the many changes we requested when developing the Key Facts page. We thank the FishBase Team for assembling the data that allowed us to implement this approach.

How to get there

You get to the KEY FACTS routine by clicking on the respective button in the BIOLOGY window of the species in question.

Internet

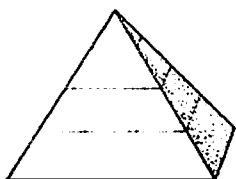
On the Internet, you get to the 'Key Facts' page by clicking the respective link in the 'More information' section of the 'Species

Summary' page. Note that you can save the Key Facts page to your harddisk and that it will function off-line.

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- Rainer Froese, Maria Lourdes D. Palomares and Daniel Pauly**

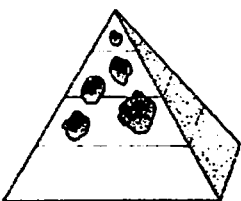
Trophic Ecology



Unfished ecosystem

The largest group of tables in FishBase is related to the trophic ecology of fishes and presents information on habitat, food items, diet composition, food consumption and predators of various fish species. The broad 'ECOLOGY table' of Froese et al. (1992) also covered environmental tolerance and behavior, but only few suitably standardized datasets were found and such information previously entered is now made accessible in the **Remarks** field of the **SPECIES** table, and in several fields (temp., pH, and H) in the **STOCKS** table.

The information on trophic ecology, which can be used for construction of Ecopath models (see Box 21), is presented in the following tables:



Single species management

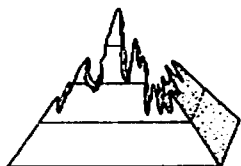
The **ECOLOGY** table presents information on the environment, e.g., the body of water which the species inhabits, and its feeding habits (incl. trophic levels);

The **FOOD ITEMS** table lists organisms that have been found in the stomach or are otherwise known to be ingested by a given species;

The **DIET** table gives the percentages (in weight or volume) of the different types of food item reported from studies of stomach contents;

The **RATION** table presents the daily food intake relative to the body weight of the fish sampled, and related parameters;

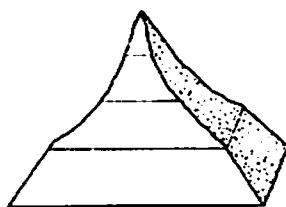
The **POPQB** table gives the annual food consumption (Q) per unit biomass (B) of a fish population and the population dynamics parameters used in its estimation;



No management

The **PREDATORS** table documents instances of a predator (not necessarily a fish) having consumed fish of a given species.

Also, a multi-level structure was created for these tables, which describes food items in increasing level of detail, from the **Foods I** field (consisting of 6 different broad food types, presented through a multiple choice field) and the **Food II** field (22 food types) to the **Food III** field (55 food types). This structure, which distinguishes stages (for both plants and animals), also allows entry of details on a given food item (e.g., name of the species ingested). Box 24 of the **FOOD ITEMS** table provides more detail on this as well as the trophic levels assigned to the different items in **Foods I, II, and III**, while Box 25 describes the method used to obtain estimates of trophic levels in fish whose diet composition is known. The **FOOD ITEMS** table provides more detail on this structure, as well as the trophic levels assigned to the different items which can be used to estimate trophic levels in fish whose diet composition is known.



Ecosystem management

Box 21. The Ecopath modeling approach and FishBase.

Developed in the early 1980s by J.J. Polovina and co-workers at the NMFS Laboratory in Honolulu, and first applied to a coral reef system north of Hawaii (Polovina 1984), the Ecopath approach for the construction and analysis of mass-balance trophic models of ecosystems was further developed by the authors. Particularly, we extended it to include a wide range of analytic routines, and encouraged its application to a variety of systems (Christensen and Pauly 1992, 1993; Pauly and Christensen 1993; Christensen and Pauly 1995). The Ecopath approach consists of the following steps:

1. Define the area (ecosystem), and period to be modeled, and functional groups (i.e., 'boxes', or state variables) to be included in the model (these definitions depend mainly on the density of available data);
2. For each functional group (i), obtain preliminary estimates of all but one of the parameters of the Ecopath master equation: $B_i \cdot (P/B)_i \cdot EE_i = Y_i + \sum B_j \cdot (Q/B)_j \cdot DC_{ij}$, where B_i and B_j are the biomasses of i and of its consumers j, respectively; P/B_i the production/biomass ratio (i.e., the mortality of i (Allen 1971)); EE_i the fraction of i's production ($P = B_i(P/B)$) that is consumed within the system; Y_i the fisheries catches; Q/B_j the relative food consumption; and DC_{ij} expresses the fraction of i in the diet of j;
3. Use the various routines of Ecopath to solve the system of linear equations in (2) for the entire system; and
4. Use the network of flows defined by this system of equations to derive statistics such as trophic levels (see Box 23) transfer efficiencies, niche selection indices, natural mortality estimates (see POPGROWTH table), etc.

Ecopath and FishBase have a number of common characteristics, notably their goal of bridging the gaps between fisheries science and related disciplines; their wide availability; a vast network of users and collaborators; and through these, the provision of standards for their respective disciplines: ecosystem modeling, in the case of Ecopath; applied ichthyology in the case of FishBase.

However, the relationships between Ecopath and FishBase extend far beyond this. As an example, the trophic levels now incorporated in FishBase, and the analytic routine linking them with the FAO CATCHES are derived from Ecopath applications (see Pauly and Christensen 1995). Conversely, the entries in the TROPHIC ECOLOGY tables of FishBase are largely meant to assist Ecopath users in deriving preliminary estimates of the Q/B and DC parameters of the system of equations in (2) above; while the M values in the POPGROWTH table provide estimates of P/B in unexploited fish stocks. Readers' suggestions on this and related topics may be sent to FishBase (fishbase@cgiar.org), or to Villy Christensen (v.christensen@fisheries.ubc.ca), who maintains Ecopath. See also the Ecopath homepage (www.ecopath.org), from which the latest update of Ecopath can be downloaded free of charge, and various information obtained on its application and dissemination.

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In order to improve FishBase output for ecosystem modeling, a new routine was created to construct a simple representation of the trophic structure of an ecosystem. This draws on data in the ECOLOGY table and employs the concept presented by Lindeman (1942; see Box 28).

How to get there

You get to the suite of TROPIC ECOLOGY routines through the **Biology** button in the SPECIES window and the **Trophic Ecology** button in the BIOLOGY window.

Internet

On the Internet, you find the various TROPIC ECOLOGY tables in the 'More information' section of the 'Species Summary' page. Alternatively, you can create lists of species with available data on e.g., Diet or Ration by clicking on the respective radio button in the 'Information by Topic' section of the 'Search FishBase' page. In that section, you also find radio button for **Ecopath parameters** and **Trophic pyramids**.

Acknowledgments

Many thanks to Pascualita Sa-a for suggesting numerous improvements to the Diet Composition table, and R. Froese for his interest in and support of trophic ecology as a component of FishBase.

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The ECOLOGY Table

The head section of this table, defining habitats, is straightforward, and consists mainly of yes/no choice fields indicating the environmental preferences of a species. The categorical breakdown of possible habitats summarizes the otherwise lengthy text descriptions for species found in different types of environment, and makes such descriptive data accessible to rigorous queries.

Fields

Three major habitat types are considered here, i.e., freshwater, brackish water and saltwater. Freshwater bodies are represented through yes/no fields, i.e., **streams, lakes and caves**. The last field in this row is appended to **caves** and is ticked 'yes' when the species in question is an exclusive cave dweller. Brackish water bodies are lumped together under the field **estuaries/lagoons/brackish seas**, which include (estuarine) river mouths. The final category, saltwater, is divided between the inshore (intertidal) and offshore (marine) zones and is further categorized by a choice field indicating latitudinal temperature zones. Further subdivisions refer to the type of substrate in the intertidal zone, i.e., **soft** (sandy, muddy, silty) and **rocky** shores. Saltwater bodies are categorized, with respect to the continental shelf, into **oceanic, neritic and coral reefs** with substrates specified as **soft bottom** (sandy, muddy, silty), **hard bottom** (rocky), **sea grass** and **macrophyte beds**.

We are not very satisfied with these classifications, which seem simple enough, but are still complex enough to have precluded clear choices for many species. We would appreciate suggestions for simpler, yet more rigorous approaches for classifying aquatic habitats.

The next section presents general information on the feeding habits of fish.

*Fish are classified by
feeding type*

Feeding Type is a choice field whose three categories give a general idea of the trophic level occupied by a species within a food web (see also Box 22). Thus, a primary consumer which consumes 'mainly plant/detritus' (herbivores) may have values of trophic level between 2.0 and 2.19; secondary, tertiary, etc. consumers which consume 'mainly animals' (carnivores) may have trophic levels equal to or greater than 2.8; and fish which are partly herbivore and partly carnivore, i.e., omnivores which consume 'plants/detritus + animals' may have trophic levels between 2.2 and 2.79.

Feeding habit is a choice field which describes the feeding habits of fish occupying various zones along the water column. Most pelagic species are either predators 'hunting macrofauna' throughout the water column, 'filtering plankton' as they swim near the water surface, or selectively grazing on plankton ('selective plankton feeding').

Box 22. Herbivory as a low-latitude phenomenon.

The ECOLOGY table uses a multiple-choice field to define broadly the trophic niche of fishes, with herbivory being equated to one of the choices, i.e., for fishes consuming 'mainly plants/detritus'. Similarly, a value of near two (i.e., $\text{troph} - 2 \text{ s.e.} \leq 2$) in the 'troph' field of the ECOLOGY table implies herbivory.

This allowed construction of a FishBase plot of % herbivorous fishes vs. latitude (Fig. 34), i.e., to make accessible in visual form the fact that herbivorous fish species tend to be far more frequent in low than in high latitudes, although their overall percentage among all fishes is small (>1.1%). Both of these phenomena can be explained by the difficulties most fish have in establishing and maintaining, throughout and subsequent to a feeding bout, the low pH levels required for digestion of plant material, especially at low temperatures.

The '>' symbol used above refers to the fact that: (1) not all species have Ecology records; (2) 4% of the more than 4,000 species with Ecology records do not have feeding type information; and (3) that non-herbivorous feeding habits are used as default for species without records. Still, we expect, when this field is completed for all species, that the overall number of herbivorous species will remain under 2%, and the shape of the graph unchanged, i.e., with a bulge at low latitudes.

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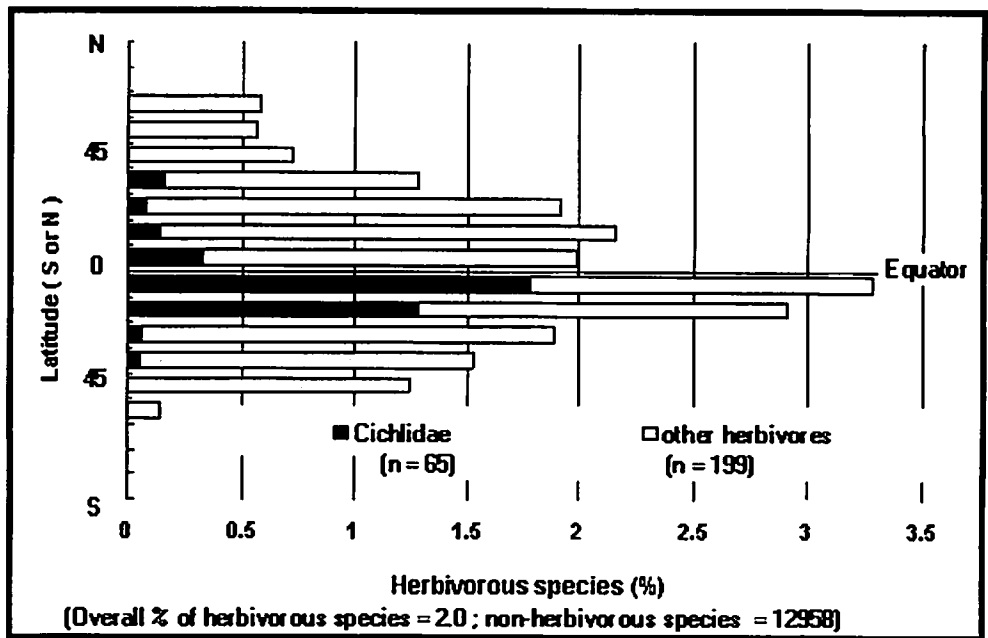


Fig. 34. Percentage of herbivorous species of Cichlidae and of other fish, by latitude. See Box 22 for a discussion of this graph.

Another important attribute of fish, included in the ECOLOGY table is their trophic levels (here abbreviated 'Troph', which defines their position within a food web (see Box 23). Trophs can be estimated using various methods. The ECOLOGY table accounts for this by having two fields for entries of trophs and their standard errors (s.e.): one from the DIET COMPOSITION table and the other from the FOOD ITEMS table (see Box 25). In both cases, the troph estimates are either the single value that is currently available or the median number of values available from several studies or localities. The troph estimates in the ECOLOGY table pertain to juvenile/adults or adults unless otherwise noted. A graph (Fig. 35) can be called to show the relationship, among fish species, of their median troph vs. their maximum length.

Box 23. Trophic levels of fishes.

Trophic levels (here abbreviated to 'troph', to avoid overlap with 'TL', used for total length), express where fish and other organisms tend to operate in their respective food webs.

Unlike counts of dorsal fin rays, trophs are not attributes of the organisms for which feeding is being categorized, but of their *interactions* with other organisms. Thus, to estimate the trophs of fish, we must consider both their diet composition, and the trophs of their food item(s). The troph of a given group of fish (individuals, population, species) is then estimated from

$$\text{Troph} = 1 + \text{mean troph of the food items} \quad \dots 1)$$

where the mean is weighted by the contribution of the different food items.

Following a convention established in the 1960s by the International Biological Program, we attribute primary producers and detritus (including associated bacteria) a definitional troph of 1 (Mathews 1993).

Thus, for example, an anchovy whose diet would consist of 50% phytoplankton (troph = 1) and 50% herbivorous zooplankton (troph = 2) would have a troph of 2.5. The last value is an estimated, fractional troph, differing conceptually and numerically from the integer values that are often assumed for higher trophs, and which we think are too imprecise and inaccurate to be useful in any kind of analyses.

An omnivore is a "species which feeds on more than one trophic level" (Pimm 1982). Thus, an omnivory index (O.I.) can be derived from the variance of the trophs of a consumer's food groups. The O.I. takes values of zero when all feeding occurs at the same troph, and increases with the variety of food items' trophs.

Routines for estimation of trophs and O.I. values are incorporated in the Ecopath software, which has been applied to a large number of ecosystems (see Pauly and Christensen 1995; Pauly et al. 1998 and Box 21). Troph estimates from Ecopath have been found to correlate closely with troph estimates based on stable isotope ratios (Kline and Pauly 1998).

This has led to numerous troph estimates for a wide range of taxa becoming available, notably for the invertebrates, fish, marine mammals and other groups covered by FAO statistics, and now included in FishBase.

The diet compositions given, within FishBase, for many species of fishes, also allow the estimation of trophs. The trophs of the preys required for such computation are given in a sub-table of the FOOD ITEMS table.

It is anticipated that analyses based on the trophs incorporated in FishBase will tend to combine estimates from a number of groups (as e.g., in the analyses which led to Fig. 4), so that inaccuracies on some estimates will be compensated for by inaccuracies with opposite signs, related to other groups. For more rigorous approaches to uncertainties, standard errors are also attached to most estimates of trophs, based on $s.e. = \text{SQR}(\text{O.I.})$, where O.I. is the omnivory index presented above.

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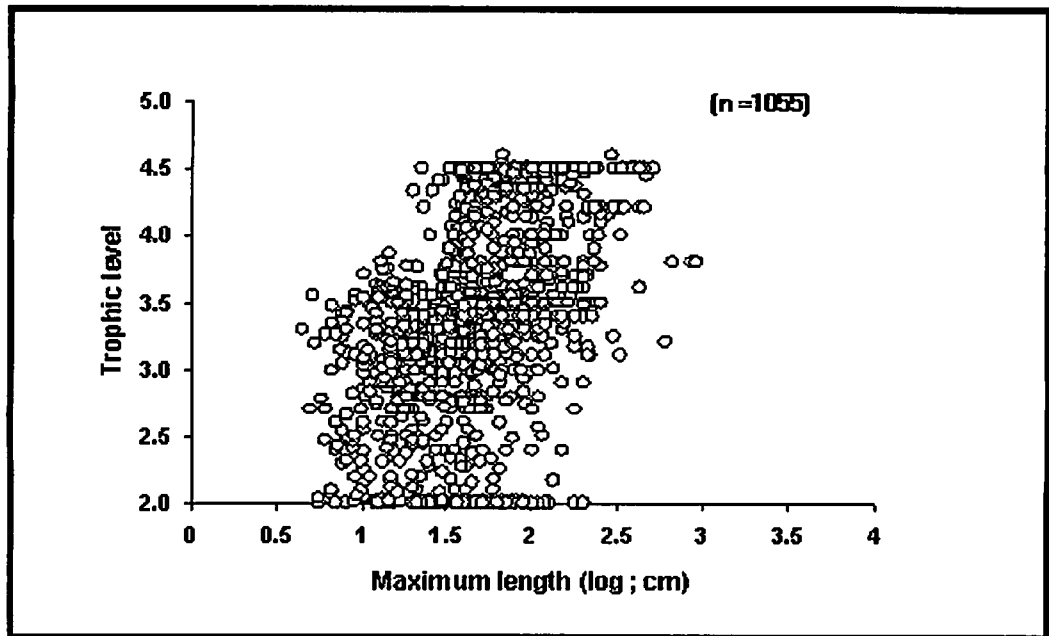


Fig. 35. Relationship between trophic levels and maximum length of fish species. Note positive slope, indicating that larger species tend to be more piscivorous than smaller species.

How to get there

You get to the ECOLOGY table by clicking on the Ecology button in the SPECIES window. You get to the graph of troph vs. length among species from (1) the ECOLOGY window; or (2) by clicking on the Reports button in the FishBase Main Menu, on the Graphs button in the PREDEFINED REPORTS Menu, and on the Trophic ecology button in the GRAPHS Menu.

You get to the graph of herbivory vs. latitude by clicking on the Reports button in the FishBase Main Menu, on the Graphs button in the PREDEFINED REPORTS Menu, and on the Trophic ecology button in the GRAPHS Menu.

Internet

On the Internet, you find the ECOLOGY table if you click on the respective link in the 'More information' section of the 'Species Summary' page. Main food and Trophic level are also shown in the 'Key Facts' page available from the 'More information' section. You can create a list of all species with ecology data if you select the respective radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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The FOOD ITEMS Table

The FOOD ITEMS table highlights from a set list, the food items reported to be consumed by a particular fish species. Clicking on any of the highlighted food items (under the Food II field) leads, via a list, to the FOOD ITEM DETAILS, with information on the Food group, Food name, Stage/part, Commonness of the food

item, Country where the sample was obtained and a Remarks field.

A compilation of different food items consumed by a fish species can be used to identify staple food preferences in various fish species for which detailed diet composition data are not available, and in preliminary estimates of trophic level (see Boxes 23, 24 and 25).

Food items define predator-prey relationships

The information contained in the FOOD ITEMS table is useful in defining predator-prey relationships among fishes.

Box 24. Hierarchy of food items.

To standardize the fields of the trophic ecology tables in FishBase, a hierarchy of food items was created. This refines choices from Food I (6 choices), via Food II (22 choices) to Food III (55 choices). The hierarchy is as follows:

Food I	Food II	Food III
detritus	detritus	<i>debris; carcasses</i>
plants	phytoplankton	<i>blue-green algae; dinoflagellates; diatoms; green algae; n.a./other phytoplankton</i>
	other plants	<i>benthic algae/weeds; periphyton; terrestrial plants</i>
zoobenthos	sponges/tunicates	<i>sponges; ascidians</i>
	cnidarians	<i>hard corals; n.a./other polyps</i>
	worms	<i>polychaetes; n.a./other annelids; non-annelids</i>
	mollusks	<i>chitons; bivalves; gastropods; octopi; n.a./other mollusks</i>
	benthic crustaceans	<i>ostracods; benthic copepods; isopods; amphipods; stomatopods; shrimps/prawns; lobsters; crabs; n.a./other benthic crustaceans</i>
	insects echinoderms	<i>insects sea stars/brittle stars; sea urchins; sea cucumbers; n.a./other echinoderms</i>
zooplankton	other benthic invertebrates	<i>n.a./other benthic invertebrates</i>
	jelly fish/hydroids	<i>jellyfish/hydroids</i>
	planktonic crustaceans	<i>planktonic copepods; cladocerans; mysids; euphausiids; n.a./other planktonic crustaceans</i>
	other planktonic invertebrates	<i>n.a./other planktonic invertebrates</i>
nekton	fish (early stages)	<i>fish eggs/larvae</i>
	cephalopods	<i>squids/cuttlefish</i>
	finfish	<i>bony fish n.a./other finfish</i>
others	herps	<i>salamanders/newts; toads/frogs; turtle; n.a./other reptiles</i>
	birds	<i>sea birds; shore birds; n.a./other birds</i>
	mammals	<i>dolphins; pinnipeds; n.a./other mammals</i>
	others	<i>n.a./others</i>

The FOOD ITEMS table should be consulted for the trophic levels assigned to these various groups.

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Sources

More than 800 references have been used in the FOOD ITEMS table. Among these are Hiatt and Strasburg (1960), Randall (1967), Scott and Crossman (1973), Allen (1985), Randall (1985), Whitehead (1985), Hickley and Bailey (1987), Maitland and Campbell (1992) and Sierra et al. (1994).

Verification of the more than 16,000 records, covering over 4,000 species, in the FOOD ITEMS table was done by checking the taxonomic affinities of the food items. Because some animal groups utilized as food occupy various habitats, inconsistencies occurred in the functional classification of certain food items; examples are the cyclopoid copepods, which, unless otherwise specified, may include both planktonic and benthic forms. In these cases, we deduced the functional group of a food item from the habitat and behavior of the species that consume it, pending further verification.

Fields

*We assigned trophic levels
to food items*

To standardize the entries in the FOOD ITEMS and related trophic ecology tables, a hierarchical structure was created with three levels of precision (**Food I**, **Food II** and **Food III**) for the entries (Box 24). The lower levels of this structure can be viewed by double-clicking on any **Food I** buttons of the FOOD ITEMS table. This opens the FOOD TROPHS table, which presents, for each food level, estimates of Trophs (+/- s.e.), thus enabling computation of trophs in fish whose diet composition is known (see Box 25). The sources of the troph estimates are given in a **Reference** field, with a **Remark** field providing additional information. In cases where the troph was estimated from the troph of other groups, this is indicated in the **Remarks** field, and no source ref. is given.

Food I indicates broad food groups that are consumed. The **Food II** buttons, when highlighted, may be clicked to display a list of **Food III** items available under the respective **Food II** category. Double-clicking on any item in this list displays the respective FOOD ITEM DETAILS window, with information on **Food III** presented through the following details:

- The **Food group** field, which refers to the family (or higher order group) or common name of a food item;
- The **Food name (text)** field refers to the scientific name of the food item, if specified;
- The **Commonness** field refers to the percentage of specimens containing the food item, as percentage and as choice, i.e., rare (1-5%); common (6-20%); very common (21-50%); dominant (>50%). But see discussion on frequency data in the DIET table);
- The food item is further defined in terms of the stage consumed (**Prey stage/Part**); the choices provided are appropriate subsets of the following list: eggs; larvae/pupae; recruits/juv., juv./adults; adults; n.a./others (for animal food); and roots; stem; leaves/blades; fruits/seeds; n.a./others (for plant food);

Box 25. Estimating trophic levels from individual food items.

As documented in Box 23, trophic levels ('trophs') are typically estimated from diet composition data, covering the whole range of food items consumed by a given species at a given locality and season (see the DIET COMPOSITION table). A troph (and its s.e.) can then be estimated, from the mean trophic level of the preys, plus one.

It is also possible to obtain rough estimates of the troph and its s.e. based on individual prey items (rather than a complete diet composition), as recorded in the FOOD ITEMS table, granted that enough food items have been entered for a given species, and that one is willing to accept certain assumptions on the relative importance of these food items in the overall diet of the species.

Examination of diet compositions entered until mid-1999 ($n > 1,800$) showed that typically, the relative contribution of different food items to the overall diet composition follows a pattern described by the empirical model:

$$\log_{10}P = 2 - 1.9\log_{10}R - 0.16\log_{10}G \quad \dots 1)$$

where P is the contribution of an item to the total diet in percent;
R is the rank of the food item (in terms of its relative contribution to the total diet); and
G is the number of food items (in the DIET table, we always have $1 \leq G \leq 10$).

In the following, a description of the resampling routine is provided which is used in FishBase to estimate trophs and their s.e. from individual food items. This routine involves three cases:

Case 1: all food items are plants or detritus

Then: troph = 2.0 and s.e. = 0;

Case 2: there is only one food item, and it is neither a plant nor detritus.

Then: troph = 1 + troph of food item & s.e. = s.e. of food item (see FOOD ITEMS table for trophic levels and s.e. of food items; use Food III if possible, or else Food II or else Food I).

Case 3: There are several food items, and at least one is not a plant or detritus.

Then: run Routine A.

Routine A

Count the food items, and call their number G;

Select at random one of these food items, and give it the rank 1 ($R = 1$);

Given G, and R, solve equation (1) for P;

Select at random one of the remaining food items, give it a rank of 2 ($R = 2$) and again solve equation (1) for P;

Repeat (2) - (4) until all items have been selected ($R = 3, 4 \dots G$);

From the P values, and the trophs specific to each items, estimate a mean troph from:

$$\overline{\text{Troph}} = \frac{\sum (P_i \cdot \text{Troph}_i)}{\sum P_i} \quad \dots 2)$$

Compute s.e. of Troph from Sachs (1984)

$$\text{s.e.} = \sqrt{\frac{(\text{s.e.})^2 \cdot (P_1 - 1) + (\text{s.e.})^2 \cdot (P_2 - 1) \dots (\text{s.e.})^2 \cdot (P_G - 1)}{\sum P - G}} \quad \dots 3)$$

Save troph and s.e.; repeat (2) - (8), using different random numbers to select first, second, etc. item; stop after 100 loops.

Take grand mean of computed trophs and of their standard errors, output these and stop.

The key point of this routine is that the grand mean s.e. that is estimated considers all possible permutations of the food items in terms of the relative abundance they could have had in a real diet composition. Note that the standard errors and corresponding troph estimates obtained from this routine are tentative, and should be replaced by estimates from diet compositions whenever possible.

Reference

Sachs, L. 1984. Applied statistics. A handbook of techniques. 2nd ed. 707 p. Springer-Verlag, Inc., New York.

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- The stage of the fish having consumed the above items (Predator stage) may consist of the following choices: larvae; recruits/juv., juv./adults (used as default for cases where the predator stage is not available); adults;
- The Remarks field refers to a food item that cannot be classified under any of the choices given above. Comments relating to the food item, e.g., size, sex and age may also be provided.

Box 26. Preliminary estimation of trophic levels in fish species without food composition data.

FishBase 2000 includes new routines requiring estimates of trophic level ('troph') for all species in an ecosystem, including species for which diet composition—from which trophs are usually estimated—are lacking. As these routines aggregate data from a large number of species, approximate troph estimates can be used, as long as their central tendency remains realistic.

The approach chosen to estimate trophs for species without food information relies (1) on the demonstrated similarity of trophs in taxonomically related species (see data in ECOLOGY table), and (2) on the equally well established relationship between body size and trophic level, anchored in a value of troph = 3.0 for larvae of about 1 cm (see Fig. 36).

The procedure implementing this approach works as follows:

for species without troph estimates in the ECOLOGY table, identify the nearest relative(s) with troph estimates in the same genus; if none is available, use a troph from the same subfamily. If none is available (or a subfamily is not defined in FishBase), use a troph from the same family. If none is available, use a troph from the same order (all orders in FishBase have at least two species with troph estimate based on field data).

Estimate (mean) slope(b) for data pair(s) in (1) and the equation $\text{troph} = 3 + b \cdot \bar{L}_u$, where \bar{L}_u is the mean length in the unexploited population, estimated from $L_{\text{max}} \approx L_{\infty} = 3 \cdot \bar{L}_u$, derived from $\bar{L} = [L_{\infty} + (L' \cdot M / K)] / [(M / K) + 1]$ (Pauly and Soriano 1986)^a, when the length from which \bar{L} is computed using $L' = 0$, and $M/K = 2$.

Using mean slope (\bar{b}) obtained in (3) and the \bar{L}_u for the species with troph, compute new troph from

$$\text{Troph} = 3 + \bar{b} \cdot (\bar{L}_u)$$

The trophic level estimates obtained in this fashion are stored separately from the observation-based values in the ECOLOGY table, in a new table called ESTIMATES. Continuous updating of FishBase will ensure that the troph and other estimates in that table are over-written as soon as observation-based values become available. (Users of the CD-ROM version of FishBase 2000 should visit the Internet version of FishBase for latest updates).

Reference

Pauly, D. and M. Soriano. 1986. Some practical extensions to Beverton and Holt's relative yield-per-recruit model, p. 491-495. In J.I. Maclean, L.B. Dizon and L.V. Hosillos (eds.) The First Asian Fisheries Forum. Asian Fisheries Society, Manila.

^aNote that this equation is also used to derive the troph estimates in the ECOLOGY table that refer to the unexploited stock.

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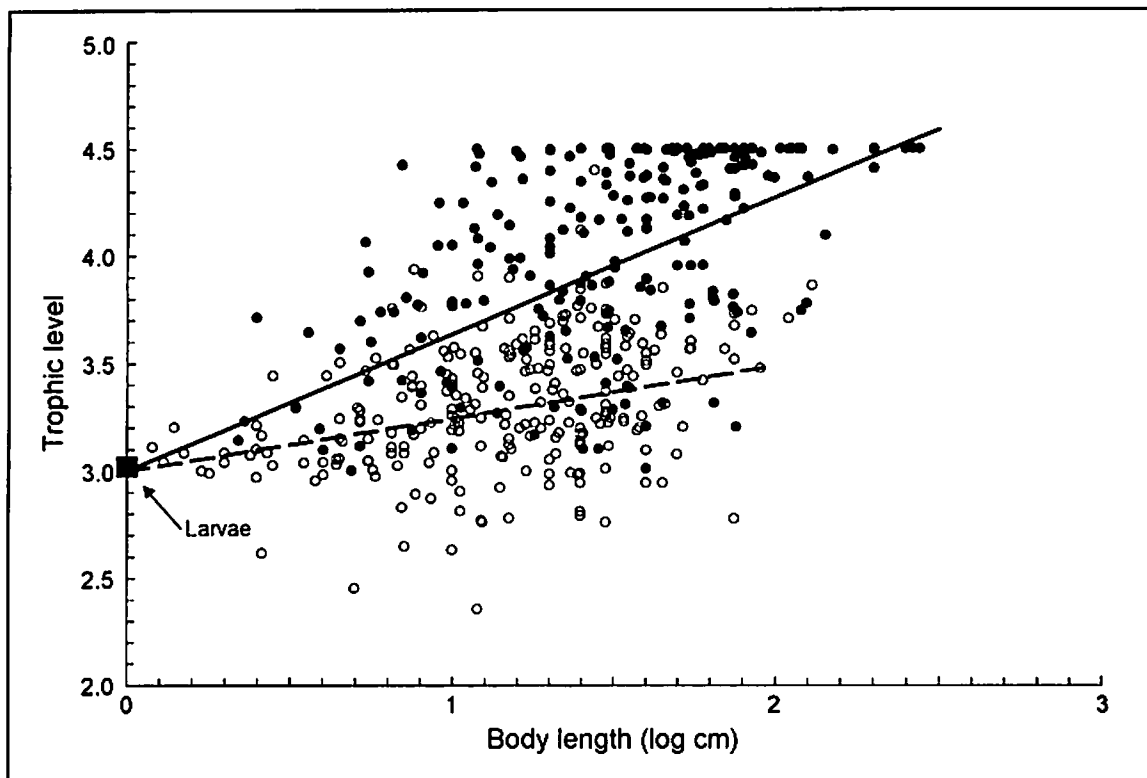


Fig. 36. Relationship between trophic level (troph) estimates and body length (in cm) in 180 species of fishes. The regression lines (forced through the origin, representing larvae with troph = 3, and length \approx 1 cm) have slopes of $b_s = 0.24$ for first-order carnivores (dotted line and open dots, representing herring and other small pelagic and demersal fishes); and $b_h = 0.63$ for higher-order carnivores (solid line and full dots, representing cod-like and other large piscivorous demersal and pelagic fishes). Adapted from Pauly et al (2001).

How to get there

You get to the FOOD ITEMS table by clicking on the **Biology** button in the SPECIES window, the **Trophic Ecology** button in the BIOLOGY window and the **Food Items** button in the TROPHIC ECOLOGY window. You get to the FOOD TROPHS table by doubleclicking on the **Food I** buttons of the FOOD ITEMS window. You get to the FOOD ITEM DETAILS window by clicking on the highlighted **Food II** buttons of the FOOD ITEMS window.

Internet

In the Internet, you find the FOOD ITEMS table if you click on the **Food Items** link in the 'More information' section of the 'Species Summary' page. You can create a list of species for which food data are available by selecting the **Food Items** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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The DIET Table

Knowledge of the diet composition of a fish species at a specific locality is useful in assessing its ecological function and impact, for the construction of ecosystem models (see Box 21), and to help define the nutritional requirements of potential aquaculture species. In FishBase, data in the DIET table are also used to estimate the trophic level of species (see Box 23).

Fish have developed specialized morphologies for food gathering

On the other hand, most demersal fish have developed various specialized methods of food gathering. Those 'browsing on the substrate', 'sucking food-containing materials' or 'grazing on aquatic plants' often live near the bottom and have developed specialized morphologies adapted to this (see e.g., de Groot 1984 for flatfishes). More specialized feeding techniques are used by those fish that depend on other organisms to feed, i.e., the parasites, commensals, cleaners and scavengers. Fish with 'variable' feeding types also exist (see for example Tiews et al. 1972 on the feeding habits of leiognathids). The choice 'other' is provided for fish with specialized food gathering habits not in the choice list; in such cases, the specific feeding type is indicated in the Remarks field.

Frequency of occurrence does not describe the diet

There is a huge number of references in the literature which provide information on the frequency of occurrence of food items in fish stomachs, which some readers may view as providing useful data on diet compositions. However, except perhaps in fish larvae, whose food items are all uniformly small, frequency of occurrence is not a good indicator of how much a food item contributes to the diet of a given population. For example, a small copepod that occurs in 50% of the examined stomachs may contribute much less to the diet than large polychaetes that are found in only 40% of the stomachs. The many indices applied to frequency of occurrence data do not remedy this basic flaw and rather confuse the topic. Editors and referees should reject

submitted manuscripts dealing with stomach contents that do not present diet data in terms of weight, volume or energy.

Sources

We have limited our entries to those quantitative reports which do not suffer from the flaw described above. Records entered in this table deal only with studies on the stomach content of fish as they occur in the wild, and not under experimental conditions. Thus, most of the information entered in the DIET table was obtained from relatively few (>460) references, notably Stevens (1966), Randall (1967), Hobson (1974), Armstrong (1982), Sano et al. (1984), Randall (1985), Gonzalez and Soto (1988), Laroche (1982), Sierra et al. (1994) and Valtysson (1995).

Diet composition data have been compiled for more than 1,400 species. We would like to have diet data for as many finfish species as possible, and would appreciate reprints for species that we have missed so far.

Status

The taxonomic classifications of the food items of the more than 3,000 records for over 1,400 species with diet compositions were checked against the *Taxonomic Code* of Hardy (1993), the Taxonomic Authority List of the Aquatic Sciences and Fisheries Information System (de Luca 1988) and Barnes (1980). Inconsistencies may arise in the functional classification of some animal food items. We have tried to reduce as much as possible the inconsistencies resulting from this by inferring the functional group of a food item from the habitat and behavior of the species that consumed it, but have probably failed to resolve all of them.

Fields

The DIET table consists of the following fields:

The **Stage** of fish sampled (choice) field has 4 options, i.e., larvae; recruits or juveniles (recruits/juv.); juveniles and adults (juv./adults) which is the default option for cases where the life stage is not specified); adults.

The **Mean length** field refers to the average length of fish in the sample in centimeters and is coupled with a length type field. The **Number** of fish sampled refers to the individual fish specimens; the percentage with empty stomachs is stated whenever available.

The **Locality** field refers to the specific site where the study was undertaken, further identified by the **Country** field before it.

The **Months covered by the study**, which appear as highlighted fields define the period of the year when the samples were obtained. Such information can help interpret the presence or abundance of specific food items in the habitat.

The **Remarks** field is used for ancillary information required if the option 'other' in choice fields within the table has been clicked or, for information which may further explain and/or describe particular food items.

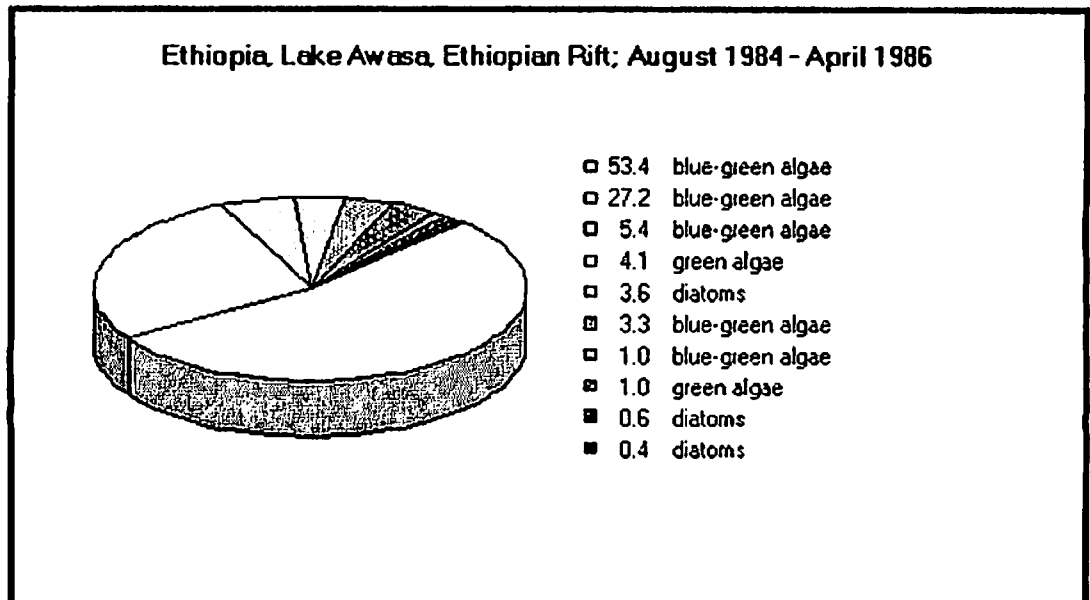


Fig. 37. Diet composition, in % volume or weight of *Oreochromis niloticus niloticus* in Lake Awasa, Ethiopia. Further breakdown of the given categories is available in FishBase.

**Food items are classified
at three levels, from broad
groups to species**

To accommodate the range of information found in the literature, food items are classified in three categories, from very general groupings in Food I to taxonomic groups in Food III (see FOOD ITEMS table and Box 24 for details on the hierarchy). Finally, the species name of the food item and/or other information can be seen in a text field by clicking on **More** button (if highlighted). For recomputed volumes, the **More** button also shows the original % in which a food item appears in the diet.

The **Prey stage** field refers to the life stage of a prey, i.e., eggs; larvae or pupae; recruits/juv.; juv./adults; adults; or to a specific part of a plant food, i.e., roots; stem; leaves/blades; fruits/seeds. The 'n.a./others' option is provided for cases in which the life stage is not stated by the source (and cannot be deduced), or when several stages are consumed.

The **% diet (numeric)** field refers to the percent weight or volume contributed by a food item to the stomach content of a fish; the percentages of the various items must add up to 100%, which is ascertained by a calculated field. Unidentified items in the diet are excluded (see **Other items in Ref.** field) and the contributions to the diet of all identified items are readjusted to bring the total back to 100%. The percentages can also be viewed in form of a pie chart (see Fig. 37).

The troph estimated from a diet composition (and from the trophs of the food items; see the FOOD ITEMS table) is displayed in a computed field, along with its standard error.

Box 27. Another approach to estimate diet composition.

We used the over 3,000 records in the DIET table to estimate the typical contribution of various food items to the diet of fish, if they were the main food, i.e., had rank 1 in a diet study based on percent contribution to total stomach content in weight or volume. The results are shown in Table 2 and Fig. 38. As can be seen from the pie chart the most common main foods of fish are animals, mainly other fish, and benthic and pelagic crustaceans. Table 2 shows the typical (here: median) contribution of functional food groups I and II to the diet when they are the main food. We plan to turn this into a software that will add percentages to food items if the ranking of their contribution (but not the actual percentage) is indicated in the literature, as is often the case. That software will also consider the typical contributions of food items if they occupy, e.g., rank 2 or 3 of a certain number of reported food items. At the beginning of the DIET chapter, we explained why diet studies expressed in frequency of occurrence are rather useless. However, if we can show that the ranking of the frequency of food items in stomachs is the same as the ranking of their contribution in percent volume or weight, then this software can make the huge 'frequency of occurrence' literature useful for food web studies. See also Box 24 which explains how we use a Monte Carlo routine to estimate trophic level from food items for which no ranking is known.

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Table 2. Median contribution to stomach contents (% volume or % weight), if the respective item was the dominant food, i.e., first item in the diet composition record; 2,420 records were obtained from the DIETS table and only functional groups with more than 10 records as dominant food were used in this analysis.

Functional group (I)	Median (%)	Functional group (II)	Median (%)	Min. (%)	Max. (%)	Records
Detritus	57	Detritus	57	25.4	100	82
Plants	64	Phytoplankton	53	26.8	100	43
		Other plants	65	18.3	100	179
Zooplankton	60	Fish (early stages)	55	22.5	100	25
		Planktonic crustaceans	60	18.5	100	376
		Other planktonic invertebrates	60	19.8	100	66
Zoobenthos	52	Benthic crustaceans	53	18.6	100	514
		Cnidarians	70	29.0	100	38
		Echinoderms	47	16.5	100	46
		Insects	50	15.6	100	187
		Mollusks	56	21.0	100	93
		Sponges and tunicates	62	21.0	98.2	31
		Worms	50	18.9	100	137
		Other benthic invertebrates	52	27.5	99.0	27
Nekton	68	Cephalopods	50	20.6	100	40
		Finfish	69	21.5	100	532

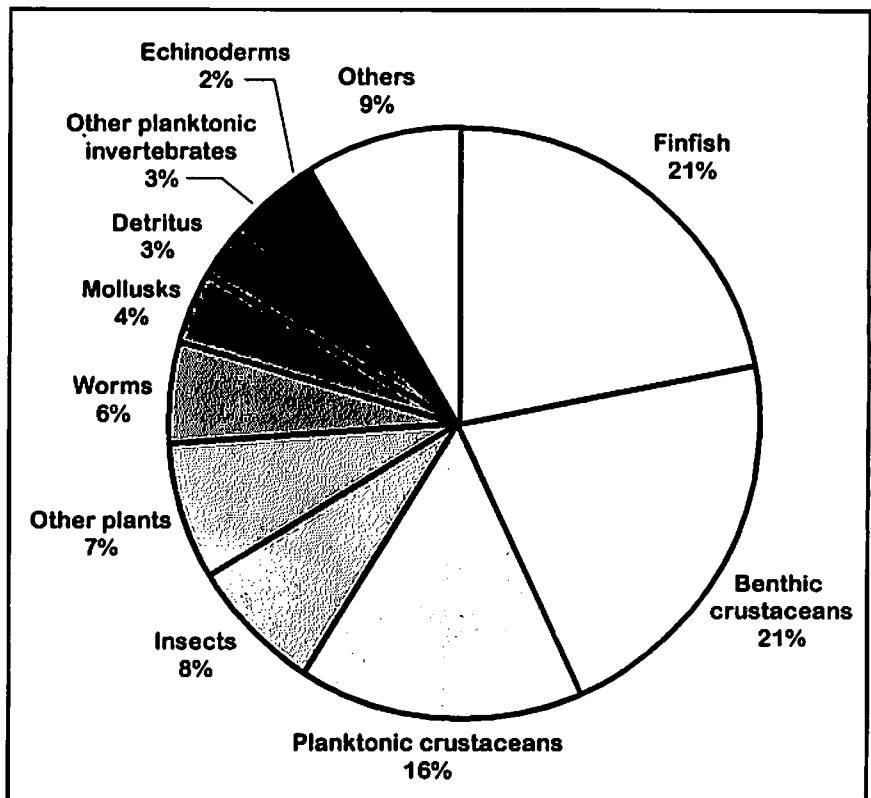


Fig. 38. Contribution of main food items to fish stomach contents (in % weight or % volume) obtained from records in the DIET table. Note that this includes only dominant food items.

How to get there

You get to the DIET table by clicking on the **Biology** button in the SPECIES window, the **Trophic ecology** button in the BIOLOGY window and the **Diet** button in the TROPHIC ECOLOGY window.

You get to the pie chart of diet compositions by locality by double-clicking on the study of interest in the DIET COMPOSITION window, then clicking on the **Graph** button in the upper right corner of the DIET window.

You get to the troph level vs. maximum length graph by clicking on the left **Graph** button in the upper right corner of the DIET COMPOSITION window.

You get to the Troph Changes by Length graph by clicking on the right button in the upper right corner of the DIET COMPOSITION window. You are given the option to include results of a regression analysis (line and equation) on this graph.

Internet

On the Internet, you get to the DIET table by clicking on the **Diet Composition** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species for

which diet data are available by selecting the Diet radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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The RATION Table

***Trophic relationships
define an ecosystem***

Like other heterotrophic organisms, fish need food to survive and grow. Within ecosystems, trophic relationships and energy flows largely define the function of various species (see Box 21, and contributions in Christensen and Pauly 1993). There are two ways of presenting species-specific consumption:

- at the individual level, i.e., as the consumption of a particular food type by a fish of a certain size, i.e., in the form of a daily ration (R_d); or
- at the population level, i.e., as the consumption (Q) by an age-structured population of weight (B), i.e., in form of population-weighted consumption per unit biomass (Q/B).

Pauly (1986) and Palomares and Pauly (1989) discuss the relationship between these two measures and methods for their

estimation. The RATION table described here and the Q/B table described further below over 400 records of R_d in over 60 species and over 160 records of Q/B in about 100 species, mostly derived from Palomares (1987), Palomares and Pauly (1989), Pauly (1989) and Palomares (1991).

Sources

The bulk of the entries in this table was taken from work performed by the first author, or with which she was closely associated. Names of food items were verified against the classification used in the *Taxonomic Code* of the National Oceanographic Data Center (NODC) (Hardy 1993).

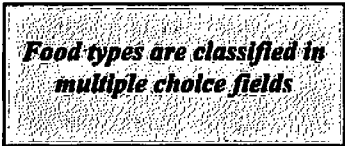
We recall that the term 'ration' (R_d) pertains to an estimate of daily food consumption by fish of a specific size. This table presents ration estimates and related parameters. Its fields are as follows:

Fields

- **Ration** (% BWD, i.e., weight of food ingested in a day 100/body weight);
- **Evacuation rate** (the fraction of the stomach content which is passed through the hindgut per hour); and
- K_1 (= food conversion efficiency = growth in weight / weight of food ingested) over a given period.

Daily ration, evacuation rate and K_1 vary with the weight of the studied fish (Fig. 39), with the type of food ingested, and the mean temperature (in °C) of the water where the fish occurs. Both **Weight of fish** and **Water temp.** are numeric fields. The **Salinity** field pertains to the body of water where the fish was sampled or to the medium of experiment and includes the choices: seawater; brackish water; freshwater.

Food type is described using two choice fields: **Food I** has six choices of functional groups: detritus; plants; zoobenthos; zooplankton; nekton; others. **Food II** provides more detailed groupings of food items following the hierarchy described in the FOOD ITEMS table and Box 24. Both of these fields include the choice 'others' for items not in the lists. The **Food name** text field is provided for more specific descriptions, e.g., the scientific or common name of the food item. Artificial food (all types of prepared feed such as pellets and fishmeal) is specified in the **Food name** field with a brief description of the preparation, e.g., moist or dry pellets.



Food types are classified in multiple choice fields

Methods used to estimate Evacuation rate and Daily ration are given. **Evacuation rate** is generally estimated from either of two general approaches:

1. laboratory studies involving sequential slaughtering or pumping out the stomach of a batch of fish fed at the same time (see Elliott and Persson 1978); or

2. fitting of a theoretically-derived model to stomach contents of wild-caught fish, covering a daily cycle (see, e.g., Sainsbury 1986).

The software package developed at ICLARM to implement the model of Sainsbury (1986), MAXIMS (see Jarre et al. 1991), is now widely used for the second approach. It is thus included as a choice for the **Method used** field for evacuation rate estimation. The other choices included in this field are 'laboratory experiments' as in (1) above and 'other'.

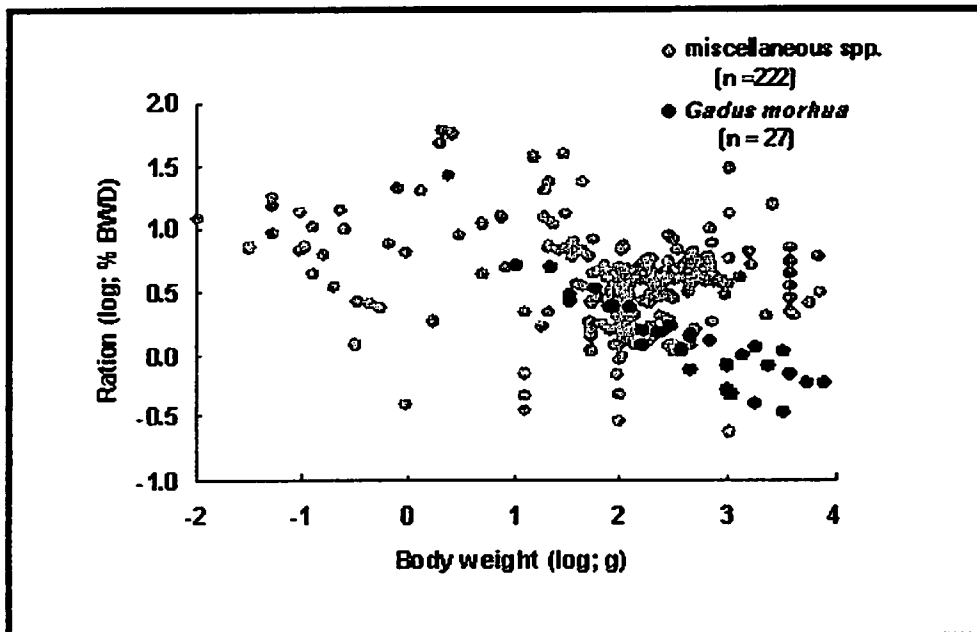


Fig. 39. Relative ration of *Gadus morhua* (black dots) compared with that of other fishes, whose large scatter is due to different food types, environmental temperature and other variables that will be standardized in future versions of this graph.

The methods available in the choice list for the estimation of **Daily ration** are: use of stomach contents data with the MAXIMS software; through the product of evacuation rate and mean stomach content (Elliott and Persson 1978); other methods based on gut contents analyses (e.g., Bajkov 1935; Gorelova 1984); indirect estimates, from Winberg's metabolic model (Winberg 1956; Mann 1978); oxygen consumption studies (Wakeman et al. 1979); and feeding experiments and/or estimates of K_1 (see Pauly 1986). The choice 'other' is provided for cases when the method used is not in the list. Here, the method must be specified in the **Comments** field.

We anticipate that the number of species and stocks covered by this table will increase in the future, as suitable datasets have been

made available, notably at the annual Science Meetings of the International Council for the Exploration of the Sea.

How to get there

You get to the RATION table by clicking on the **Biology** button in the SPECIES window, the **Trophic Ecology** button in the BIOLOGY window, and the **Ration** button in the TROPHIC ECOLOGY window.

You get to the graph of ration vs. body weight by clicking the **Graph** button in the upper right corner of the LIST OF RATION STUDIES window.

Internet

On the Internet, you get to the RATION table by clicking on the respective link in the 'More information' section of the 'Species Summary' page. You can create a list of species with available Ration data by selecting the respective radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

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The POPQB Table

Population-based food consumption estimates must account for age structure

Pauly (1986) introduced the concept of population-based estimates of food consumption (i.e., estimates that account for the age structure of populations), defined by:

$$Q/B = \frac{\int_{t_r}^{t_{max}} \frac{(dw/dt) N_t}{K_1(t)} dt}{\int_{t_r}^{t_{max}} W_t N_t dt} \quad \dots 1)$$

where

- Q/B is the food consumption per unit biomass;
- K and t₀ are parameters of the von Bertalanffy growth equation or VBGF (see 'Population Dynamics', this vol.);
- W_t is the mean weight at age t predicted by the VBGF, whose derivative (dw/dt) expresses growth rate;
- K₁ is the gross food conversion efficiency expressed as a function of age t, related to size through the model:

$$K_1 = 1 - (W_t/W_\infty)^\beta \quad \dots 2)$$

- N_t is the number of survivors of age t in the population exposed to a mortality Z, as predicted from:

$$N_t = N_0 \cdot \exp(-Z \cdot (t - t_0)); \text{ and} \quad \dots 3)$$

- t_r and t_{max} refer to the age of recruitment into and age of exit from the population, respectively (see also Palomares and Pauly 1989).

Equation (2) implies K₁ = 0 at W_∞, i.e., the conversion of food into flesh stops when a fish reaches its asymptotic weight W_∞, and its food intake is used only for maintenance (maintenance Q/B). Note that most published asymptotic size estimates pertain to the length L_∞. A length-weight relationship, represented by the constant b (often set = 3 in the absence of a wide range of L/W data pairs) is then used to relate W_∞ and L_∞ (see 'Population Dynamics', this vol.).

Z = F + M

Total mortality (Z) as referred to in equation (3) consists of natural mortality (M) + fishing mortality (F). In unexploited populations, where F = 0, all mortality is due to M. Water temperature is another variable affecting fish growth and metabolism and thus food consumption (Palomares and Pauly 1989; Pauly 1989; Palomares 1991). This is considered here through a field for the annual mean environmental (water) temperature, in °C.

As in the RATION table, choice fields for **Food type** and **Salinity** and a text field for **Locality** are provided. **Food type** includes choices for the food type involved in the Q/B estimate. The choices are: detritus; plants; zoobenthos; zooplankton; nekton; and others. The choice 'others' is used for populations fed dry or moist pellet or other artificial food. The **Remarks** text field is used for further details.

The habitat type of the population is first established by the type of water body, i.e., seawater, brackish water or freshwater, then by the **Locality** and **Country** where it was sampled.

A graph is available which plots Q/B vs. W_{∞} (see Fig. 40).

A plot of Q/B vs. W_{∞} is available through the graph button on the upper right corner of the FOOD CONSUMPTION window. This plots all relative food consumption ($\log Q/B; \text{year}^{-1}$) and asymptotic weight pairs available for the current species in comparison with those available in FishBase.

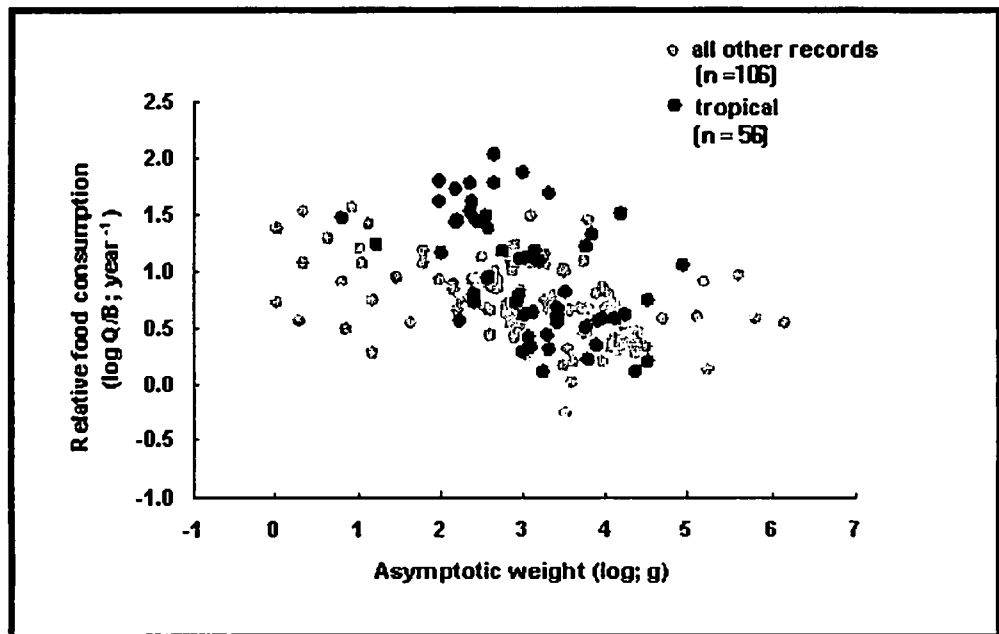


Fig. 40. Relative food consumption of tropical fishes (black dots) compared with that of other species.

How to get there

You get to the POPQB table by clicking on the **Biology** button in the SPECIES window, the **Trophic Ecology** button in the BIOLOGY window and the **Food consumption** button in the TROPHIC ECOLOGY window.

Future development of this table may involve accommodating alternatives to equation (2), as presented in Temming (1994). Also,

it is anticipated that sufficient entries of Q/B will become available for generalized relationships to emerge that will go beyond those presented by Pauly (1989) or Palomares (1991).

Internet

On the Internet, you get to the POPQB table by clicking on the **Food consumption** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species for which data are available by selecting the **Food consum.** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

- Palomares, M.L.D. 1991. La consommation de nourriture chez les poissons: étude comparative, mise au point d'un modèle prédictif et application à l'étude des réseaux trophiques. Ecole Nationale Supérieure, Institut National Polytechnique de Toulouse. 211 p. PhD thesis.
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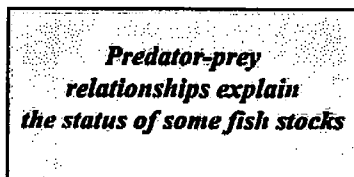
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The PREDATORS Table

The PREDATORS table lists the reported predators of a particular fish species. This table includes a **Locality** field; **Predator classification** fields, **Predator group and name**; **Prey stage** and its contribution to the diet of the predator, in percent. The information compiled in this table may be of use to fishery and conservation workers, as predator-prey relationships may help explain the status of some fish stocks. The information is also used for the construction of TROPHIC PYRAMIDS (this vol.). In addition, this information can be used to test current hypotheses about the relative sizes of prey and predators (Box 29; see also Fig. 41).

Sources

The records in the PREDATORS table (>3,000 records for >1,200 species) were extracted from over 380 references such as Hiatt and Strasburg (1960), Randall (1967), Scott and Crossman (1973), Mathews et al. (1977), Ebert et al. (1991), Uchida (1981), Collette and Nauen (1983), Meyer and Smale (1991), Hensley and Hensley (1995) and Tokranov and Maksimenkov (1995). The taxonomic classification of predator species other than fish was checked against the *Taxonomic Code* (Hardy 1993) and the *Taxonomic Authority List of the Aquatic Sciences and Fisheries Information System* (de Luca 1988).



Fields

The PREDATORS table consists of the following fields:

The **Country/locality** field refers to the site where the study was undertaken.

The choices in the **Predator I** and **Predator II** fields are given in Box 28.

The **Predator Group** is a free text field referring to the family or major group of the predator species.

The **Predator Name** is a free text field referring to the scientific or common name of the predator species.

The **Predator Stage** is a choice field referring to the stage of development of the predator species with the following options: larvae; recruits/juv.; juv./adults; adults.

Box 28. Hierarchy of predators.

To standardize the choices provided for the predator fields of the **PREDATORS** table of FishBase, a hierarchy like that for food items was created, roughly analogous to the Food I-III choices in the **FOOD ITEMS** table (see Box 24). These are:

Predator I	Predator II
cnidarians	jellyfish/ hydroids; sea anemones; corals
mollusks	gastropods; squids/cuttlefish; octopus
crustaceans	copepods; mysids; isopods; amphipods; stomatopods; euphausiids; shrimps/prawns; lobsters; crabs; other crustaceans
insects	insects
echinoderms	sea stars
finfish	sharks/rays; bony fish; n.a./other finfish
herps	salamanders/newts; toads/frogs; crocodiles; turtles; snakes
birds	sea birds; shore birds
mammals	whales/dolphins; seals/sea lions
others	others

This hierarchy includes only animals commonly reported to consume fish including fish larvae. Groups that feed only occasionally on fish (as do, e.g., South American ostriches, see Darwin 1845) such as tunicates feeding e.g., on *Vinciguerria* must be entered in the 'others' category and specified in the **Food Group** field.

Reference

Darwin, C. 1845. Journal of researches into the natural history and geology of the countries visited during the voyage of *H.M.S. Beagle*. Murray, London.

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The % of stomach contents field refers to the percentage weight or volume by which the prey contributes to the stomach contents of a predator. If a precise percentage of volume is not available, an indicator of the 'commonness' of the prey item in the diet of the particular predator is provided in the field beside it.

Big fish eat small fish

For both **Prey** and **Predator Stage**, the *juv./adults* option is the default when no stage is specified in the references for either prey or predator species.

The **Prey Stage** is a choice field referring to the stage of development of the prey species with the following options: *eggs*; *larvae*; *recruits/juv.*; *juv./adults*; *adults*.

The **Remarks** field is used to describe or specify the prey item that was classified as 'other' in the **Predator I** and **II** fields or other pertinent information.

Box 29. Predator-prey ratios in fishes.

Relating the size of predatory fishes to the size of their fish prey was our first analysis confirming the ability of FishBase to test relatively complex hypotheses, using data not initially gathered for that purpose.

The hypotheses tested here were:

- that the ratios of predator : prey sizes are similar among fishes of different species, and in the neighborhood of 4 : 1 when sizes are expressed as body lengths; and
- that the residuals about the mean predator : prey sizes are log-normally distributed, as postulated by Ursin (1973).

The data used to test these hypotheses were extracted from the DIET table, i.e., all cases where the prey is a fish, its life stage was entered, its length is available in the SPECIES table and is of the same length type as the predator's, and its calculated prey length (see below) is smaller than the predator's, to exclude parasitic fish such as lampreys.

Very few food and feeding habit studies in the literature indicate the size of ingested organisms, and hence the DIET and PREDATORS tables do not include fields for these. In the absence of size data specific to each study, the size (=length) of predators and prey were estimated as follows:

- for each species, read the maximum length (L_{max}) and the common length (L_{com}) in the SPECIES table;
- for predators or prey for which the stage is 'adult', use L_{com} as 64% of L_{max} . [This was decided after verifying that in species for which both entries exist, L_{com} is on the average $0.64 * L_{max}$];
- for all species for which the life stage of the predator was 'juveniles and adults', use $\frac{1}{2}$ of L_{max} ;
- for all species for which the life stage is 'juveniles', use $\frac{1}{3}$ of L_{max} .

[Note that this treatment ignores cases where the prey are fish eggs and larvae, or where the predators are larvae; these cases were deleted from the analysis discussed here].

Though approximate, these conversions yield a clear pattern (see Fig. 41), confirming the hypothesis in (1). The second hypothesis was also verified, though this is not shown here.

Fig. 41 can also be used, obviously, as reference for true exceptions, e.g., gulpers (Fam. Eurypharyngidae) which can consume fish well above their own size, or filter-feeders and grazers, which consume prey that are orders of magnitude smaller than themselves.

Reference

Ursin, E. 1973. On the prey preference of cod and dab. *Medd. Danm. Fisk. Havunders. N.S.* 7:85-98.

Daniel Pauly

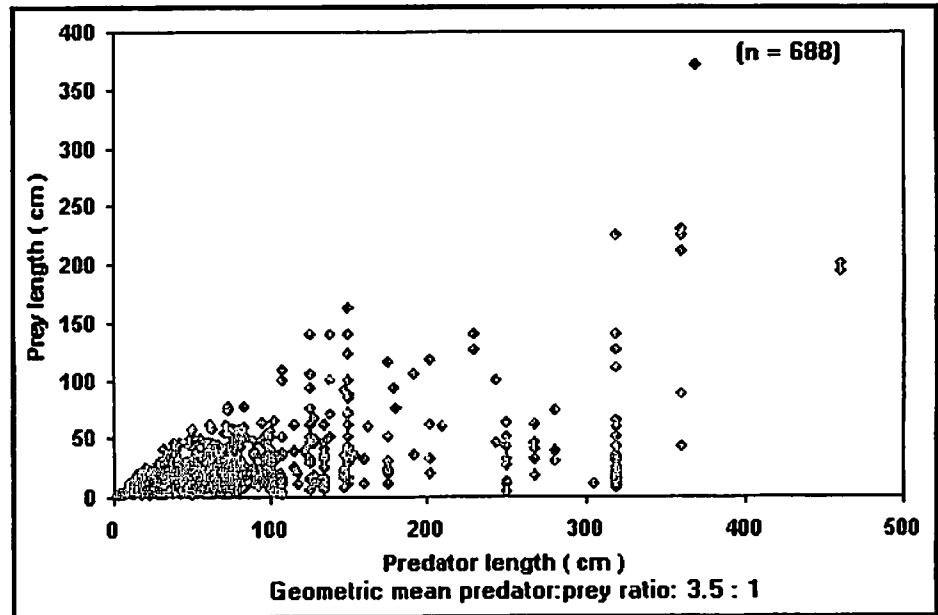


Fig. 41. Predator vs. prey length in miscellaneous fish species. See Box 29 for a discussion of this graph.

How to get there

You get to the PREDATORS table by clicking on the **Biology** button in the SPECIES window, the **Trophic Ecology** button in the BIOLOGY window and the **Predators** button in the TROPHIC ECOLOGY window. Note that a double-click anywhere within the row on the Predator List view will bring you to that specific record in the PREDATORS table.

Internet

On the Internet, you get to the PREDATORS table by clicking on the **Predators** link in the 'More information' section of the 'Species Summary' page. You can create a list of species for which data are available by selecting the **Predators** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

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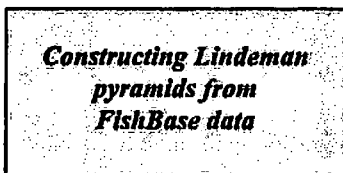
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- Tokranov, A.M. and V.V. Maksimenkov. 1995. Feeding habits of predatory fishes in the Bol'shaya River estuary (West Kamchatka). *J. Ichthyol.* 35(9):102-112.
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Trophic Pyramids

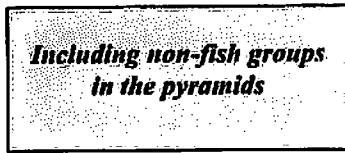
There are numerous ways to define and represent an ecosystem, and the choice of approach used, when studying an ecosystem, depends on a complex of reasons. Foremost among these are the availability of (1) the input data required for the system to be studied, (2) other ecosystems previously studied with the same approach, and (3) the background and skills of the would-be modeler(s).

Given the data in its DIET COMPOSITION, PREDATORS, FOOD ITEMS and FOOD CONSUMPTION tables, FishBase has amongst its clients the users of the Ecopath approach and software (Christensen and Pauly 1992, with updates in www.ecopath.org). Indeed, these clients are the main reason why a routine was developed which, for any selected country and/or ecosystem (type), assembles and exports a file with information on the fish occurring in the country and/or ecosystem in question, culled from the above and other, related FishBase tables.



As it turns out, this output, judiciously linked, can be used to generate directly, without analysis by Ecopath, a simple representation of the trophic structure of an ecosystem, i.e., a 'Lindeman pyramid' (see Lindeman 1942), as commonly used to summarize food web information. Thus, once the ecosystem or part of a country to be modeled has been chosen, the routine in question does the following:

- For each species, extract the trophic level ('troph') from the ECOLOGY table, or if none is available, from the ESTIMATES table (see Box 26 for a brief description of this new, very special table);
- Group all species of fish in classes of ½ troph, from the first class (2.00-2.49) to 5.00+ (i.e., including all values higher than 5);
- For all species with entries in the DIET COMPOSITION or FOOD ITEMS tables, group the food items by their troph, i.e., the same classes of ½ troph as in (2), using the default trophs for preys in the FOOD TROPHS table;
- For each non-fish vertebrate species with an entry in the PREDATORS table, include the predator in the appropriate ½



troph class (note that the PREDATORS table now includes fields for the troph of predators and their size, with defaults for the former being provided in the FOOD TROPHS table);

- For each $\frac{1}{2}$ troph class, compute mean body size (\bar{L} , with standard error, s.e.) of the groups included therein, from $\bar{L} \approx 1/3 L_{\max}$, using L_{\max} values from the Species and/or the ESTIMATES table for fishes, and from the FOOD ITEMS table or the PREDATORS table for invertebrate preys, and non-fish vertebrates, respectively;
- Output a list of the fish, of the invertebrates, of the plants/detritus, or of the non-fish vertebrates, by troph class, along with their mean size and related statistics, when the corresponding element of the graphic representation of a Lindeman pyramid is double-clicked on.

This approach, which summarizes data from various FishBase tables, thus relies on a classic of the ecology literature for its metaphor, i.e., on a pyramid whose steps represent different trophic levels and the species (and/or functional groups) therein.

We intend to improve the routine underlying this pyramid along two lines:

- By identifying new ecological inferences that can be drawn from ecosystem-specific lists of taxa arranged by trophic levels and additional data extracted from FishBase, e.g., by considering the food consumption and transfer efficiencies of the species involved; and
- By establishing further links, still to be developed, between Lindeman pyramids and full-fledged Ecopath models.

You get to the TROPHIC PYRAMIDS routine from the FishBase Main Menu by selecting the **Reports, Graphs, Trophic Ecology** and **Trophic Pyramids** buttons.

Internet

On the Internet, you get to the TROPHIC PYRAMIDS routine by selecting the respective radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

- Christensen, V. and D. Pauly. 1992. The ECOPATH II - a software for balancing steady-state ecosystem models and calculating network characteristics. *Ecol. Modelling* 61:169-185 [see www.ecopath.org for updates].
- Lindeman, R.L. 1942. The trophic-dynamic aspect of ecology. *Ecology* 23(4):399-418.
- Daniel Pauly, Rainer Froese and Ma. Josephine France D. Rius**

Reproduction

Fish display an astonishing variety of reproductive modes

Fish display an astonishing variety of reproductive modes, ranging from parthenogenesis in the molly *Poecilia formosa* to permanently attached parasitic males in the deep-sea fish *Haplophryne mollis*. Similarly, fecundity ranges from 300 million eggs per year in *Mola mola* to a few live born offspring, e.g., in many sharks (Lagler et al. 1977). Parental care may be absent, as in many pelagic fishes, or involve various kinds of nest guarding or mouthbrooding. This variety implies that constraints to the ability of fish populations to reproduce themselves will also take different forms. Knowledge of reproduction is therefore important for proper management and conservation of fish species.

Information on reproduction in FishBase is assembled in three tables: REPRODUCTION, MATURITY and SPAWNING. The REPRODUCTION table documents the general mode and the type of reproduction that apply to the species throughout its range. The MATURITY and SPAWNING tables, on the other hand, present information on the size and age at first maturity and spawning of different populations of the same species, occurring at different localities. These tables are described below.

The REPRODUCTION Table

Where egg and sperm meet . . .

The REPRODUCTION table contains information on the reproductive mode, the frequency of spawning, whether a species is a batch spawner or not, and the type of reproductive guild to which each species belongs. Descriptions of the life cycle, and of the mating and spawning behavior are also presented in this table.

Fields

The **Mode** of reproduction is classified into the following choices: dioecism; protandry; protogyny; true hermaphroditism; parthenogenesis. The mode of **Fertilization** refers to where the egg and sperm meet, which may be: external; internal (in the oviduct); in the mouth; in a brood pouch or similar structure; or elsewhere.

The **Spawning frequency** is described by the following choices: one clear seasonal peak per year (i.e., the spawning season is brief, lasting a few weeks or months and little or no spawning occurs outside of it); throughout the year, but peaking once (i.e., some spawning activity occurs throughout the year, but there is one broad seasonal peak); two seasonal peaks per year (i.e., some spawning may occur throughout the year, but two peaks are clearly visible [usually one larger than the other, and separated by 5-7 months]); no obvious seasonal peak (i.e., spawning occurs throughout the year, with no well-marked seasonal peaks); variable throughout the range (i.e., spawning occurs as in the first and second choices at high latitudes, and as in the third and fourth choices at low latitudes); once in a lifetime (i.e., spawning usually occurs only once and death usually follows). Note that this field

refers to the species in general and that the spawning frequency might be different for populations at the limit of the latitudinal range of a species.

The **Batch spawner** field states whether individuals accomplish multiple spawning during the spawning season.

The **Reproductive guild** is described by the combination of two choice fields, following a classification suggested by Balon (1990). The first field pertains to the type of parental care with the choices: nonguarders; guarders; bearers. The second field refers to the pattern of care for the eggs or young, with the choices: open substratum egg scatterers (nonguarders that leave eggs after spawning in the water column or on any substrate, e.g., rocks, gravel, sand, plant, etc.); brood hiders (nonguarders that deposit eggs in inconspicuous places, e.g., caves, rock interstices, gravel depressions, inside live invertebrates, etc.); clutch tenders (non-nesters that guard eggs at the water surface, on underside of objects or any substrate, e.g., rocks, plants, etc.); nesters (fish which deposit and often guard eggs in nests, e.g., mucus bubbles, rocks, gravel, sand, holes, base of sea anemones, plants, etc.); external brooders (fish which incubate eggs externally on parental body, e.g., pouch, mouth, gill cavities, pelvic fins, etc.); internal live bearers (fish which fertilize eggs internally, with development taking place inside the maternal body).

*Reproductive guilds
follow a classification
suggested by E. Balon*

Information on life cycle, mating and spawning behavior not included in the list of choices, and other information are accommodated in the **Description of life cycle and mating behavior** field.

Box 30. The latitudinal distribution of hermaphroditism.

The most common way for the gonads of fish to be distributed is for females to develop ovaries, and for males to develop testes, and to function accordingly. This is called 'dioecism'.

However, in some groups, individuals that started off as females may turn into males (protandric hermaphroditism), or conversely (protogynous hermaphroditism); more rarely both sets of organs may simultaneously occur and function in the same individual (true hermaphroditism), known in *Rivulus marmoratus*.

Fish species in which either of the two common forms of hermaphroditism predominates (as opposed to occurring in a few isolated individuals) account for only a small percentage of all fish species and are concentrated in families such as the Serranidae, Labridae and Scaridae, and in lower latitudes.

Still, the percentages output by the FishBase plot of hermaphroditism by latitude (see Fig. 42) are not as reliable as may be wished, as the graph could be made to generate sensible results only by assuming that all species presently without entries in the 'Mode' field of the REPRODUCTION table are dioecious. Filling in this field for all species may thus still lead to changes in the shape of this graph, which presently displays a suspicious dip at the equator, where we expect the maximum will eventually be.

Daniel Pauly

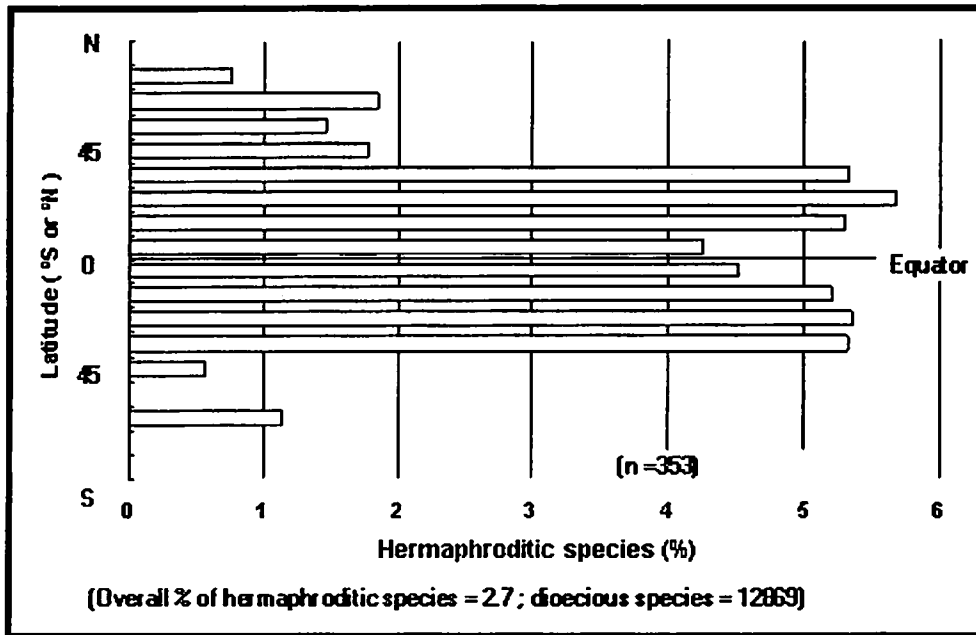


Fig. 42. Percentage of hermaphroditic fishes in relation to latitudinal range. See Box 30 for a discussion of this graph.

Status

To date, over 3,700 records extracted from nearly 400 references have been compiled. We plan to increase drastically our coverage of modes and types of reproduction by using the classic Breder and Rosen (1966), Thresher (1984), aquaculture and aquarium literature and other compilations.

Graphs

A plot of hermaphroditism by latitude (Fig. 42) can be generated (see Box 30). This graph can be accessed by clicking consecutively on the following buttons: **Reports** in the Main Menu, **Graph** in the Predefined Reports window, **Reproduction and Early Stages** in the Graphs window and **Hermaphroditism vs. Latitude**.

How to get there

You get to the REPRODUCTION table by clicking on the **Biology** button in the SPECIES window and the **Reproduction** button in the BIOLOGY window and **REPRODUCTION** in the following window.

Internet

On the Internet, you get to the REPRODUCTION table by clicking on the **Reproduction** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Reproduction** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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Armi Torres

The MATURITY Table

Surviving to sexual maturity and being able to contribute to the gene pool define fitness for an individual. Collectively, those surviving individuals determine the survival of the population. For a management regime to ensure, in the face of exploitation, that a sufficient number of juveniles reach maturity usually requires information on the size and age at first maturation.

Sexual maturation has been known to be associated with physiological and behavioral changes, the latter being sometimes manifested in the form of breeding aggregation, migration and territoriality. The relationship between these biological changes and growth, mortality and longevity has been studied by Alm (1959), Beverton and Holt (1959) and Pauly (1984), among others (see Box 30). Using data in FishBase, Froese and Binohlan (2000) have likewise demonstrated that size and age at sexual maturity are strongly correlated with growth, maximum size and longevity.

Box 31. The reproductive load of fish.

Few topics seem as obvious, yet are so misunderstood, as the relationship between the growth and reproduction of fishes. The conventional wisdom, reiterated in a multitude of papers, reports and books, is that fish tend to grow fast until they reach length at first maturity, then grow more slowly "because the energy formerly used for somatic growth is now used for reproduction." This may be called the 'reproductive drain' hypothesis.

Obvious as it may seem, this hypothesis is probably wrong and an alternative has been proposed: it is the slowing down of the growth process which triggers off maturation, not maturation and spawning which stop growth (Iles 1974; Koch and Wieser 1983; Pauly 1984; Thorpe 1987). Also, because of the strong positive allometry with which the gills of fish grow which are capable of reaching large sizes, their body growth can continue well beyond L_m ; thus, they have low reproductive loads L_m/L_∞ (Pauly 1984).

To evaluate competing hypotheses such as these, one can examine their corollaries, i.e., the predictions that follow from them. Many small fish are known to quickly grow to a size close to L_∞ , then spawn and reduce their growth drastically. In contrast, large fishes tend to approach L_∞ only gradually, with a slight reduction in growth starting near $\frac{1}{2} L_\infty$, when they start spawning. This generates the descending trend of our plot of reproductive load vs. asymptotic length (see Fig. 43), which thus corroborates the second of the above hypotheses. The reproductive drain hypothesis, on the other hand, cannot explain a graph such as presented here, and its interpretation would thus require another *ad hoc* hypothesis.

References

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Daniel Pauly

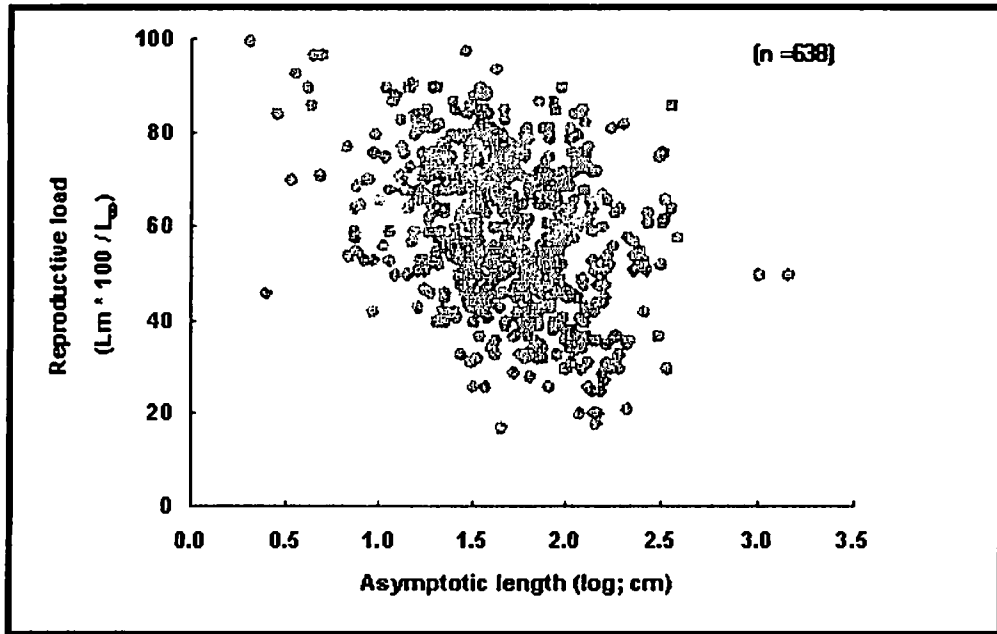


Fig. 43. Reproductive load for various fishes. Note descending trend (see Box 30 and Fig. 44 for interpretation).

Sources

There are maturity records for over 1,300 species from about 1,000 references

The MATURITY table contains information on length and age at first sexual maturity for over 1,300 species (over 3,000 records), from about 1,000 references. Among the major sources of information are Beverton and Holt (1959), Compagno (1984a, 1984b), Dorel (1985), García-Cagide et al. (1994), Kailola et al. (1993), Kromer (1994), Last and Stevens (1994), Lévêque (1997) and van der Elst and Adkin (1991).

In the literature, information on sexual maturity comes in various, closely related categories:

1. the median or mean length or age, i.e., the length or age at which 50% of the population become mature for the first time;
2. the length or age at which a certain percentage (but not 50%) of the population become mature;
3. the length or age of the smallest mature fish;
4. the length or age of the largest fish maturing for the first time;
5. as a range of the length or age of smallest (youngest) to the largest (oldest) mature fish (3 and 4);
6. as a range of the mean length or age at maturity; and
7. unqualified values.

Initially, this table included only information pertaining to the median or mean length or age (category 1). Such value is usually derived through linear interpolation, probit analysis, fitting of a logistic curve, or otherwise estimated from a plot of percent

mature over the length or age. In most cases, though, the method used is not mentioned. Later the table was modified to accommodate the variety of existing information.

Fields

The first category of information is entered in the L_m or t_m fields, whereas the **Range** fields accommodate information of categories 2-7. Unqualified values (category 7) were entered as minimum value in the **Range** fields. In some cases, the **Comment** field provides details on a value that has been entered.

Status

To verify the lengths at first maturity (L_m), we checked whether the corresponding ratio L_∞/L_m remained within the range known to occur in fishes (Beverton and Holt 1959).

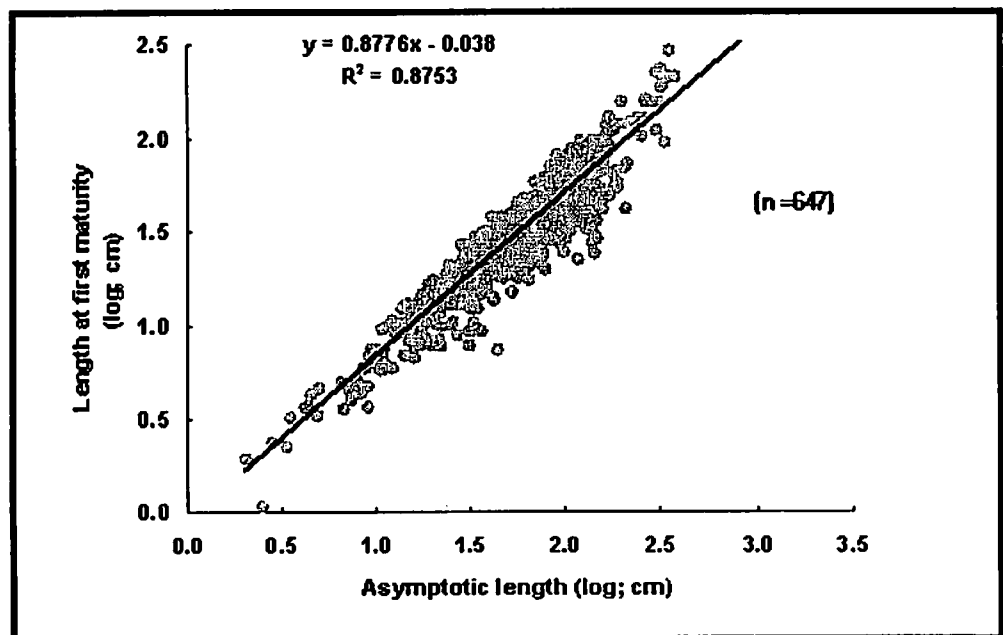


Fig. 44. Length at first maturity vs. asymptotic length. Same data as in Fig. 43, but shown as plot of $\log L_m$ vs. $\log L_\infty$. While close, the relationship is not strictly proportional: L_m increases in proportion to a power of L_∞ of less than unity (i.e., 0.9), which is why the reproductive load in Fig. 43 declines with L_∞ .

How to get there

You get to the **MATURITY** table by clicking on the **Biology** button in the **SPECIES** window, the **Reproduction** button in the **BIOLOGY** window and the **Maturity** button in the **REPRODUCTION AND EARLY STAGES** window. You get to the **Maturity Report** by clicking on the **Reports** button in the **Main Menu**, the **Population Dynamics by Family** button in the **PREDEFINED REPORTS** window, and the **Maturity Information** button in the next window.

Internet

On the Internet, you get to the MATURITY table by clicking on the **Maturity** link in the 'More information' section of the 'Species Summary' page. The **Key Facts** link in the same section estimates length at first maturity from an empirical relationship for all species for which the maximum length is known. You can generate a list of all species with available data by selecting the **Maturity** button in the 'Information by Topic' section of the 'Search FishBase' page. In the 'Information by Family' section of that page, you can select a family, select the **Graphs** radio button, and then create several graphs relating to length at first maturity.

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Crispina Binohlan

The SPAWNING Table

There is a spawning herring population at any time of the year

Spawning seasons may vary considerably among populations of the same species. For example, in the North Atlantic, there is a spawning herring population at any time of the year.

The SPAWNING table therefore presents information on the spawning season, sex ratio, absolute and relative fecundity, fecundity-length relationship and daily spawning frequency of various stocks (populations) of the same species at various localities.

Fields

Country and **Locality** fields identify spawning locations, while the **Spawning ground** field refers to the habitat type where spawning occurs which may be: lacustrine; riverine; estuarine; coastal; shelf; oceanic.

The spawning **Season** states the months of the year when spawning takes place. The monthly percentage of mature females can be entered here. When '111' is used here, this refers to months during which mature females were reported, but without indication of their relative abundance.

A graph can be generated to show the seasonality of reproduction in a given stock, and which is based either on percentages, or entries of '111' values. In the latter case, the data are smoothed (over 3 months), which also generates approximate standard errors. Also, a composite graph can be generated which combines the data of several graphs into a single plot. When its standard errors are low, this indicates a similar seasonality of spawning for all stocks of the same species (see Fig. 45).

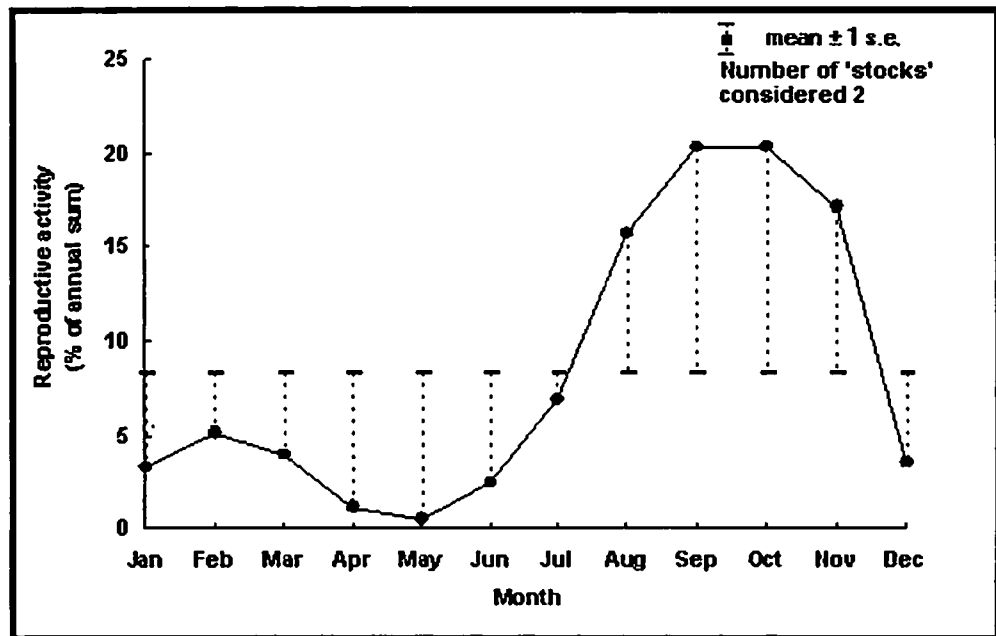


Fig. 45. Seasonality of spawning in *Engraulis ringens* off North/Central Peru.

The **Temperature** field gives the range of water temperature in degree Celsius at which spawning normally occurs, while the **Sex ratio** pertains to the average percentage of spawning females in a spawning stock. If a published % Sex ratio was given as a fraction (number of females/number of males), it was transformed using:

$$\% \text{ Sex ratio} = \frac{\text{number of females}}{\text{number of females} + \text{number of males}} \cdot 100$$

***Fecundity ranges from
300 million eggs to
a few live born offspring***

Fecundity, defined as the number of eggs found in a ripe female, is often reported in the literature without indication of the corresponding body weight. While such information is less useful than relative fecundity (see below), we decided to nevertheless include it in this table. To accommodate cases where size information is available, we added fields allowing entry, for each fecundity record, of a range of body weights and lengths. Also, a choice field is provided to identify the type of length measurement used. The choices consist of: **SL** (Standard Length); **FL** (Fork Length), **TL** (Total Length), **WD** (Width of Disc, in rays), **NG** (not given in source) and **OT** (other length type).

The **Relative fecundity** is given where available and defined as the number of mature oocytes in a female divided by the total weight of that female.

***Fecundity-length
relationships are rarely
given in the literature***

The **Fecundity-length relationship** would be the most useful information but is rarely given in the literature. Still we have provided fields for entry of this information, as follows:

Size: consists of two fields referring to the smallest and largest fish considered when the fecundity-length relationship was derived. A choice field defines the type of length measurement used (see above);

n: pertains to the total number of specimens used for deriving the fecundity-length relationship;

a: refers to the multiplicative factor **a** of the fecundity-length relationship of the form $F = aL^b$, wherein **F** is the fecundity in number of eggs and **L** is the length in cm;

b: refers to the exponent of the fecundity-length relationship;

r: pertains to the correlation coefficient of the log-linear form of the fecundity-length relationship.

The **Daily spawning frequency** applies to **batch spawners** only, and gives the frequency of spawning per day (e.g., 0.5 means half of the females spawn every day, i.e., an individual female spawns every second day, see e.g., Hunter and Goldberg 1980; Hunter and Leong 1981; Pauly and Soriano 1987).

Additional information about spawning site and season is given in the **Comment** field.

Status

The SPAWNING table contains over 2,800 records for more than 2,000 species. Many entries contain only the spawning season, but over 700 records also report sex ratio or fecundity.

The present coverage will expand and gradually assimilate the huge volume of available literature on spawning, especially on commercial species.

How to get there

You get to the SPAWNING table by clicking on the **Biology** button in the SPECIES window, the **Reproduction** button in the BIOLOGY window, and the **Spawning** button in the following window.

Internet

In the Internet, you get to the SPAWNING table by clicking on the respective link in the 'More information' section of the 'Species Summary' page. You can create a list of species with available data by selecting the **Spawning** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

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Armi Torres

Ichthyoplankton

*Computers can help
in identifying
ichthyoplankton*

An important method of fishery biology is the ichthyoplankton survey, used to estimate the size of a spawning stock from the numbers of eggs or larvae produced (e.g., Rankine and Bailey 1987). A precondition for such surveys is the ability to identify fish eggs and larvae. It has been shown that computerized systems in general and databases in particular can help with this task (Froese and Schöfer 1987; Froese 1988, 1989; Froese et al. 1989; Froese 1990a, 1990b; Froese and Papisissi 1990; Froese 1990b). Also, morphological characters of eggs and larvae can be used to test hypotheses about life-history strategies (e.g., Froese 1990a).

We have been looking for an institution willing to assume responsibility for the updating and further development of our existing ichthyoplankton tables, described further below. The Institut für Meereskunde, Kiel, Germany, has secured funding for the development of LarvalBase, a substantial upgrade of the existing ichthyoplankton tables in FishBase. If you are interested to collaborate with LarvalBase, please contact www.larvalbase.org.

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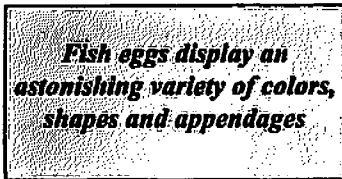
Rainer Froese

The EGGS Table

Fish eggs display an astonishing variety of colors, shapes, appendages, sizes and places of development. The EGGS table tries to standardize such information in order to assist in fish egg identification and in comparative studies.

Fields

The EGGS table has fields for the **Environmental parameters** that are usually associated with the occurrence of fish eggs, such as **Temperature, Depth range, Salinity, pH and Oxygen content** of the water. A **Remarks** field accommodates any additional environmental information.



The **Place of development** is given as a choice field with the options: buoyant (pelagic); on the bottom (demersal); fixed on plant or stone; in sand or gravel; in open nest; in covered nest (i.e., burrow or tunnel); in bubble nest; in mouth (mouthbrooders); attached to parental body; in brood pouch; in female (live-bearers); outside the water; in another animal (i.e., bivalve); other.

The **Shape of egg** can be classified as: spherical; ovoid; elongated; other.

The **Attributes of the egg** can be: smooth; sculptured; with filaments; with tendrils; with stalk; in jelly matrix; other. In addition, the eggs can be sticky or not sticky.

The **Color of eggs** can be: transparent; white; yellow, orange, amber; brown, black, gray; green; other.

The **Color of oil globule(s)** can be: yellow; orange/red; green; other.

The **Number of oil globules and their diameter** as well as the **Egg diameter** can be given as a range.

The **Perivitelline width** and the **Chorion thickness** are two additional identification characters, which can be stated as percent of a **Reference diameter**.

Additional characters that may be helpful for identification can be stated in a text field.

Status

To date the EGGS table covers more than 400 species, mostly from the North Atlantic or Mediterranean. Information has been drawn from more than 600 references such as Russell (1976), Fahay (1983) and Moser et al. (1984). No serious checking has been done so far and thus the table is likely to contain errors.

How to get there

You get to the EGGS table by clicking on the **Biology** button in the **SPECIES** window and the **Reproduction** button in the **BIOLOGY** window and the **Eggs** button in the next window.

Internet

On the Internet, you can access the EGGS table by clicking on the respective link in 'More information' section of the 'Species Summary' page, either in FishBase or in LarvalBase (www.larvalbase.org). You can create a list of species with available data by selecting the **Eggs** radio button in the 'Information by Topic' section of either FishBase or LarvalBase.

References

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Rainer Froese

The EGGDEV Table

That fish eggs develop faster at high temperature than at low temperature has been known at least since Dannevig (1895), and this theme has been amplified—and quantified—by many authors (see Pauly and Pullin 1988, and Fig. 46). The effect on egg development of factors other than temperature has been less studied: there are no datasets that could be used to identify such factors unequivocally and quantify their effects across a large number of fish species. The sole exception to this is egg size, which is usually documented as egg diameter.

**Large eggs develop
more slowly than small eggs**

Various authors have noted that large eggs develop—other things being equal—more slowly than small eggs (see, e.g., Breder and Rosen 1966). The first demonstration of this effect across a wide range of species may, however, be that of Pauly and Pullin (1988) whose compilation of fish egg development times, egg diameters and corresponding temperature for 84 teleost species from 50 references, provided the impetus for the development of the EGGDEV table, and its first entries.

Fields

The EGGDEV table has the following fields:

Egg development time: Duration from spawning/fertilization to hatching, in days; ideally this should refer to the time when 50% of the eggs have hatched, but often refers to a midrange.

Egg diameter in mm: This should be replaced by the diameter of a sphere equivalent to the volume of non-spherical eggs when such occur, e.g., in engraulids.

Water temperature in °C: Refers to the mean temperature to which the eggs are exposed.

Salinity: Given in two fields, one for ppt, the other a choice field. Options are seawater; brackish water; and freshwater.

Data type: A choice field with the options: based on field data; based on laboratory experiments; based on aquarium observations; other.

Remarks: a field for miscellaneous comments, e.g., on 'egg diameter' referring to a spherical equivalent, or a description of how estimates were obtained.

These fields are complemented by the Reference, Locality and Country fields such as used in other tables.

Uses

Pauly and Pullin (1988) derived a multiple (log linear) regression model to enable prediction of egg development time from knowledge of water temperature and egg diameter. An obvious use of the data in the EGGDEV table is to improve their model, based on the larger dataset now available. Such a model, possibly

including dummy variables for taxonomic groupings, may help testing Pauly and Pullin's contention that the taxonomic affinities of teleosts do not affect their egg development time, given the same temperature and egg diameter. Such testing may have important implications for the life-history theory.

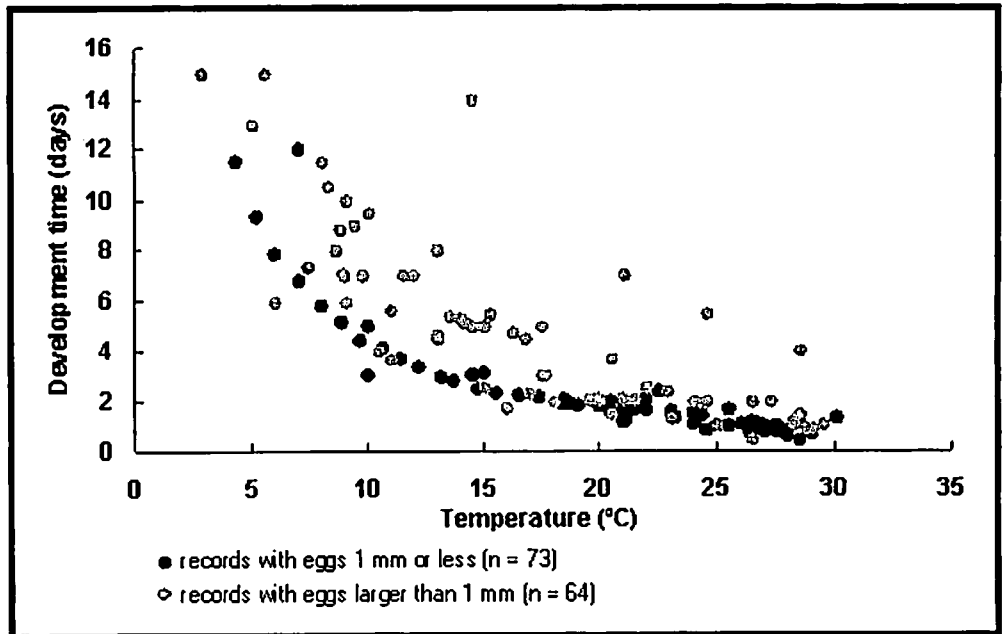


Fig. 46. Relationship between the mean development time of fish eggs and the mean temperature of the water in which they develop. See Box 32 for a discussion of this graph.

Box 32. Temperature and the development of fish eggs.

It has been known to scientists for at least a century, and probably much longer to those involved in fish culture, e.g., of carp in ancient China, or medieval Europe, that the time required by fertilized fish eggs to hatch decreases with increasing temperature.

The two FishBase graphs dealing with egg development, based exclusively on the entries of the EGGDEV table, account not only for temperature but also for egg size – a factor that has received far less attention, though it also affects egg development (Pauly and Pullin 1988).

A plot of development time vs. temperature (see Fig. 46) differentiates eggs with diameters of 1 mm or less from larger eggs; it clearly shows that, at a given temperature, smaller eggs develop faster than larger eggs.

This theme is further explored in the second plot (Fig. 47), of 'temperature-adjusted egg development time' vs. egg diameter, which displays, as expected, an increasing trend, notwithstanding a simultaneous increase of variance. Note that this graph has a Y-axis roughly corresponding to the 'degree-days' of the practitioners, but with Kelvin ($K = °C + 273.16$) being used to ensure linearity over a wide range of temperatures.

Reference

Pauly, D. and R.S.V. Pullin. 1988. Hatching time in spherical, pelagic, marine fish eggs in response to temperature and egg size. *Environ. Biol. Fish.* 22(4):261-271.

Daniel Pauly

Egg size and development time are very important in captive breeding

Also, egg size and development time are very important in all captive breeding of fish because they can influence the design of hatchery equipment and the management and husbandry of all the life-history stages of fish held in captivity. Small eggs produce small larvae with small mouths that are often more difficult to feed than large larvae. Therefore, the EGGDEV table can provide some guidance for the requirements and likely success of breeding fish in captivity. This is important when considering potential new species for aquaculture.

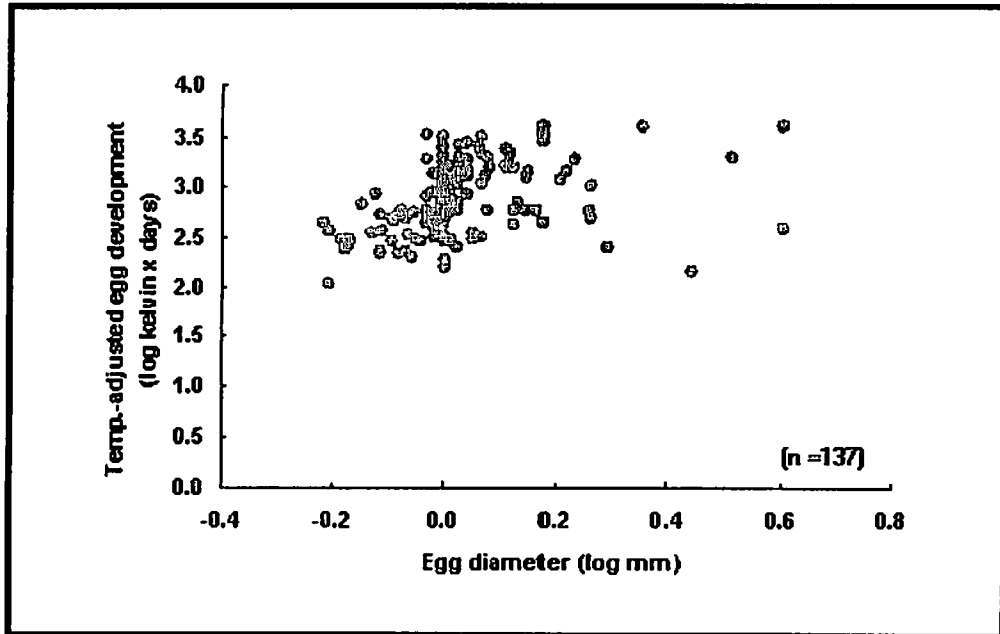


Fig. 47. Temperature-adjusted development of fish eggs as a function of egg diameter. See Box 32 for a discussion of this graph.

How to get there

You get to the EGGDEV table by clicking on the **Biology** button in the SPECIES window, the **Reproduction** button in the BIOLOGY window and the **Egg dev.** button in the next window.

Internet

On the Internet, you get to the EGGDEV table by clicking on the **Egg dev.** link in the 'More information' section of the 'Species Summary' page in either FishBase or LarvalBase (www.larvalbase.org). You can create a list of species with available data by selecting the **Egg dev't.** radio button in the 'Information by Topic' section of either FishBase or LarvalBase.

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Daniel Pauly and Roger S.V. Pullin

The LARVAE Table

Morphological characters of fish larvae change dramatically in the course of larval development

Morphological characters of fish larvae—as well as their ecological niche—may change dramatically in the course of larval development, i.e., the period from hatching to metamorphosis. This is true for body proportions as well as for pigmentation. Spines, teeth and fin rays begin to develop around the mid-time of larval development. Such variability makes fish larvae difficult to identify.

Froese (1990) developed and compared different computer-based methods for identification of fish larvae, including numerical taxonomy, expert systems and relational databases. He concluded that overall, the database approach was the easiest to implement and use, because most larvae could be identified by a combination of few characters only (see also Froese 1988, 1989; Froese et al. 1989, 1990; Froese and Papisissi 1990).

Sources

To date, the LARVAE table covers over 1,000 species mainly from the North Atlantic and the Mediterranean. Relevant information has been derived from more than 800 references such as d'Ancona (1956), Russell (1976), Fahay (1983), Moser et al. (1984) and Halbeisen (1988).

Fields

For postlarvae (i.e., larvae in a development stage between absorption of yolk-sac and metamorphosis) the table provides fields for the **Length at first feeding**, the **Months** when the larvae occur, the typical water parameters such as ranges of **Depth**, **Temperature**, **Salinity** and **Oxygen** concentration.

Because of their variability, many of the following descriptive, meristic and morphometric characters are given as a range from 'early' to 'late' stages.

Striking features drastically reduce the number of possible species in an identification session

For descriptive characters, the table accommodates **Striking features** such as 'stalked eyes' or 'tube-like snout', and **Striking shape** such as 'eel-like' or 'tadpole-like'. Since such features are rare, they drastically reduce, when they occur, the number of species that need to be considered in an identification session.

The **Shape of gut** is also a distinctive character, and may be triangular, spherical or looped, elongated, tube-like or aberrant. The **Gas bladder** may be visible, invisible or pigmented. **Spinal armature** may be present at different locations on the head.

Rows of melanophores may be present on the tail as: dorsal row; ventral row; lateral row; dorsal + ventral row; dorsal + lateral row; ventral + lateral row; dorsal + lateral + ventral row; no rows. It has been shown that these pigmentation patterns are very powerful characters for identifying fish larvae (Halbeisen 1988; Froese 1990). **Other melanophore** patterns may be present on the tail, head and trunk and are classified in two additional choice fields.

Urostyle region and Peritoneum may be pigmented; **Pectorals and Pelvics** may be absent or of striking shape, with or without melanophores.

Meristic characters pertain to the number of **Myomeres** or **Vertebrae**, counted in total and/or from head to anus. **Additional characters of postlarvae** are given in a text field.

Finally, the LARVAE table contains fields for metric characters in percentage of a **Reference length**, i.e., **Preanal length, Prepectoral length, Preorbital length, Diameter of eye, Depth at eye, Depth at pectorals, and Depth at anus**, for early, flexion and late postlarval stages.

For yolk-sac larvae, the table first describes the typical **Larval area** in a text field. It then gives the **Place of development**, the **Length at birth**, the **Preanal length** (i.e., from snout to anus) as percent of total length, the shape and pigmentation of the **Yolk-sac**, the consistency of the **Yolk**, and the number, position and pigmentation of **Oil globules** in the yolk.

The pigmentation of the yolk-sac larvae on head, trunk and tail is classified into the most common patterns and is a main entry for identification. **Additional characters** are presented in a comment field.

How to get there

You get to the LARVAE table by clicking on the **Biology** button in the SPECIES window, the **Reproduction** button in the BIOLOGY window and the **Larvae** button in the next window.

Internet

In the Internet, you get to the LARVAE table by clicking on the **Larvae** link in the 'More information' section of the 'Species Summary' page of either FishBase or LarvalBase (www.larvalbase.org). You can create a list of species with available data by selecting the **Larvae** radio button in the 'Information by Topic' section of 'Search FishBase' or LarvalBase.

Acknowledgments

I acknowledge the contribution of the late Hans-Wilhelm Halbeisen who showed that the pigmentation patterns in fish larvae can be classified. He developed—based on this discovery—the first concise fish larvae identification key for a larger area. Many of the larval pictures in FishBase are based on illustrations in his key (Halbeisen 1988). I also thank Wolfgang Welsch for his help with digitizing many of the larvae pictures. Finally, I thank Christine Papisissi for performing many of the measurements in the morphometrics section of the LARVAE table.

Internet

On the Internet, you get to the LARVDYN table by clicking on the **Larval dyn.** link in the 'More information' section of the 'Species Summary' page in the either FishBase or LarvalBase (www.larvalbase.org). You can create a list of species with available data by selecting the **Larval dynamics** radio button in

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Rainer Froese

LarvalBase

LarvalBase is a new module of FishBase

LarvalBase is a new module in FishBase aiming to present relevant information about fish larvae. To date, FishBase holds little information on ichthyoplankton and lacks detailed data on fish larvae identification and rearing. The LarvalBase project will close this gap and will complete various datasets in FishBase relevant to fish larvae.

LarvalBase is a comprehensive information system on fish larvae

Specifically, LarvalBase wants to build a comprehensive information system on fish larvae in aquaculture. For instance, egg size and development time are important in captive breeding of fish because they can influence the design of hatchery equipment and the management and husbandry of the life stages of fish held in captivity. Where new species are considered, LarvalBase will be able to generate a profile of the most probable requirements for the rearing process. At some stage, we hope that it will be possible to estimate the potential of a species to be reared successfully at a specific site by using the combined information in FishBase and LarvalBase.

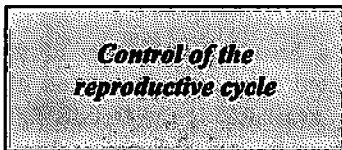
Aquaculture scientists and other professionals often find it difficult to get information on species that have potential to be reared under local conditions. This is a situation where a well-focused database can help. Thus, the major concern of LarvalBase is to provide fisheries and hatchery managers with fast and easy access to all information relevant to the identification and rearing of fish larvae

for aquaculture and stock enhancement and for the conservation and re-establishment of fish biodiversity.

Although the number of farmed finfish (about 200) is relatively small, there is a huge amount of aquaculture data available in journals and reports. Making generalizations from these data has been hampered by the lack of standardization in aquaculture experiments. These constraints will be addressed by efforts to standardize data. LarvalBase strives to provide a 'model form' that can be followed by specialists dealing with larval rearing.

LarvalBase deals with the period after hatching in two tables (Larval Nursery System and Fry Nursery System). The main larval stage is defined as the period from hatching (including the yolk-sac stage) until metamorphosis; sometimes the latter coincides with the 'weaning' period (i.e., transition from live food to formulated feed). The subsequent period is defined as the fry stage consisting of fish that have passed metamorphosis and need feed different from the larval stage. In addition, fry usually need to be transferred to other holding facilities for on-growing. The following stage is known as alevins or fingerlings. Alevins have all features of adults. This stage is usually sold to on-growing farms and/or used for stocking ponds, lakes, or large tanks in order to produce market-size fish.

The BROODSTOCK Table



Although several species can be reared on the basis of eggs and larvae collected from the wild (e.g., milkfish or eels), large-scale production of fry needs a broodstock of captive spawners for reliable production of eggs. The ability to control the reproductive cycle of species under cultivation is thus most important. Such knowledge ensures that hatcheries are able to maximize their production of eggs and fry and thus can tailor their production to the needs of the farms which grow fish up to table size.

The BROODSTOCK table gives basic information on biotic and abiotic conditions for proper broodstock management.

Fields

The first **Broodstock** field gives a classification of major triggers to induce breeding, while the second **Broodstock** field indicates the preferred method of gamete release.

The field **Spawning behavior** complements the broodstock fields and gives a more detailed description of the spawning behavior, e.g., necessary environmental factors such as the presence of spawning substrate or water flow and technical descriptions on how to obtain gametes.

The **Countries/Regions** field indicates the major countries where the species is known to be farmed on a commercial scale.

Stocking rate and **Sex ratio** present recommended values for the incubation of the broodstock for best results in obtaining gametes.

If ranges are given in the literature, a mean value is calculated. The fields **Male** and **Female** may indicate typical broodstock numbers.

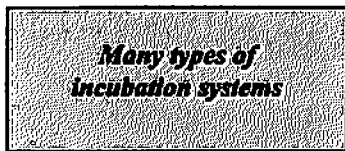
The field **Mortality** gives an indication of typical post spawning mortality.

The field **Main water source** indicates the usually used water source; an alternative source is mentioned in the field **Supplemental water source**.

The fields **Temperature**, **Spawning Temperature**, **Salinity**, **pH**, **Oxygen** and **Hardness** present the range of optimal abiotic values for the holding of the broodstock during maturation. Because temperature often has a major impact on spawning behavior, an optimal spawning temperature may be mentioned.

The free text field **Comments** may be used for further relevant notes about conditions of broodstock holding, nutritional status and spawning.

The EGG NURSERY Table



After eggs are obtained either naturally or stripped from broodstock and fertilized, they can be transferred to a suitable incubator where they remain under controlled conditions at least until they become 'eyed'. There are many different types of egg incubation systems, e.g., egg boxes, trays or jars. The appropriate type of incubator depends on the species to be reared. The EGG NURSERY table describes best conditions for successful breeding.

The field **Nursery system** gives a broad classification of the appropriate incubator for the selected species. A more specific description of the nursery system is available in the **Details** field where information can be added about the type of egg incubator, modifications, proper egg handling and egg treatment, water flow, and other recommendations.

The field **Stocking density** indicates a number for optimal stocking of eggs in the incubator. A variety of units for this value can be chosen from a drop down menu.

The field **Main water source** indicates the usual water source used for egg incubation. An alternative source is mentioned in the field **Supplemental water source**.

The fields **Temperature**, **Salinity**, **pH**, **Oxygen**, **Hardness** and **Illumination** indicate the range of optimal abiotic values for egg incubation.

The field **Egg mortality** indicates the egg mortality encountered during the complete incubation period until hatching, in percent.

The field **Eyeing** indicates the day-degrees needed until the dark pigmented retina is visible in the embryo. At this developmental

stage, eggs can be manipulated in order to separate dead or abnormal developed eggs from the healthy batch, or eggs can be transferred to another incubator if required.

The field **Time to hatch** in day-degrees and in hours gives information on the time needed for larvae to hatch. Because time to hatch depends to a great extent on the temperature, the values presented here relate to the temperature regime as noted in the respective fields.

The **Production/cycle** field indicates the productivity of a broodstock in number of eggs/batch spawning, and the field **Production/year** indicates the total productivity of the broodstock in number of eggs/year.

The free text field **Comments** may be used for further relevant notes about egg incubation such as sorting and transportation and quality control measures or treatment against infection and parasites.

The LARVAL NURSERY Table

After hatching, yolk-sac fry need to be transferred to a new environment for on-growing.

The field **Nursery system** gives a broad classification of the appropriate culture systems for the selected species. The field **Details** gives additional information on the rearing facilities, such as handling of larvae, shape and technical design of rearing facilities, and details about water supply and exchange.

The **Number of larvae** field indicates the typical number of larvae in a rearing tank, whereas the **Stocking density** field gives a relative number per unit for optimal stocking of larvae.

The field **Main water source** indicates the most common water source used for water supply; an alternate source is mentioned in the field **Supplemental water source**.

The fields **Temperature, Salinity, pH, Oxygen and Hardness and Illumination** indicate optimal abiotic values for larval rearing.

The **Time to fry** field gives information on the time needed for larvae to reach the fry stage in day-degrees and in days. Because this period depends to a great extent on the water temperature, the values presented here relate to the indicated **Temperature**.



The **Mortality** field states the range of relative larval mortality encountered during the period from hatching to fry stage, in percent.

The **First feed** field gives in day-degrees or days the time after hatching when commencement of first feeding is necessary for good survival rates.

The **Production/cycle** field indicates the number of larvae produced per cycle and unit (e.g., number/m³). The field **Production/year** indicates the total production per year and unit (e.g., number of larvae/m²). Notes about growth performance may be shown in the free text field **Growth rate**, where larval growth can be noted in relation to environmental conditions and feeding regime.

The next section **Nutrient inputs** in the **Larval Nursery System** table refers to the larval feed. The **Main food** field generally indicates the feed needed throughout the larval period until metamorphosis. **Description of nutrient input** is a free text field and describes details such as the diet sequence, food quality (e.g., the need for certain fatty acid profiles for normal development) and density of food organisms. The free text field **Comments** may be used for further relevant notes about specific requirements of the species, such as sorting, grading and transportation, critical periods, quality control measures, treatment against infection and parasites, and more.

The Fry Nursery Table

After completion of metamorphosis, fish larvae are usually transferred to a new environment such as concrete tanks, small ponds or lakes. The conditions applied here are often more natural than within the larval nursery. The table **Fry nursery system** holds information on all important aspects for this larval stage, from transport to feeding.

Fields

The field **Nursery system** gives a broad classification of the appropriate culture system for the selected species. The field **Details** is a free text field and gives additional information about on-growing facilities, their preparation in cases of, e.g., outdoor ponds, indication on handling of fry, and details about water supply and turnover rate.

The field **Number of fry** indicates the actual number of larvae released into an on-growing unit, whereas the **Stocking density** gives a number per unit for optimal stocking of the on-growing facilities (e.g., kg/m³).

The field **Main water source** indicates the most common water source used for water supply or the place (e.g., pond) where the fry were released. A water source which can be used alternatively is mentioned in the field **Supplemental water source**.

The fields **Temperature**, **Salinity**, **pH**, **Oxygen**, **Hardness** and **Illumination** give the range of optimal abiotic values for fry. **Illumination** in case of natural light in outdoor cultures (e.g., ponds, tanks) may indicate that shading against sunlight is required.

Biotic values are presented in the next table section: **Production**. The **Time to alevins** in day-degrees and in days gives information

on the time needed for fry to reach the stage of alevins (or fingerlings). Because this period depends among others (e.g., feeding) on the temperature regime, the values presented here relate to the indicated water temperature in the on-growing facilities.



Mortality after metamorphosis

The **Mortality** field indicates the range of fry mortality encountered during the period from larvae (end of the larval stage, i.e., from metamorphosis) to alevins, in percent.

Production/cycle indicates the amount of fry produced per cycle and rearing unit (e.g., number/m³), the field **Production/year** indicates the total production in amount of fry per year per unit (e.g., number/m²). Notes about the growth rate may be shown in the free text field **Growth rate**, where growth of the fry can be described in relation to the actual environmental conditions and feeding regime.

The next section **Nutrient inputs** refers to the food and feeding regime for the fry. The **Main food** field indicates the different food needed throughout the fry period. **Description of nutrient input** is a free text field and describes in detail, e.g., the diet sequence, the different sizes of formulated feeds, food quality (e.g., the need for certain fatty acid profiles for normal development) and density of food organisms or amount of formulated feed to apply.

The free text field **Comments** may be used for further relevant notes about specific requirements of the species, such as sorting, grading and transportation, stunting, critical periods, quality control measures, or treatment against infection and parasites.

Mini-Essay

The literature about larval rearing is very diverse, with data for the same species varying between geographic regions, and there are sometimes considerable differences with the biotic and abiotic factors among experimental rearing and commercial hatchery operation. It was often found difficult to present a rearing protocol in a concise and standardized table format valid for all purposes and localities. Thus, we decided to produce additional comprehensive essays about each species in LarvalBase. These essays can be accessed by clicking on the button **Mini-Essay** which is present in each table but only active if a mini-essay is available for the respective species.

Status

Only a few mini-essays are available at present. Please volunteer to cover species of which you have a good knowledge. Please contact the project leader of LarvalBase for more information (www.larvalbase.org).

Water Quality Button

Within all LarvalBase tables, a button **Water Quality** is present and opens a table showing values about optimal water quality (by species) and indications on harmful concentrations of a wide variety of organic and inorganic substances (e.g., nitrite, nitrate,

ammonia, ozone, chlorine, polychlorinated biphenyls, DDT, etc.) which are of concern in larval rearing and aquaculture of fish.

Status

If data about **Water Quality** are available for a species, the respective button is active (black). At present, these records are available only for a few species.

Picture Button

Larval photos as well as drawings of developmental stages of eggs and larvae are important for identification or to check if regular development occurs. Thus, LarvalBase intends to add these kinds of illustrations for each species in LarvalBase. The **Picture** button is active (black) if an image is available for a certain species.

Status

Larval photos are very difficult to obtain, nevertheless LarvalBase aims at the presentation of at least one photo for each species. Just a few photos come with the present version of LarvalBase. Please help if you have photos about fish larvae and juveniles in your collection. The same is true for drawings of developmental stages.

Internet

While this version of LarvalBase on CD-ROM is rather a preview of forms than a complete collection of data, the [www-version](http://www.larvalbase.org) of LarvalBase will be completed continuously (updates about every 4 weeks; visit www.larvalbase.org to see our progress).

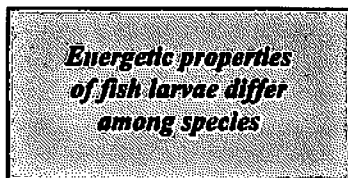
How to get there

All tables described above can be accessed from the **SPECIES** table. From there, click on the **Biology** button and from there choose **Reproduction**. You will see buttons for **Broodstock**, **EggNursery**, **LarvalNursery** and **FryNursery**. The buttons are active (black) if related information is available. **Mini-Essays** about larval rearing are accessible from within the LarvalBase tables.

Bernd Ueberschär

Houde and Zastrow's LARVDYN Table

The LARVDYN table was developed by Edward D. Houde and Colleen E. Zastrow (1993) who kindly supplied it for distribution through FishBase. We quote from their publication (p. 290):



“Growth rates, mortality rates, and energetic properties of teleost larvae differ among species and among ecosystems. In this synthesis, the ingestion rates required to support mean growth of larvae were estimated and energy budgets were developed. Weight-specific growth coefficients (**G**), instantaneous mortality rates (**Z**), larval stage durations (**D**), gross growth efficiencies (**K_g**), and weight-specific oxygen uptake (**QO₂**) were obtained from published sources and categorized by marine and freshwater species. Rates and properties were subcategorized by marine ecosystems and by taxonomic groups. The strong temperature dependencies of rates and properties for larvae were adjusted by analysis of covariance to allow mean values to be compared among ecosystems and taxa.”

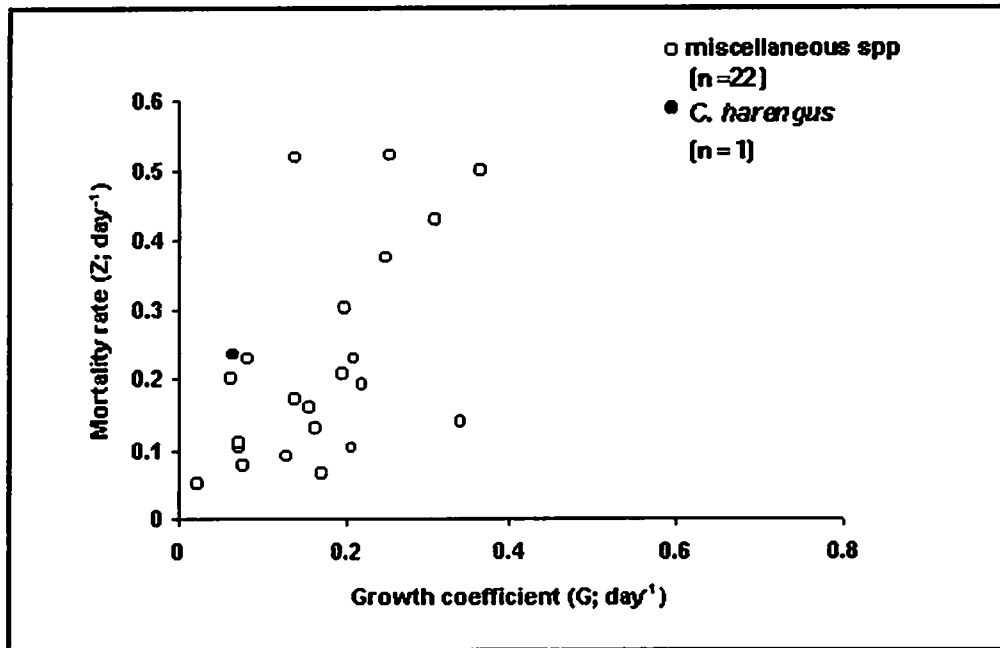


Fig. 48. Relationship between mortality and growth in larvae. Light dots: all data points in FishBase; black dot: record for herring larvae.

The table covers about 100 species with information drawn from more than 200 references. This information is used to generate different types of graphs. Fig. 48 is one illustration. We intend to expand that coverage, as new information becomes available. Inputs and queries from FishBase users would be much appreciated.

How to get there

You get to the LARVDYN table by clicking on the **Biology** button in the SPECIES window, the **Reproduction** button in the BIOLOGY window and the **Larval dyn.** button in the next window.

Internet

On the Internet, you get to the LARVDYN table by clicking on the **Larvaldyn.** link in the 'More information' section of the 'Species Summary' page. Alternatively, you can select the **Larval dynamics** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

Reference

Houde, E.D. and C.E. Zastrow. 1993. Ecosystem- and taxon-specific dynamic energetics properties of fish larvae assemblages. *Bull. Mar. Sci.* 53(2):290-335.

Rainer Froese

Morphology and Physiology

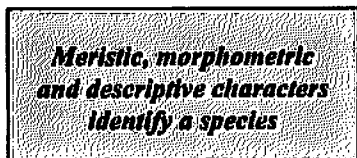
The MORPHOLOGY Table

The word 'morphology' refers both to the branch of biology dealing with the form and structure of organs or other parts of organisms, and with the form and structure of organism as a whole.

Similarly, the MORPHOLOGY table of FishBase aims to fulfill two related goals:

- i. to provide standardized and thus comparable, concise descriptions of the fishes included in FishBase; and
- ii. to allow for quick species identification based on characters used in (i).

In fish, the major characters used for description and identification are descriptive, referring to distinguishable characters (e.g., shape of caudal fin), morphometric, referring to continuous variables (e.g., head length as a fraction of body length) or meristic, referring to discontinuous variables (e.g., the number of rays and spines in a dorsal fin).



The MORPHOLOGY table incorporates descriptive characters in multiple choice fields and morphometric and meristic characters in numeric fields. It is mainly the meristic characters that are used for quick identification, following the database identification scheme of Froese and Papisassi (1990). The structure of the MORPHOLOGY table and the choice of fields it includes are based on a close study of major texts in ichthyology (e.g., Lagler et al. 1977) and consultation with numerous colleagues. Some of the terms employed in the table are highly specialized; their definition may be found in the FishBase Glossary.

Fields

The MORPHOLOGY table contains 67 choice fields, 79 numeric fields and several remarks fields. Choice fields present the user with preprogrammed choices of descriptions for a body part or feature (e.g., **Cross section** - circular; oval; compressed; flattened; angular; others (see **Remarks**)). The choices included were kept to a minimum, including only general descriptions covering the most common shapes or forms. In most cases, an 'Other (see **Remarks**)' choice is included for those species which might have aberrant features or shape of a body part. When 'Other' is chosen for a field, a detailed description of the particular body part is included in the **Remarks** field.

Numeric fields on the other hand, were used for morphometrics and meristics. In most cases, ranges were entered in separate lower and upper limit fields. When a range or several values are given in the literature, but the field allows only a single number to be entered (as in the fields for body proportions), the mean of the available values was entered.

The **Remarks** field accommodates characters that are either not included in the choice fields or require more detailed descriptions. In these fields, distinctive features, and how these features might be found in closely related species, are highlighted. Notes on color variations (ontogenetic, sexual and geographic) are also entered in this field, when available.

As the number of species in FishBase increased, we found it too time-consuming to fill the more than 140 fields of the MORPHOLOGY table for all species. We decided to reduce the number of 'active' fields to those regularly covered in taxonomic books (standard meristics and diagnosis) and to fill these on a regular basis. This has meanwhile been completed for all bony fish of Japan and British Columbia, and for all marine fishes of Micronesia and of Southern Africa (Smith and Heemstra 1986). Also, all families covered by FAO catalogues or in Randall's *Indo-Pacific Fishes* series are complete. We plan to complete and verify the MORPHOLOGY table by family (see Box 1, this vol.) and by using major faunal works such as Skelton's (1993) *Freshwater Fishes of Southern Africa*.

Uses

One important use for the information contained in the MORPHOLOGY table is for quick fish identification (see 'Quick Identification', this vol.). The current preprogrammed routine requires a minimum amount of information as search criteria, viz.:

- FAO area from which the fish was collected;
- habitat (freshwater, brackish, saltwater);
- depth at which the fish was collected;
- size of the specimen;
- number of dorsal fin spines;
- number of dorsal fin soft rays;
- number of anal fin spines;
- number of anal fin soft rays;
- order or family (optional).

The data in the MORPHOLOGY table can be used for quick identification

A search typically results in less than 10 possible species

The routine searches through the database and displays the list of species that matches the user-provided criteria. Typically, such a search results in less than 10 species of the same family. The user then can go through the pictures and through the full morphologic description to verify an identification. This search routine works also if one or more of the fields are left empty. In such cases, the list of species thus generated becomes longer. Note, however, that to date, the MORPHOLOGY table contains data for only about 8,000 species and is complete for only a few areas or families (see above). The information provided varies in degree of completeness, from very scanty, as in the case of *Pellona castelnaeana*, to almost complete, as in the case of *Lutjanus*

biguttatus. Also, the data have not been thoroughly checked, and thus may contain errors.

Reports

Preprogrammed routines for printing Species Synopses and Summaries make use of information in the MORPHOLOGY table. The routine for printing a synopsis for one species, for example, extracts the **Additional Characters** field which gives distinctive descriptions, the dorsal and anal fin element counts, and other information from the SPECIES and STOCKS tables. It then prints out a comprehensive report of the information available for that species, plus all the references used (see 'Reports', this vol.).

Sources

Data in the MORPHOLOGY table stem from all *FAO Species Catalogues* published so far, other taxonomic revisions, faunal books and journal articles, e.g., Burgess (1978), Trewavas (1983), Allen (1985), Cohen et al. (1990), Lévêque (1990), Randall et al. (1990), Allen (1991), Myers (1991), and Heemstra and Randall (1993).

How to get there

You get to the MORPHOLOGY table by selecting a species, then clicking on the **Biology** button in the SPECIES window, the **Morphology and Physiology** button in the BIOLOGY window, and the **Morphology** button in the next window. You get to the Quick Identification routine by clicking on the **Species** button in the Main Menu window and the **Quick Identification** button in the SEARCH BY..... window. The internal name of this is MORPHDAT.

Internet

On the Internet, you get to the MORPHOLOGY table by clicking on the **Morphology** link in the 'More information' section of the 'Species Summary' page. You can create a list of species with available data by selecting the **Morphology** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

References

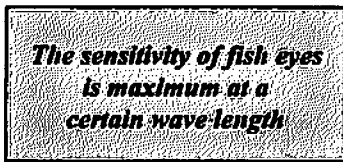
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- Rainer Froese and Rodolfo B. Reyes, Jr.**

The VISION Table

This form, devoted to the vision of fish concentrates on eye pigment on the retina of fish eyes and is based on the work of Denton and Warren (1956), Munz (1964), Munz and McFarland (1973), Ali and Wagner (1975), and Hobson et al. (1981), from which all (409) records so far, pertaining to 371 fish species, were extracted.

Fields



The above authors showed that the Sensitivity of a fish eye is maximum at a certain wavelength (in λ_{\max}). This value in nm, and its 95% confidence interval (if available) are the essential entries for the table.

A yes/no field allows recording the presence of other pigments (as in Table 3 of Hobson et al. 1981).

A text field for remarks completes this small table.

Users of this table should read the above papers for details on the methods used to estimate λ_{\max} .

Status

Updating the VISION table will involve:

- including all species covered in the above-cited papers (by identifying the valid names of several species for which the above authors used now outdated names);
- adding new records from more recent papers, to be identified using the Zoological Record, and the Science Citation Index through its citations to any of the above references; and
- adding information on the relative size of the eyes of each fish species, their activity cycle (diurnal or nocturnal), and depth range, all correlates of λ_{\max} .

The information in this table can be used to test hypotheses relating the physiology and the ecology of fishes, as initiated in the references below.

How to get there

You get to the VISION table by clicking on the **Biology** button in the SPECIES window and the **Eye pigment** button in the BIOLOGY window.

Internet

As of December 2000, this table was not available on the Internet.

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Daniel Pauly

The BRAINS Table

Most fishes have small brains, at least when compared with warm-blooded vertebrates. However, holding this against them would be as silly as trying to draw inference about the worth of different groups of people from the (mismeasured) size of their brains (Gould 1981).

Rather, we should realize that fish have evolved the brain size they need, and then use the brain size difference among species of fish to draw inferences on their 'needs', i.e., on their niche (see, e.g., Bauchot et al. 1989). The brain size database assembled by Roland Bauchot and his collaborators and kindly made available for inclusion as a table of FishBase allows inferences of this sort. The following describes, based on Bauchot and Bauchot (1986), how this database was created.

Over 2,800 brains were dissected from over 900 species of teleost fishes (see Fig. 49). Many of the fishes were collected at tropical and subtropical localities such as the Hawaiian and Marshall Islands, New Caledonia, Queensland, Australia, the Philippines, southwest India, Mauritius and Réunion, Gulf of Oman, northern Red Sea, Senegal and the Caribbean, but also in France and the North Atlantic. All fish were weighed before removal of the brain and their standard and/or total length taken. The brain was cut from the spinal cord at the first spinal nerves, the meninges and blood vessels removed, blotted and weighed, and then preserved in Bouin solution.

Box 33. Brain size and oxygen consumption.

With a large dataset on relative brain size at hand, we were tempted to test some obvious hypotheses. Fig. 50 shows a first attempt to link the BRAINS table with other physiological data, here the OXYGEN table. Both datasets present measurements on individual fish, which in both cases are strongly correlated with weight.

Therefore, we used the slope of the log-log relationship of oxygen consumption vs. body weight and relative brain weight vs. body weight, respectively (plotting for all available data) to correct the individual values for the influence of body weight. For the plot of brain size vs. O₂ consumption, we then took the average of the available values for species with at least three records of both brain size and oxygen consumption. Fig. 50 shows that despite a fair amount of variance, the hypothesis that large brains require more oxygen, and are therefore more common in active fish with higher metabolic rates, cannot be refuted. We expect the variance to be less once the OXYGEN table (see this vol.) has been more thoroughly checked, and its own sources of variance further identified.

Rainer Froese and Daniel Pauly

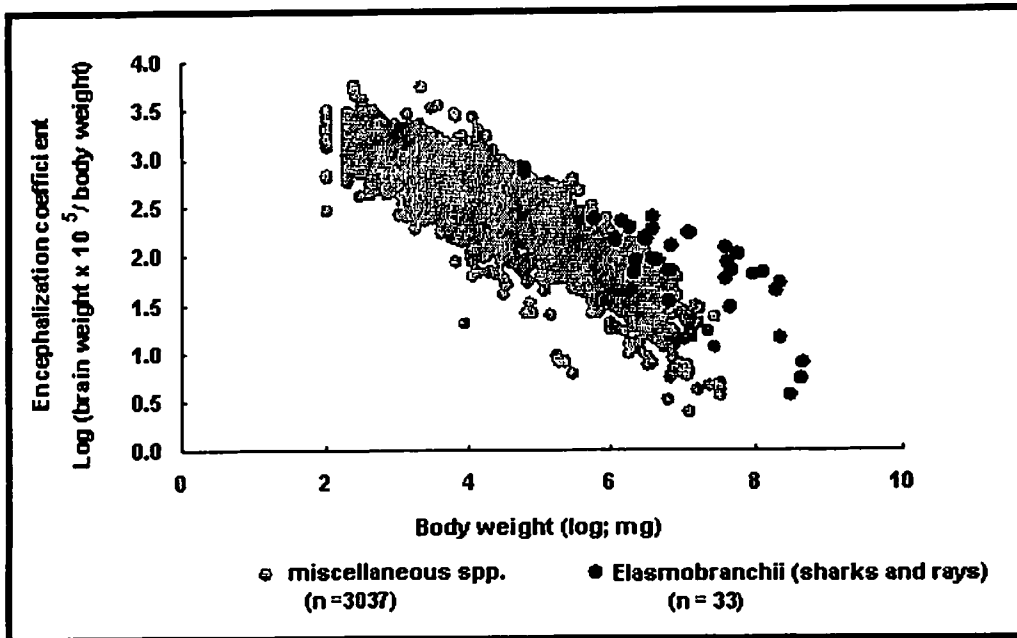


Fig. 49. Relationship between relative brain weight and body weight. Light dots: miscellaneous records in FishBase; black dots: data for sharks and rays, which have large brains, possibly to support their electrosensing ability. In contrast, 6 of the dots below the cloud belong to lampreys.

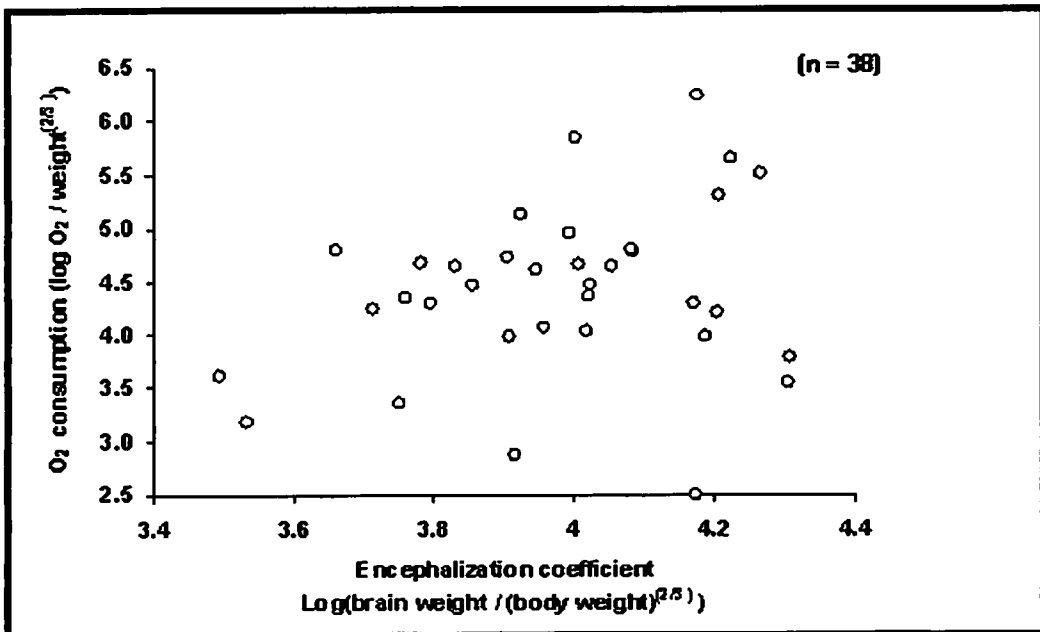


Fig. 50. Oxygen consumption vs. relative brain weight in 30 species of fishes. See Box 33 for a discussion of this graph.

*Juveniles have relatively
larger brains*

Because juveniles have a larger brain relative to body weight than adults (Bauchot et al. 1979), it was mostly adult fishes which were used for comparative studies. However, some series were also obtained which range from juveniles to large adults, thus allowing the study of ontogenic changes in brain size.

The single-fish records thus obtained are presented here under the current species names, and consist of the following elements:

- brain weight (in mg);
- body weight (in g);
- a first encephalization coefficient (a calculated field = brain weight / body weight, see Fig. 49);
- a second encephalization coefficient, standardizing for body weight (a calculated field = brain weight / body weight)^{2/3}, (see Fig. 49);
- body length (SL and/or TL, in cm).

These single records are presented for each species in the form of a table, with at least one, and up to 73 rows.

Subsequent work on this table will include incorporation of over 200 records with species names that we have so far been unable to link with valid FishBase names. One of us (James Albert) from the Department of Anatomy, Nippon Medical School, Tokyo, is developing this table further and has already contributed 77 species records representing 18 new families. A paper that analyzes the extended dataset has been prepared (Albert et al. 1999). Also, Ms. Xiomara Chin, Institute of Marine Affairs, Trinidad & Tobago contributed brain weights obtained during her thesis work (Chin 1996).

How to get there

You get to the BRAINS table by clicking on the **Biology** button in the SPECIES window, the **Morphology and Physiology** button in the BIOLOGY window and the **Brains** button in the next window.

Internet

On the Internet, the BRAINS table can be accessed by clicking on the **Brains** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Brains** radio button in the 'Information by Topic' section of the 'Search FishBase' page. If you select the **Graphs** radio button in the 'Information by Family' section of that page, you can create **Relative brain weight graphs** for different families.

Acknowledgments

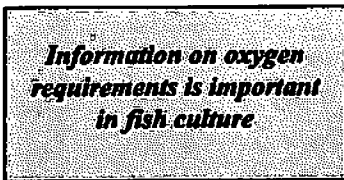
We thank R. Bauchot and his collaborators for entrusting FishBase with their valuable records, and J.-C. Hureau for painstakingly transferring them to a file format that we could read. We also thank Ms. X. Chin for 14 records of Caribbean fish brain weights.

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The OXYGEN Table



Metabolism is a physiological process reflecting the energy expenditure of living organisms and hence their food requirements (in heterotrophs). The metabolic rate of fish is usually measured by their rate of respiration, i.e., their rate of oxygen consumption (see Fig. 51). Information on oxygen consumption is not only useful in comparative physiology, but in fish culture and fishery management as well. It provides insights in solving the problems associated with rearing fish or transporting live fish, among others (Froese 1988; see also Box 33).

The OXYGEN table documents the oxygen consumption of fishes based on experiments reported in the published literature, together with factors known or likely to affect metabolic rate, notably body weight; temperature; salinity; oxygen concentrations; activity level; swimming speed; and major applied stress factor. Additional experimental details, such as the number of fish, and other information may be in the Comment field. The following fields provide details on the above-listed factors.

Oxygen consumption: Pertains to the amount of oxygen used by fish in $\text{mgkg}^{-1}\text{h}^{-1}$. If the consumption was reported in other units, these were transformed to mg oxygen per kilogram fish per hour. In addition, a computed field was included in which the oxygen consumption at temperatures between 5 and 30°C was re-expressed as the corresponding consumption values at 20°C, based on the multipliers in Table 3.3 in Winberg (1971).

Sex: A multiple-choice field consisting of: fry; juveniles; female; male; mixed (for both male and female); unsexed (for unknown sex).

Weight: Refers to the weight in g of the test organism. If there was more than one fish in an experiment, the mean weight in g was recorded.

Number: The total number of individual fish used in the experiment.

Temperature: The mean water temperature, in °C, during the experiment.

Salinity: The mean salinity in ppt during the experiment. If the salinity was not stated, 35 ppt was assumed for marine species and 0 ppt for freshwater species. For diadromous fishes, such assumption was pointed out in the **Comment** field. Erroneous assumptions will affect the calculated oxygen saturation only slightly.

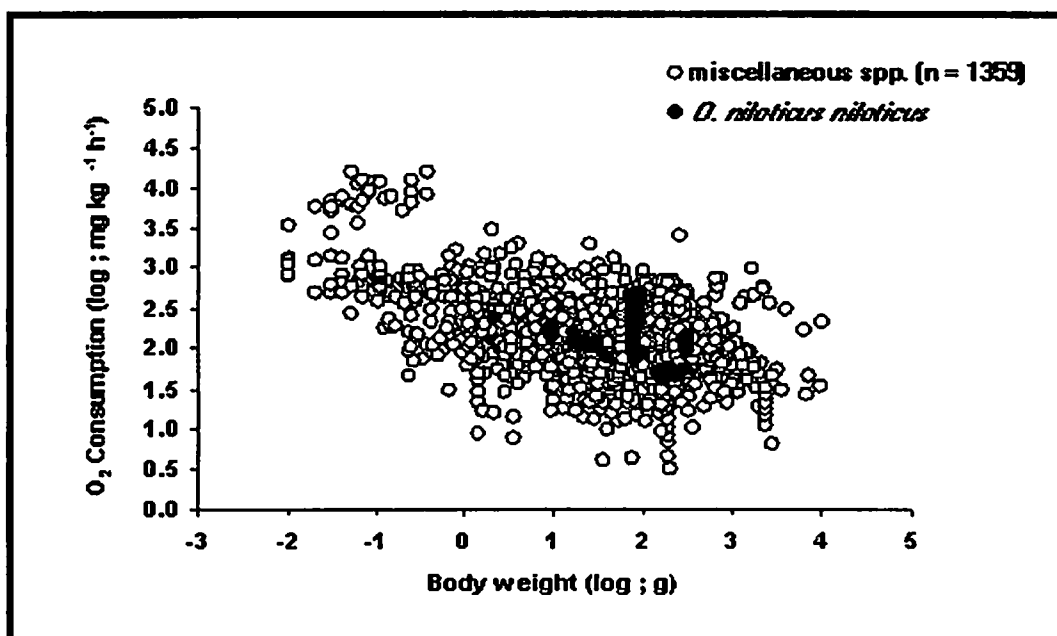


Fig. 51. Relative oxygen consumption of *Oreochromis niloticus niloticus* compared with miscellaneous species. Note the relatively straight descending line of standard/routine metabolism vs. body weight and the vertical series of values caused by stresses applied.

Oxygen (mmHg): Refers to the average partial pressure of oxygen in mmHg in the test water. As stated by Thurston and Gehrke (1993), this value was estimated through assumptions based on the description of the test method when not given in the original paper. These assumptions included corrections for test temperature and water salinity.

Oxygen (mg/l): This field pertains to the oxygen concentration of the test water in mg/l. If there is an entry in the oxygen (in mmHg) field, the values in mg/l were not extracted from the literature but calculated from the mmHg values, using the following transformation:

$$\text{mg/l} = \text{mmHg} * \beta / 0.5318$$

where β is the Bunsen coefficient for oxygen at the given temperature and salinity (Colt 1984).

100% oxygen saturation: This field states, for reference purposes, the calculated maximum oxygen content, in mg/l of the water at the given temperature and salinity.

Saturation%: This field expresses the actual oxygen content of the test water as percent of the maximum possible oxygen content. Typical saturation levels were around 90%. Values below 70% were classified as 'hypoxia', values above 105% were classified as supersaturation (see Applied Stress).

Activity level: A choice field that allows accounting for the effect of activity on metabolic rate. The available choices for this field are: standard metabolism (resting fish); routine metabolism (spontaneously active fish); active metabolism (swimming fish).

Swimming speed: Refers to the swimming speed of the fish as another index of activity. Speed was either reported as or converted to body length per second (BL/s) with 'BL' usually corresponding to total or fork length.

Applied stress: This is a choice field that pertains to stress applied before or during an experiment. The choices include: none specified; temperature (changes or extreme values); photoperiod (unusual duration or timing of light exposure); feeding (during or right before the experiment); starvation (no food offered for more than 24 h); toxins; hypoxia (insufficient oxygen); hypercapnia (excessive amount of carbon dioxide in the blood resulting from their being forced to swim rapidly); (changes in) salinity; high pH; low pH; sedative; transport; other stress. If the choice is 'other', the stress should be specified in the **Comment** field.

A variety of stresses have been applied to fish

Uses

The OXYGEN table can be used to test hypotheses on the relationships among different activities and stresses to which fish are exposed, to estimate energy (food) consumption for trophic modeling and to connect growth, morphology and metabolic rate, among other things.

Sources

The OXYGEN table contains the largest collection of data on fish metabolism

The OXYGEN table probably contains the largest collection of data on oxygen consumption of fish, with close to 7,000 records for about 300 species. The information was obtained from over 400 references such as Winberg (1960), Congleton (1974), Gorelova (1977), Marais (1978), Subrahmanyam (1980) and Neumann et al. (1981). Of these records, 6,400 stem from the database 'OXYREF' compiled by Thurston and Gehrke (1993). The remainder have been added by FishBase staff.

Status

Verification was done by going back to the original literature and checking the values and other relevant information reported. However, this has been done, for few of the entries to date.

FishBase staff will continue to add new records and to verify the information entered so far.

How to get there

You get to the OXYGEN table by clicking on the **Biology** button in the SPECIES window, the **Morphology and physiology** button in the BIOLOGY window, and the **Metabolism** button in the next window.

Internet

In the Internet, you get to the OXYGEN table by clicking on the **Metabolism** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Metabolism** radio button in the 'Information by Topic' section of the 'Search FishBase' page. If you select the **Graphs** radio button in the 'Information by Family' section of that page, you can create **Relative oxygen consumption** graphs for different families.

Acknowledgments

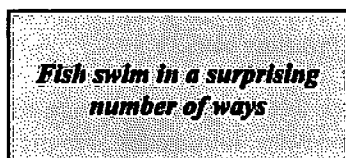
We are grateful to R.V. Thurston and P.C. Gehrke for offering the database OXYREF for distribution through FishBase.

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- Armi Torres and Rainer Froese**

The SWIMMING and SPEED Tables

Immersion in water is the closest approximation to weightlessness. Moreover, teleosts, through their invention of the gas bladder, have learned to escape the drag of gravity with the least energy expenditure. The downside of being under water is the fact that any movement has to push aside water, a particularly dense and heavy medium. The physics and physiology of fish swimming are summarized in Blake (1983) and Webb (1984) and the most recent comprehensive review in this field is that of Videler (1993).



***We follow Lindsey's
classification***

This section describes the manner in which fish swim, something they do in a surprising number of ways; also, available records on the swimming speed of fish are presented.

The classification of the swimming modes of fish adopted here stems from Lindsey (1978), who reviewed much of the earlier literature on this topic. This classification consists of two levels, the first (Roman numerals) describing what may be called the swimming 'type', the second (bullets) describing the swimming 'mode' proper, viz.

I. Movements of body and/or caudal fin:

- Anguilliform;
- Subcarangiform;
- Carangiform;
- Thunniform; and
- Ostraciiform.

II. Undulation of median or pectoral fins:

- Amiiform;
- Gymnotiform;
- Balistiform;
- Rajiform; and
- Diodontiform.

III. Oscillations of median or pectoral fins:

- Tetraodontiform;
- Labriform.

The modes in (I) imply a gradual transition from undulation of the entire body (including the trunk) being used for propulsion (anguilliform mode) to propulsive forces being generated only by the oscillating caudal fin (thunniform and ostraciiform modes).

***A gradual transition from
undulation to oscillation***

The ranking of the modes in I and II to III further implies a gradual transition from undulations to oscillations as the movements generating the major propulsive force, and thence the above scheme can also be represented as a graph, with a trunk-to-caudal-fin axis as ordinate and an undulation-to-oscillation axis as abscissa (see Fig. 1 in Lindsey 1978).

This implies that the assignment of a swimming mode to a given fish species will always contain a subjective element, even if we ignore the fact that fish may have two swimming modes (we consider here only the dominant mode, e.g., labriform in parrotfish, Family Scaridae, even if parrotfish revert to the subcarangiform mode when escaping from presumed danger (authors' pers. field obs.)).

Thus, the entries of this table (i.e., the choices of the types and modes listed above) may be revised from time to time as a result of our familiarization with this topic and its literature. This will not,

however, affect the first set of entries, based on Lindsey's examples [Species explicitly assigned to a certain swimming mode by Lindsey (1978) in both the **MainRef.** and **Ref.** fields] and their obvious extensions (e.g., from *Anguilla anguilla* to all Anguillidae, and thence to all Anguilliformes).

Note also that this table presently pertains only to juvenile and adult fishes. Fish larvae—for obvious reasons—have a limited repertoire of swimming types and modes.

The aspect ratio of the caudal fin of a species closely correlates with its average level of activity (Pauly 1989). The Aspect ratio (A) of the caudal fin is calculated from:

$$A = h^2 / s$$

where h is the height of the caudal fin and s its surface area (Fig. 52). The proximal border of the caudal fin surface is defined as a straight vertical line through the narrowest portion of the caudal peduncle, i.e., the portion of the peduncle surrounded by the fin is considered part of the caudal fin area (see Fig. 52).

*The caudal fin as
life-style indicator*

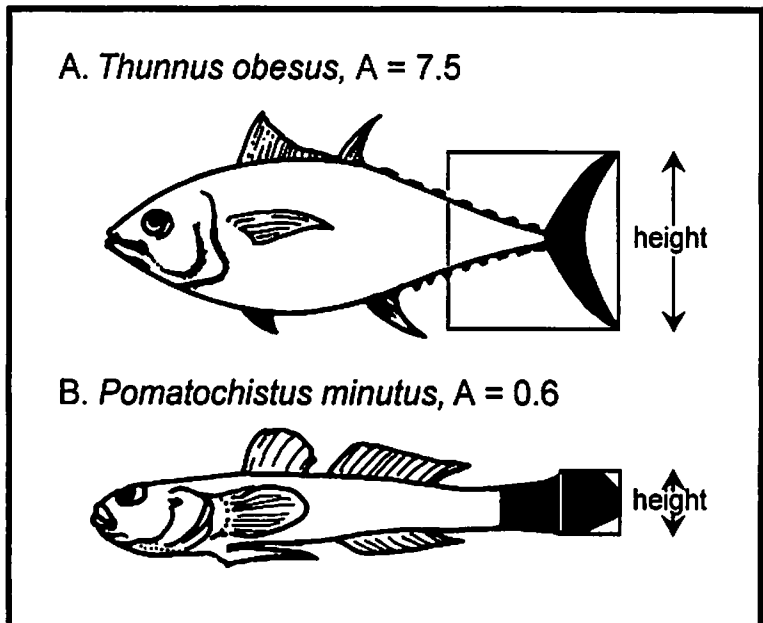


Fig. 52. Aspect ratio ($A = h^2/s$, h = height of the caudal fin; s = surface area of fin) of a pelagic fish (A = 7.5) and a bottom dweller (B = 0.6). Note the correspondence between aspect ratios and modes of life.

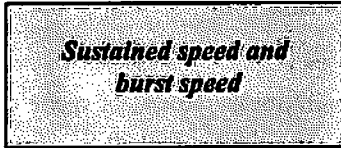
Note that this definition of A differs slightly from that presented in Pauly (1989), where only the caudal fin proper was used for calculating s.

A reference may be given to document an aspect ratio; when none is given, the aspect ratio was calculated, by planimetry, from a fish picture in FishBase or another readily available source.

Status

The SWIMMING table contains swimming type and mode for over 2,700 species.

The SPEED table contains 255 records with maximum swimming speeds for 80 species. The information was extracted from over 50 references such as Bainbridge (1958, 1960), and Webb (1971) and compilations such as Sambilay (1990). An effort was made to distinguish between 'sustained' (i.e., maintained for more than 3 minutes), and 'burst' swimming (maintained for a few seconds only) (see Fig. 53), as well as other swimming modes (Hammer 1995).



Fields

The SPEED table consists of the following fields:

Length: This field pertains to the length of fish in cm as stated in the publication. The type of length measurement used consists of the following choices: SL (Standard Length); FL (Fork Length); TL (Total Length); BL (for the term 'body length', stated in the publication but without the type of length measurement being indicated).

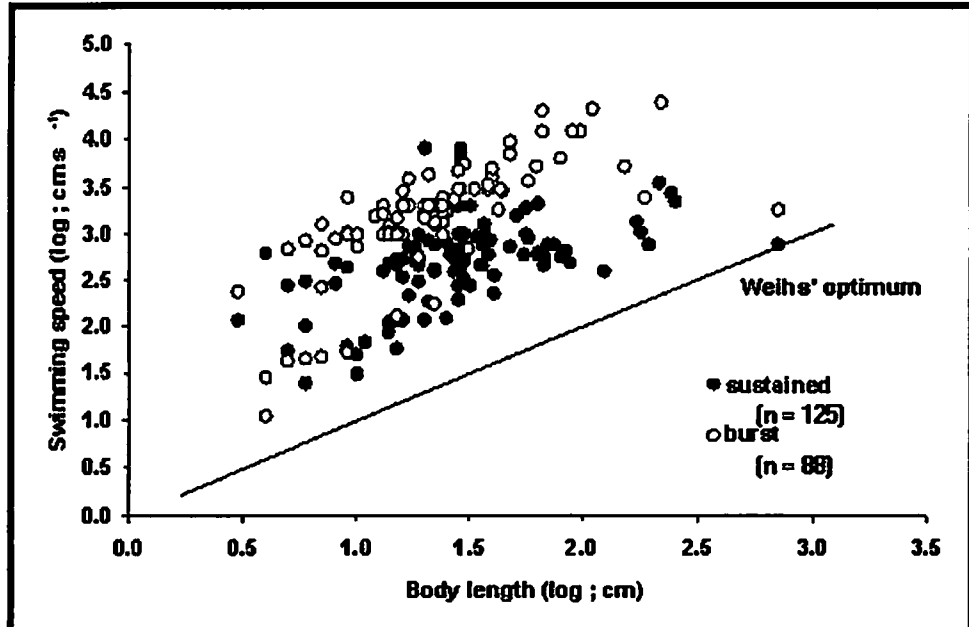


Fig. 53. Relationship between swimming speed and body length of fishes. Note that burst speed is about 10 times higher than sustained speed. Note also that no fish appears to swim at speeds below Weihs' (1973) line of minimum energy expenditure per distance covered, whose slope (1 : 1, implying strict proportionality of speed and length), however, is the same as that of the observations in this figure.

The **Swimming speed** gives the speed of the fish per second as reported in the source. A choice field is provided for the type of length measurement used. The choices are the same as above (SL, FL, TL, BL) and m/s (for meter per second). A calculated **Speed** field in meter per second is also provided (see **Derived values**).

Mode: This field describes the mode of swimming as: sustained (swimming at this speed for a prolonged time); burst (a maximum swimming speed which can be maintained for less than a minute only); other.

Comment: States the length or weight measurement, or mode of swimming if not in the choice list. Any transformation of length type should also be stated here.

Derived values: Gives the transformation values from different units of speed to standard length per second (SL/s) and to meter per second (m/s). This makes it possible to compare the swimming performance of fishes with forked, rounded or other shapes of caudal fin. Where available, the a and b values used to transform fork length or total length to standard length are given as used in:

$$SL = a + b \cdot L$$

where L is the reported fork or total length. If the transformation is based on one measurement only, hopefully a typical adult, the intercept a is set to 0 (see also the 'LENGTH-LENGTH table', this vol.).

How to get there

You get to the SWIMMING and SPEED tables by clicking on the **Biology** button in the SPECIES window, the **Morphology and physiology** button in the BIOLOGY window, and either the **Swim. type** or **Swim. speed** buttons in the next window.

Internet

On the Internet, you get to the SPEED table by clicking on the **Speed** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Swim. Speed** radio button in the 'Information by Topic' section of the 'Search FishBase' page. As of December 2000, information on swimming type was not yet available on the Internet.

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Rainer Froese, Armi Torres, Crispina Binohlan and Daniel Pauly

The GILL AREA Table

To survive, grow and reproduce, fish, like all heterotrophic animals, need food and oxygen. However, while a huge literature exists on the food and feeding habits of fishes (accommodated within FishBase through several tables and graphs), much less exists in the literature on the organs and processes which allow energy to be extracted from this food.

The essential process is respiration, and it is accommodated, in part, in the OXYGEN table. The important organs—the gills—are dealt with in the present table.

*All published gill areas
we could find*

This table presents the overwhelming majority of measurements of the gill area in fishes so far published, i.e., of the surface area that limits their oxygen intake and hence their metabolic and growth rates (Pauly 1979, 1981, 1994). Most of the measurements stem from the compilations of Hughes and Morgan (1973), De Jager and Dekkers (1975), and Palzenberger and Pohla (1992).

Hughes (1984) discusses some of the problems related to gill area measurements, and their interpretation, and this work should be consulted before analyzing the information in this table. Pauly (1979, 1981, 1994) and Longhurst and Pauly (1987) present the elements of a theory of fish growth from which hypotheses can be derived that can be tested using gill area measurements; practical uses of such measurements include pollution and ecotoxicological studies.

Fig. 54 shows that gill area in fishes increases with body weight, though the slope of the log-log plot of less than 1 implies that relative gill area must decrease with body size.

Fig. 55 shows relative gill area, plotted against body weight. As expected, this log-log plot shows that relative gill area declines with body weight, with a slope of about -0.2. However, this plot masks species-specific differences, which are important when the relationship between gill area and growth is studied (Pauly 1981).

Accounting for these differences requires consideration of swimming modes and/or caudal fin aspect ratios. We expect to have, in FishBase, a graph directly linking growth performance and gill area, and taking these extraneous factors into account.

Also, the contents of this table will be updated, using appropriate references, and your suggestions concerning this are welcome.

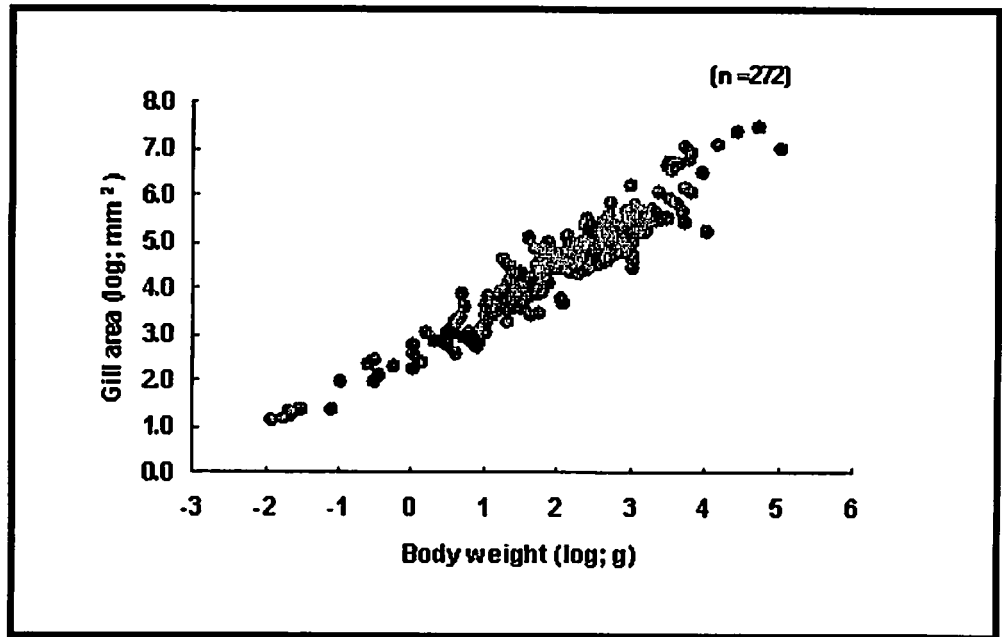


Fig. 54. Relationship between gill area and body weight (272 records for 110 species).

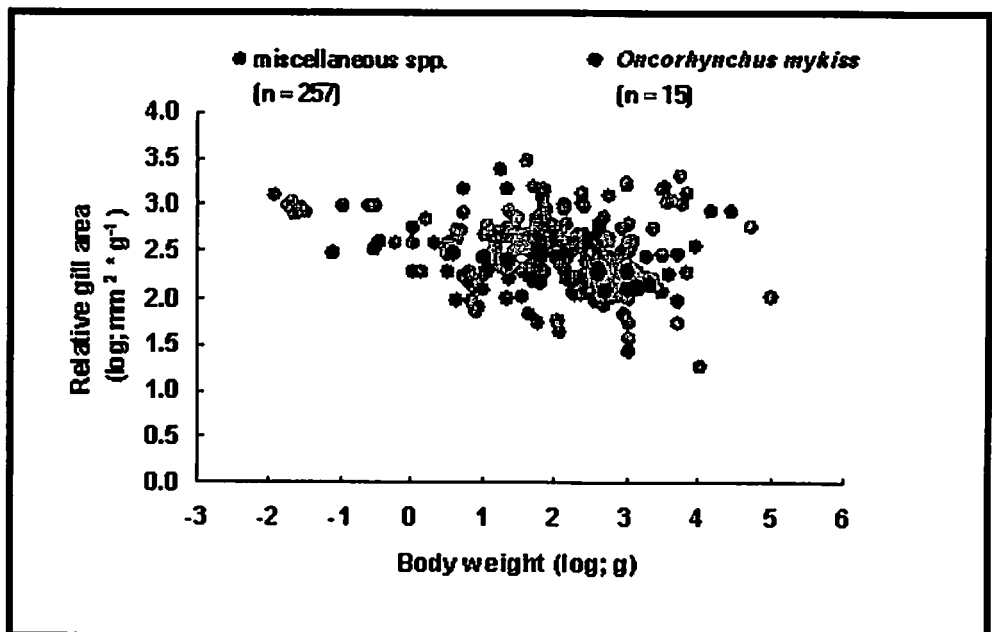


Fig. 55. Relationship between relative gill area of *Oncorhynchus mykiss* vs. its body weight (black dots), compared with relationships for miscellaneous fishes (light dots).

Fields

The key field of this table is the **Gill area** (in cm²), which must always be related to **Body weight** (in g).

A field for a derived variable, **Gill area/body weight** (cm²/g) is also available, as well as for the blood/water distance, i.e., for the thickness of the gill epithelium (in nm).

A **Remarks** field allows for methodological or other comments.

How to get there

You get to the GILL AREA table by clicking on the **Biology** button in the SPECIES window, the **Morphology and physiology** button in the BIOLOGY window, and the **Gill area** button in the next window.

Internet

On the Internet, you get to the GILL AREA table by clicking on the **Gill area** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Gill area** radio button in the 'Information by Topic' section of the 'Search FishBase' page. If you select a family and the **Graph** radio button in the 'Information by Family' section of this page, you can create **Gill area** graphs for various families.

Acknowledgments

I thank Professor G.M. Hughes for his willingness to answer, over the years, my various queries about fish gills.

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Daniel Pauly

The PROCESSING Table

This table represents our attempt at incorporating fish as consumable products into FishBase.

Fields

As presently conceived, the table consists of four elements:

1. a set of fields identifying species and stock, and the **Locality** from where the reported fish samples were obtained (because regional differences of taste, texture, etc. do occur);

***Fish as
consumable products***

2. fields for presenting the contribution to overall **Body weight** of different body parts, i.e., **Head, Trunk, Skin, Fins, Bones, Meat, Fillet, Viscera, Roe, Testes, Liver**;
3. fields for entering the gross chemical composition (percent **Moisture, Protein, Fat and Ash**) of different body parts (meat/fillet; liver; roe; viscera; head/bone/fins; waste/offal), and
4. a **Remarks** field for presentation of organoleptic properties given different modes of preparation (frying, smoking, canning, etc.). **Comment** fields are also provided for any other remarks pertaining to weight proportions and chemical composition.

Data for percentage weight and chemical composition of different body parts are accessed by clicking on the **Weight proportions** and **Chemical composition** buttons, respectively.

Sources

Almost all of the entries so far (682 records for 505 fish species) stem from Bykov (1983); indeed, the **PROCESSING** table was largely developed to accommodate the entries in this book.

With hindsight, however, we feel that this table needs to be thoroughly revised, such as to enable:

- replacing the often vague entries in the **Remarks** field by a set of multiple choice fields, to allow standardization of organoleptic properties, processing methods and description of physical appearance;
- accommodating the detailed and extensive chemical analyses in Vinogradov (1953), the products in OECD (1978) and other similar compilations, and possibly the cookbooks and fish recipes of various cultures; and
- linking with the **COMMON NAMES** table, which also includes (brief) product descriptions (see the '**COMMON NAMES** table', this vol.)

We would appreciate responses by colleagues interested in collaborating with us on this—a development that would make FishBase useful to a whole new group of users.

How to get there

You get to the **PROCESSING** table by clicking on the **Biology** button in the **SPECIES** window, the **Fish as food** button in the **BIOLOGY** window and the **Processing** button in the following window.

Internet

As of December 2000, the **PROCESSING** table was not yet accessible on the Internet.

References

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Daniel Pauly, Emily Capuli and Rainer Froese

Genetics and Aquaculture

As is the case with many other organisms—both plant and animal—the diversity of fish is presently being compromised, because of both overexploitation and habitat modification (including pollution).

Moreover, germplasm transfers—intentional and accidental—have caused strong genetic changes in numerous populations of (mainly freshwater) fishes. Such impacts can only be understood with a thorough knowledge of the genetics of fish populations, both in captivity and in open waters.

The study of genetics produced an extensive body of data such as karyotypes, electrophoretic data, heritability values from selection and genetic improvement studies, and molecular genetic data. These data are widely scattered throughout the literature making comparative studies very tedious. The FishBase tables were designed to bring these together in a standardized format. To support the acquisition, storage and use of knowledge on genetics, data have been divided into four areas:

*Genetic data are diverse
and widely scattered
throughout the literature*

- GENETICS - presenting species-specific features such as chromosome number and morphology, sex-determining mechanism, genetic markers and cellular DNA contents;
- ELECDAT - presenting, for a studied population, the different studies, loci, observed allele frequencies and related statistics;
- GENEDAT - presenting heritability values and responses to selection;
- STRAINS - presenting key information on cultured strains of tilapia and carp such as the source and size of the founder stock, distinctive trait(s), effective breeding number, etc.

Information relevant to aquaculture is provided in the following tables:

- CULTSYS – presenting information on culture performance under various scenarios;
- CULTSPEC – a sub-table of the one above, to accommodate species-specific information in multi-species systems;
- DISREF – providing information on common fish diseases; and
- DISEASES – recording cases of disease outbreak.

The following sections provide details on each of these tables.
Christine Casal and Liza Agustin

The GENETICS Table

Karyological and cellular DNA content data (see Fig. 56) are important for studies of the genetics and systematics of fishes.

Fields

Locality: Refers to where the samples used were collected.

Country: Refers to the country of the sampling locality.

Sex: Refers to sex of samples used (unsexed, female, male or mixed).

Tissue(s) Used: Refers to tissue(s) used for the chromosomal study.

Chromosome number: Fields are provided for the haploid/gametic and the diploid/zygotic chromosome number. If the chromosome number is variable, the range is provided in the diploid/zygotic chromosome number fields.

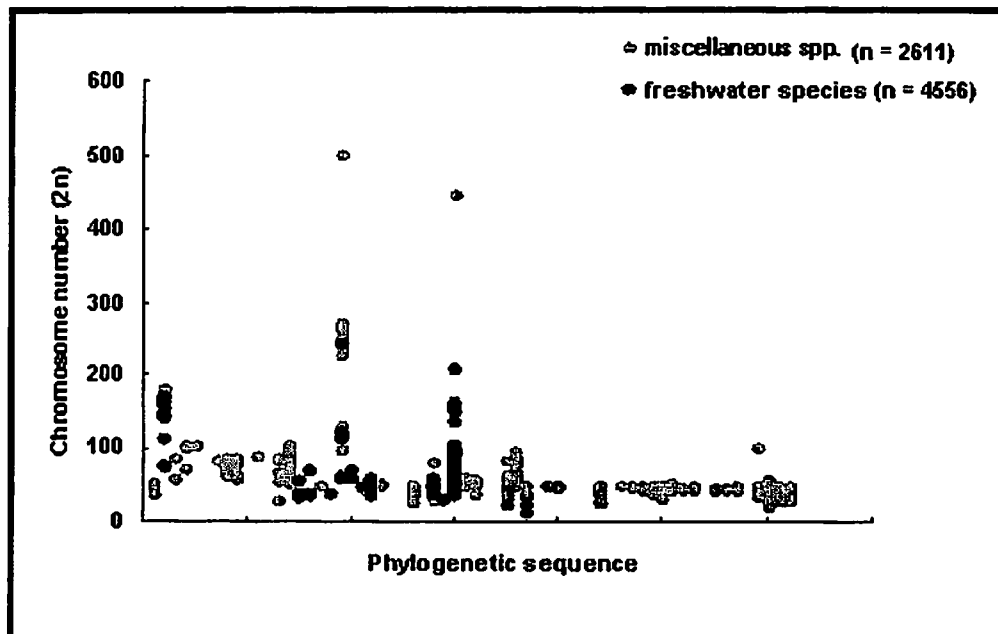
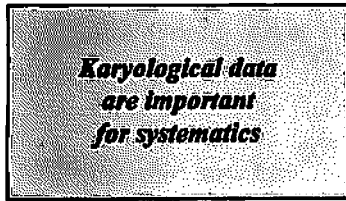


Fig. 56. Chromosome number of freshwater fishes compared with that of miscellaneous species arranged in phylogenetic sequence from primitive (left) to modern (right). Note the decrease in chromosome number and variance for modern groups. See Box 34 for a discussion of this graph.

Chromosome types: Gives the numbers of chromosomes of different types:

metacentric: chromosomes whose centromeres are approximately midway between each end, thereby forming two chromosome arms of similar length;



submetacentric: chromosomes whose centromeres are not at the middle of the chromosome (ratio of long arm to short arm is approximately 2:1);

subtelocentric: chromosomes with a more terminally placed centromere, forming very unequal chromosome arms (ratio of long arm to short arm is approximately 3:1);

telocentric/acrocentric: chromosomes whose centromeres appear to be at the very tip of the chromosome;

meta-submetacentric: metacentric and submetacentric chromosomes.

subtelo-acrocentric: subtelocentric and acrocentric chromosomes.

Chromosome arm number: Gives the total number of chromosome arms, which is largely dependent on the chromosome types (e.g., a metacentric chromosome will have two arms while a telocentric chromosome will only have one).

Sex-determining mechanism: Gives information on how males and females of the species are designated (choices include xx-xy, xx-xo, etc. for those with sex chromosomes or no sex-associated heteromorphic chromosomes).

Genetic marker(s): States whether genetic marker(s) exist in the species and the choices are yes and no. A marker is a phenotypic characteristic (e.g., allozyme, chromosome band, etc.) that can be used to infer the genotype of an organism.

DNA content: Gives the specific haploid cellular content (in picograms). If references exist with values different from those in this field, they are placed in the remarks field.

Remarks: For miscellaneous comments, e.g., presence of structural rearrangements, specialized chromosomal features, sex-determining mechanism, polyploidization and, if any, other morphological markers.

Status

To date, the GENETICS table covers more than 2,500 species with information extracted from over 2,200 references.

Sources

We used published references, checklists of chromosome numbers and karyotypes of different groups of fish aside from the database of Dr. Victor Arkhipchuk (1999) of Ukraine. Major sources include the Fish Chromosome Atlas of the National Bureau of Fish Genetic Resources (India) NBFGR (1998) and Klinkhardt et al. (1995).

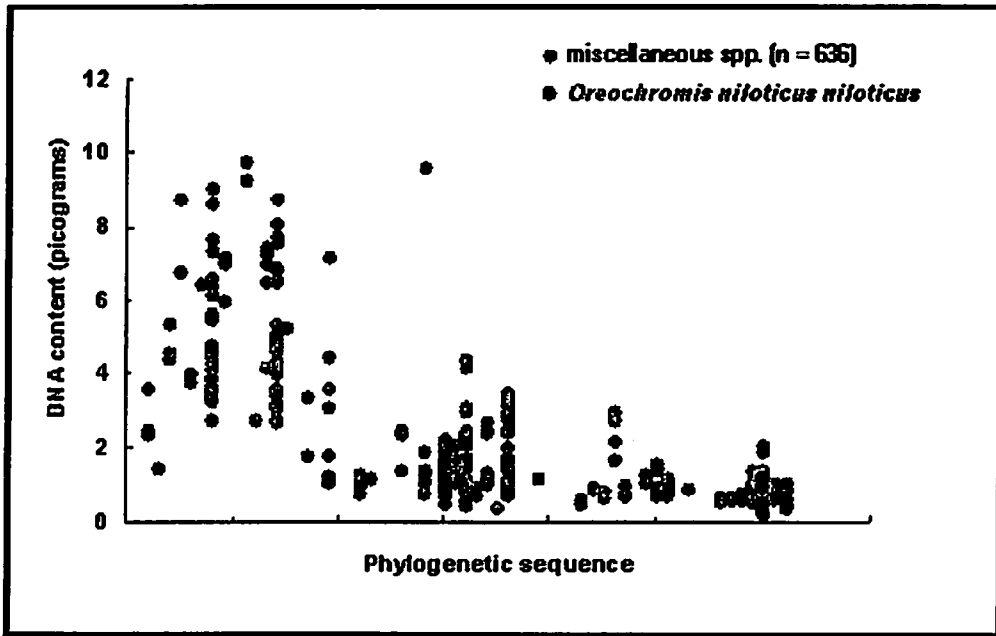


Fig. 57. DNA cell content of *Oreochromis niloticus niloticus* and miscellaneous species. Note that the decrease in DNA content from primitive (left) to modern groups (right) is similar to the independent decrease in chromosome numbers (Fig. 56).

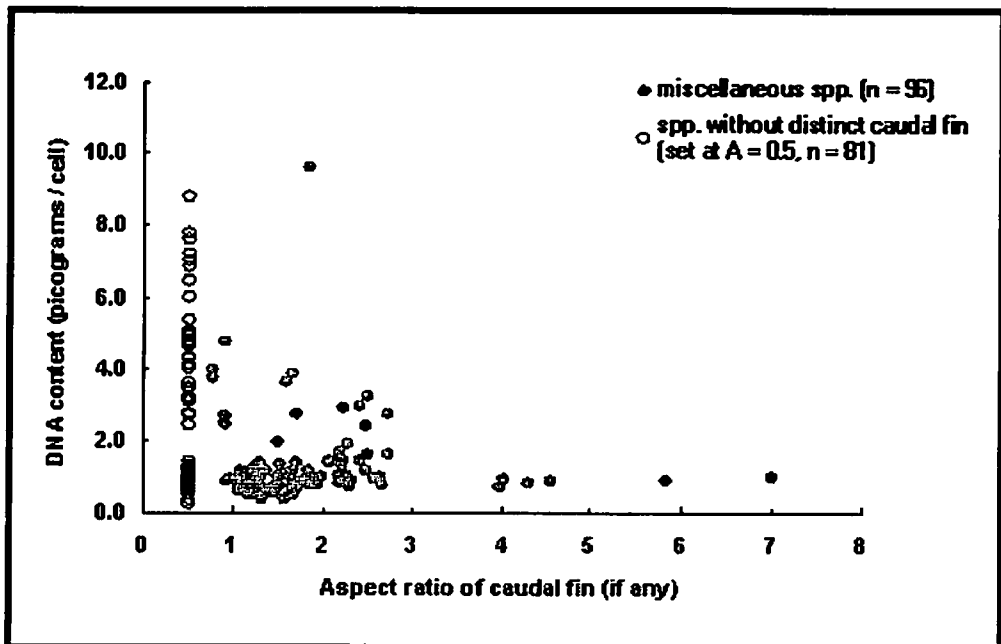


Fig. 58. DNA cell content as a measure of cell size vs. aspect ratio of caudal fin (A) as a measure of activity. See Box 34 for a discussion of this graph, and Fig. 52 for definition of the aspect ratio of caudal fins.

Box 34. DNA, cell size and fish swimming.

The DNA (deoxyribonucleic acid) content of plant and animal cells is extremely variable and few generalizations have emerged which can be used to predict the amount of DNA in the cells of a given group of organisms.

The most powerful of the existing generalizations is that the DNA content of cells tend to vary with cell size, suggesting a rough proportionality between the amount of DNA per cell, and the amount of living cellular material involved in various syntheses controlled by that DNA.

This generalization implies essentially that DNA content per cell, as recorded in the relevant field of the GENETICS table is a measure of cell size (see Cavalier-Smith 1991).

Given the tendency for organisms with large cells to have low metabolic rates, and conversely (von Bertalanffy 1951), animals with large cells (e.g., lungfishes, which reduce their metabolic rate during aestivation) will tend to have lots of DNA per cell (Thompson 1972).

In fishes, there is a clear pattern for chromosome numbers and for DNA (and hence cell size) to decline with derivedness, with perch-like fishes (high order number in Nelson's (1994) classification) exhibiting a much lower range of DNA contents than more generalized, primitive forms (Hinegardner and Rosen 1972 and see Fig. 57). [Note that chromosome number and DNA content are not correlated, as indicated by Cavalier-Smith (1991) and confirmed by a FishBase graph not reproduced here.]

This may be thought to be the result of metabolic constraints, with fish cell size (and thus DNA content) declining with the evolution of high metabolic performance, such as displayed, e.g., by tunas (Cavalier-Smith 1991).

However, as also pointed out by Cavalier-Smith (1991), there is a lower limit to the size of cells: the fact that capillaries (which are formed by single cells) cannot have a diameter much smaller than that of red blood cells.

Combining all the above, one can hypothesize that a plot of DNA content vs. the caudal aspect ratio of fish (an index of metabolic intensity, see the SWIMMING table) should have on the left side of the plot a wide range of DNA content associated with low aspect ratios (including aspect ratio set at 0.5, to represent fish which do not use the caudal fin as their main organ of propulsion, and which tend to have low metabolic rates), and, on the right side of the plot, a narrow range of (low) DNA content associated with high aspect ratios. Fig. 58 displays these features, thus corroborating hypotheses linking DNA content—via cell size—to metabolic rate.

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Daniel Pauly, Christine Casal and Maria Lourdes D. Palomares

How to get there

Clicking on the **Biology** button in the SPECIES window, then the **Genetics** button in the BIOLOGY and the following window will bring you to the GENETICS table.

Internet

On the Internet, you get to the GENETICS table by clicking on the **Genetics** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available

data by selecting the **Genetics** radio button in the 'Information by Topic' section of the 'Search by FishBase' page.

Acknowledgment

We thank P. Yershov and V. Arkhipchuk for their advice on the structure and content of this table.

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Christine Casal and Liza Agustin

The ELECDAT Table

Information based on electrophoresis has been arranged in three tables: the ELECSTUDIES table gives an overview of the studies that have been conducted on different populations of a certain species; the ELECDAT table shows the loci that have been investigated in a certain study; and the ELECSUB table contains the alleles that have been detected at a certain locus.

Together, the tables provide information on the genetic structure and variability of both natural and cultured fish populations. This is important for species/strain selection for aquaculture and will help the management and conservation programs for natural stocks.

As more data are entered in this table, it will become possible to identify research gaps (i.e., important species that have been little studied) and the most appropriate methods and reporting formats for the genetic characterization of various species.

The tables contain allele frequencies from electrophoretic studies of fish populations, both wild and cultured. They also contain information on the enzymes, the total number of loci studied, the tissues and the buffer systems used, heterozygosity values and proportions of polymorphic loci. The fields of the tables are:

Fields

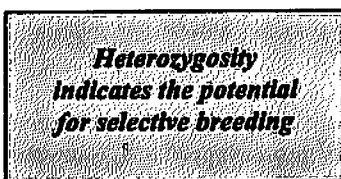
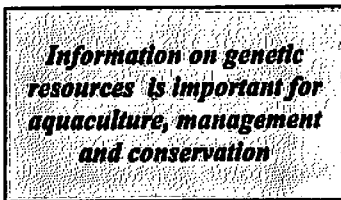
Locality and Country: Refer to the site where the specimens were collected.

Sample source: Refers to whether specimen came from captivity or open waters.

Total loci: States the number of loci examined.

The **Observed heterozygosity** is the proportion of individuals in a population that are heterozygous at a given number of loci. An individual with two different alleles at a particular locus is called a heterozygote. An individual is called a homozygote when two alleles at a particular locus are the same.

The **Expected heterozygosity**, on the other hand, is the proportion of individuals which are prospective heterozygotes based on the



allele frequencies and assuming Hardy-Weinberg equilibrium. These are computed for every locus, population and species and help to indicate, for example, the potential for selective breeding (see Fig. 59).

Gel electrophoresis is the most common method

Polymorphic loci: refer to the number of loci in a sample found to be polymorphic divided by the total number of loci examined (see Fig. 59). To standardize the data, the 95% criterion is used here, wherein a locus is considered polymorphic if the frequency of the most common allele does not exceed 0.95. If the data refer to the 99% criterion, this is indicated in the comment field.

Enzyme: Includes names, abbreviations, and numbers recommended for enzymes and other proteins commonly analyzed in fish genetics work. The names and numbers used are based on the nomenclature recommended by the International Union of Biochemistry's Nomenclature Committee (Shaklee et al. 1990).

Locus: Refers to the specific position or location of a gene on the chromosome. A gene is a specific length of DNA occupying a locus. A locus is called monomorphic if only one allele is known, and polymorphic when different alleles can occur in a locus. Where two or more loci are involved in producing different forms of a protein (isozymes), the most anodal locus is designated as 1, the next 2, and so on. Sometimes the locus is designated by letters, the most anodal is designated as A, the next B, etc.

Tissue: The type of tissue sample used for electrophoresis. The available choices are: skeletal muscle; visceral muscle; heart; kidney; liver; blood; mucus; eye lens; whole body; others. The last choice refers to tissues that are specified in the Comment field.

Method used: Refers to the type of electrophoretic method used. Gel electrophoresis is one of the most common methods for studying the genetic variation of individuals at both strain and species levels. Four choices are given: starch gel; polyacrylamide gel; sodium dodecyl sulfate; other methods.

Buffer system: Refers to the electrophoretic buffer system used for clear resolution of specific proteins and enzymes. The fifteen buffer systems most commonly used are described by Boyer et al. (1963), Ridgway et al. (1970), Shaw and Prasad (1970), Selander et al. (1971), and Clayton and Tretiak (1972).

pH: Refers to the acidity of the buffer system used.

Samples: Gives the number of samples per site or per population screened.

An allele is one of several alternative forms of a specific gene

An Allele is one of several alternative forms of a specific gene. Alleles are distinguished by their protein products (enzymes) during electrophoresis. The relative electrophoretic mobility of enzymes in a zymogram is expressed in terms of numbers. Relative mobilities are calculated based on the most common

allele, which is considered 100 (or -100 for a cathodal locus). A minus sign is assigned to any allele exhibiting cathodal mobility.

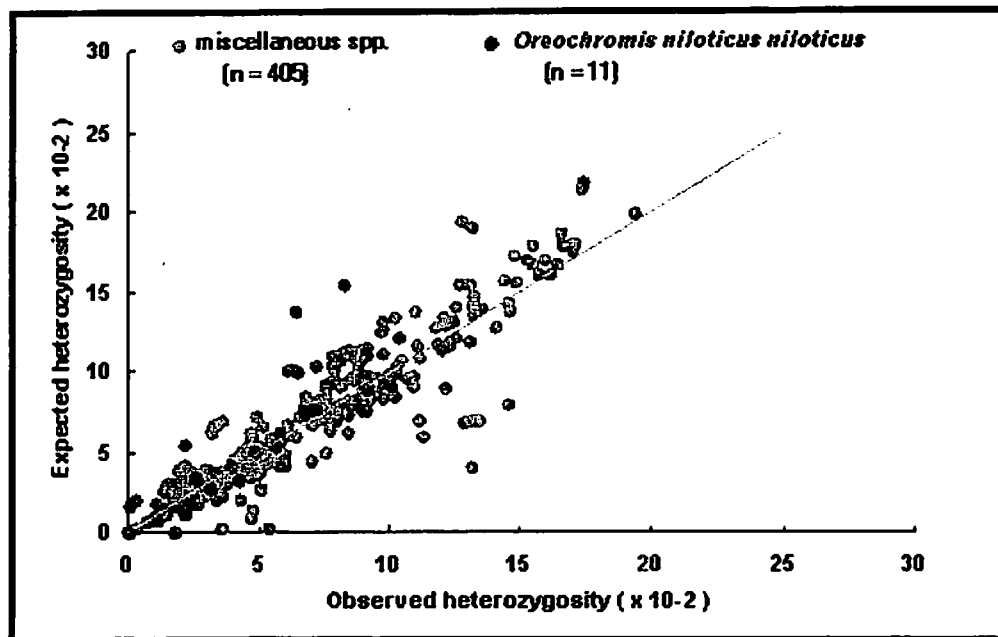


Fig. 59. Expected vs. observed heterozygosity of *Oreochromis niloticus niloticus* (black dots) and miscellaneous fishes. The line represents 1 : 1 ratios. Values well above the line may be the result of inbreeding. Values well below the line may result from crossing of strains.

The Allele frequency at a given locus is calculated using the following formula: frequency of allele A = 2 (frequency of genotype AA) + (frequency of genotype Aa) / 2n, where n = number of individuals screened.

Status

The tables currently hold over 11,000 records (one record represents alleles at a single locus) of allele frequencies for over 900 studies of over 800 fish populations/strains of over 200 species. The updating of this table in collaboration with and using the references identified by Skibinski et al. (1991) has made it the largest repository of data on the genetic variability of fishes.

Graphs

Several graphs can be generated from this table showing:

- the correspondence line between expected and observed heterozygosity (see Fig. 59); examines whether genetic variability (H and P) has been reduced in captive populations relative to populations from open waters;
- the relationship between DNA content and phylogenetic order following Nelson's *Fishes of the World* (1994) (see Fig. 57);

- the relationship between chromosome number and DNA content; and
- the relationship between DNA content and aspect ratio of the caudal fin (see Fig. 58 and Box 34 for an explanation of this graph).

All these graphs can be accessed through the GENETICS table, by highlighting the specific species. Alternatively, you can select them from the Graphs menus under Reports.

Sources

Important references used so far are Winans (1980), McAndrew and Majumdar (1983), Macaranas et al. (1986, 1995), van der Bank et al. (1989), Carvalho et al. (1991) and Pouyaud and Agnèse (1995).

To achieve a complete coverage of the allele frequencies and related information on fish so far published is a rather daunting challenge and will involve resolving the problems posed by lack of standardization among publications, which still precludes pooling of data (Agustin et al. 1993, 1994).

How to get there

Clicking on the **Biology** button in the SPECIES window, the **Genetics** button in the BIOLOGY window, then the **Allele Frequency** button in the following window will give a list of populations studied and by clicking on the **specific locality**, you get to the details of the specific study.

From this point, you get to the ELECDAT table by clicking on the **Electrophoretic data** button. A list of enzymes used is then presented and clicking on a particular enzyme gives you details of the enzyme involved.

You get to the ELECSUB table by clicking on the **Allele Frequencies** button at the bottom of this window.

Internet

On the Internet, you get to electrophoretic data by clicking the **Allele frequencies** link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available data by selecting the **Allele frequency** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

Acknowledgments

We thank R.E. Brummett, A.E. Eknath, G.C. Mair, J.G. McGlade, D. Pauly, R.S.V. Pullin and D.O. Skibinski for their advice on the structure and contents of this table.

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- Christine Casal and Liza Agustin**

The GENEDAT Table

This table aims to assist the application of genetics to modern aquaculture, and thus contains records of heritabilities and responses to selection. The genetic improvement of farmed fish requires breeding programs to enhance traits of high economic importance (such as growth rate, age at maturity, carcass quality and many more; see also Box 35 on 'Selective breeding of Nile tilapia'). The fields of this table are:

Fields

Locality and Country: Refer to the site where the experiment was done.

Trait: Pertains to the desirable phenotypic character for improvement by selective breeding. The choices include: growth rate; age at first maturity; size at first maturity; egg number; egg size; egg weight; egg survival; larval survival; disease resistance; behavior; resistance to environmental factors; dressing weight; carcass quality; fat content; protein content; food conversion; anatomical modification color and other. Traits not included here are mentioned in the Comment field.

Box 35. Selective breeding of Nile tilapia.

Nile tilapia (*Oreochromis niloticus*) has been the most widely farmed tilapia species since the 1980s. However, Pullin and Capili (1988) found that little attention had been given to the genetic improvement of its farmed populations and that broodstocks outside Africa had been derived from very small founder populations and had probably been mismanaged, with consequent genetic drift, inbreeding depression, and introgressive hybridization with other species, notably *O. mossambicus*. Also in 1988, an international workshop was convened to review the status of tilapia genetic resources for aquaculture (Pullin 1988). This confirmed the wealth of tilapia genetic resources in Africa, the limited genetic diversity of tilapia broodstocks used for aquaculture outside Africa, and the need for more investment in research for the genetic improvement of tilapias.

Based upon these findings, ICLARM, in consultation with colleagues from AKVAFORSK, Norway, who had pioneered the selective breeding of farmed salmon (Gjedrem 1985) and from the Philippine Bureau of Fisheries and Aquatic Resources and the Freshwater Aquaculture Center of Central Luzon State University, Philippines, secured funding from the United Nations Development Programme (UNDP) for the Genetic Improvement of Farmed Tilapias (GIFT) project. With the help of many colleagues and institutions in Africa, Asia and Europe, four new wild founder populations of Nile tilapia (from Egypt, Ghana, Kenya and Sénégal) and populations of four strains of Nile tilapia in current use by farmers in Asia ('Israel', Singapore, Taiwan, and Thailand) were assembled, after strict quarantine, in the Philippines. Their performance was compared in 11 different farm environments. The surprising result was that, with the exception of the Ghana strain, the wild African strains grew as well or better than the Asian farmed strains.

A subsequent large experiment—a complete 8 x 8 dialle cross to compare the performance of all 64 possible hybrids among these strains—showed no substantial heterosis (hybrid vigor) and the GIFT project team therefore decided to pursue a strategy in which genetic material from the best families of all strains would be incorporated, according to their performance rankings, in a synthetic strain. This synthetic strain has since been subjected to selective breeding for good growth, over seven generations.

The GIFT strain of fish is being further developed through research and commercialized by a non-profit foundation, the GIFT Foundation International, Philippines. A recent project, supported by the Asian Development Bank, found the estimated yield potential of the GIFT strain to be significantly higher than that of some of the existing farmed strains in Asia, though there were some variations; for example, improvements were about 54% in Vietnam and 97% in Bangladesh (ICLARM-ADB 1998). While the information about the potentials of the GIFT fish on farms continues to grow, the GIFT fish are also under investigation to explore the basis of their domestication and the applicability of the GIFT project methods to other species. For example, a researcher at the University of British Columbia (Bozynski 1998) has found that although the GIFT team selected fish for fast growth, they have also, in this process, selected quietly behaved fish. This fits with the history of agriculture, in which docility has been one of the most important attributes for domestication. Quiet fish grow faster and their low aggression lessens some environmental risks.

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Mean: Refers to the average value of the investigated trait.

Unit: Pertains to the unit of measurement of the trait (e.g., g, weeks, mm).

S.D.: Refers to the standard deviation from the mean of a given trait.

C.V.: Refers to the coefficient of variation of the investigated trait, defined by the formula $C.V. = S.D./mean$.

Heritability (h^2): Refers to the proportion of additive genetic variance in the total phenotypic variation, i.e., will the trait be expressed or passed on to the offspring? If a trait is sufficiently heritable, selective breeding is likely to be very effective. However, if h^2 is low, i.e., close to zero, environmental factors have caused most of the variation and therefore little genetic gain can be obtained by selection.

S.E.: Refers to the standard error of the mean of heritability.

Method: Refers to the method used to estimate heritability. The choices are: sib analysis; offspring/parent regression; realized heritability; others. Methods not included here are mentioned in the second Comment field.

Selection studies: Indicates whether a selection study has been performed.

Response %: Gives the response to selection expressed as a percentage.

Method: Refers to the method of selection. The choices are: mass selection; individual selection; sib selection; family selection; within family selection; index selection and tandem selection; others. Methods not included here are mentioned in the third Comment field.

Heritability determines the probability for a trait to be passed on to the next generation

Status

To date, about 200 records for 9 species and strains have been entered. The information was obtained from references such as Gjedrem (1983), Gjerde (1986) and Tave (1988).

How to get there

Clicking on the **Biology** button in the SPECIES window, the **Genetics** button in the BIOLOGY window, then the **Heritability** button in the next window brings you to the GENEDAT table.

Internet

This table is not available on the Internet.

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The STRAINS Table

This table allows the documentation of the ancestry of cultivated strains of fish. It was developed primarily to serve as the Tilapia Strain Registry recommended by The Second International Symposium on Tilapia in Aquaculture (ISTA II) in 1987, in Bangkok, Thailand (Pullin 1988). The information was subsequently extended to cover other species utilized in aquaculture, as recommended in Articles 7 and 10 of the Convention on Biological Diversity (UNEP 1992). The genetic data, including histories of founding population, broodstock management, status of the strain and descriptions of the distinguishing characters of the strains will assist in the utilization and conservation of intraspecific genetic variation in aquaculture. Nomenclature standardization continues to be a problem and there is presently no universally accepted system for naming strains within a species.

As domestication of aquatic species progresses, one can expect more genetically distinct strains will emerge. These strains may emerge through the simple act of domestication and restricted gene flow among farms or through breeding practices, such as selective breeding, chromosome-set manipulation (polyploidization and sex reversal), hybridization and/or gene transfer.

The strains registry can be used as a source to locate fish with specific characters, e.g., red tilapia, and to track genetic improvement technologies. However, by recording the number of breeding individuals in the strain, the registry can also serve as a watch list for potentially threatened strains, similar to the World Watch List for Domestic Animal Diversity (Scherf 1995), where endangered breeds/strains can be recorded and flagged for immediate conservation efforts.

Fields

The STRAINS table includes the following fields:

For cultured strains, the strain description is found in the STOCKS table where it is labeled **Stock definition**. It designates the name of a strain and describes its original year of transfer, and size of founder stock.

Country: Refers to the country where the strain is found.

StrainCode: A unique combination of letters and a 3-digit number. The first two letters refer to the first two letters of the genus; letters 3-5 refer to the first three letters of the species; letters 6-7 refer to the first two letters of the subspecies. The number is sequential. If no subspecies exists, the letters 6-7 are XX. For hybrids, the letters 6-7 are HX.

Trait: Refers to the character(s) or trait(s) that distinguish a strain from its founding stock. The choices are the same as in the GENEDAT table.



*FishBase can
accommodate hybrids*

Size of founding stock: Refers to the number of founding members comprising the original population.

Breeding strategy: Refers to the method of propagation of the stock and includes chromosome manipulation (polyploidization and sex reversal), selective breeding, hybridization, gene transfer, and normal mating.

Viability (Y/N)?: Refers to whether the strain is reproductively viable. For example, a strain of all female triploid trout would not be able to reproduce.

Female: The number of female founding members in the original population.

Male: The number of male founding members in the original population.

Number of broodstock: Refers to the *current* number of fish used as breeders and helps determine the conservation status of and threat of extinction to the strain.

Year of first breeding: Refers to the year when the founder stocks first reproduced.

Source of founding stock: A choice list of the environment: wild or captive and the site where the founder stock came from. The Country is also given here.

StrainCode of source: Refers to the StrainCode of the stock from which the founding specimens were obtained.

Year of arrival: Refers to the year the founder stock arrived at its new site or locality.

Availability of strain: Refers to where the strain is being used and how it may be acquired.

Status

To date, the strain registry is only preliminary: its records have not been checked and it includes only slightly over 70 strains of tilapia and carp.

Sources

Important references used so far are Khater and Smitherman (1988), Pullin (1988), Pullin and Capili (1988), Komen (1990) and Eknath et al. (1993).

We are planning to document more hybrids and improved genetic strains, following the design of the Trout Strain Registry of Kincaid and Brimm (1994).

How to get there

Clicking on the **Biology** button in the SPECIES window, the **Genetics** button in the BIOLOGY window, then the **Strains** button in the following window brings you to the STRAINS table.

If strains are recorded for a particular species, clicking on the **Biology** button in the SPECIES window will produce a list containing the species in general and the cultured strain(s). You get to the BIOLOGY window after selecting a particular strain.

Internet

The STRAINS table was not yet available on the Internet in November 2000.

Acknowledgments

We thank Liza Agustin, Ambekar E. Eknath, Harold Kincaid, Wolfgang Villwock and Ulricke Sienknecht for their advice on the structure and contents of this table. We thank Harold Kincaid for giving us a copy of the National Trout Strain Registry Software.

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The CULTSYS Table

Knowledge on the culture performance of fish in various aquaculture systems is useful to assess the suitability of species for aquaculture and to help identify appropriate aquaculture methods and culture systems for these species.



The main purpose of the CULTSYS table is to summarize data on aquaculture experiments. The table contains information on the experimental systems and includes physico-chemical parameters, quality and quantity of nutrient inputs and production by species (see also the 'CULTSPEC table' below), thus providing a model for a form which scientists might follow when reporting aquaculture experiments.

Fields

The Country where the culture was conducted is given.

The Name of the farm, station or institute refers to the location where the experiment was conducted; details on Latitude, Longitude and Altitude may also be entered.

Year: Pertains to the date when the experiment was conducted.

Type of culture: Refers to mono- or a polyculture, i.e., whether one or several species are cultured in the same pond.

Sex: Refers to classification of fish used in aquaculture. Choices include: monosex male; monosex female; mixed sex.

Semi-intensive culture systems are more sustainable

Culture system I gives a broad classification of the culture system with the choices: intensive (high density, food added); semi-intensive (medium density, no food but fertilizer added); extensive (low density, nothing added); experimental.

Culture system II gives a more detailed description of the culture system with the choices: ponds; integrated farm pond system; sewage- (excreta and wastewater) fed system; rice field; raceways; static tanks; silos; cages; pens; farm dams; other (see Description of culture system).

The number of Production units is given including the Area (ha), Average depth (m) and the Volume of the experimental units (m³).

Main water sources are classified

Main water source: Describes the main water supply. The choices are: rainfall; spring; river/creek; lake; reservoir; estuary; lagoon; ocean; groundwater; tap water; cooling water; sewage; other (see Description of culture system). The Supplemental water source offers the same choices as in the main water source.

The physico-chemical parameters present values for Temperature, Salinity, pH, Oxygen (mg·l⁻¹), Oxygen saturation (%) and Alkalinity (mg·l⁻¹ CaCO₃). Ranges are entered in separate lower and upper limit fields and in most cases, the mean or midrange of the available values is calculated.

Description of culture system: Accommodates more detailed description of the whole culture system and water source(s).

Main food: Refers to major source of nutrition. Choices are: *in-situ* production; *in-situ* production plus added feed; only added feed.

Feed quantity: Refers to the total amount of feeds added in kilograms in either wet weight or dry weight.

% BWD: Pertains to the dry weight of feed provided in % of the wet weight of fish fed per day.

Feed quality: Refers to the percentage protein content in dry weight.

Nitrogen and Phosphate fertilizer inputs are given either by $\text{kg}\cdot\text{ha}^{-1}$ or $\text{kg}\cdot\text{ha}^{-1}\cdot\text{day}^{-1}$.

Description of nutrient input presents a detailed description of the main food, including diet composition, food conversion, etc., in a text field.

Comments: For miscellaneous comments not addressed by fields available.

Production: unit cycles (kg/m^2 , kg/m^3 , $\text{kg}/\text{m}^3/\text{d}$ and $\text{kg}/\text{m}^2/\text{yr}$); production period in days as well as production cycles are also given.

Status

Although the number of farmed finfish (under 200) is relatively small, there is a huge amount of aquaculture data available in journals, reports, etc. Progress in entering such data has been hampered by the lack of standardization in aquaculture experiments. These constraints are being addressed by increased efforts to document and to standardize data and by providing species profiles (see below).



The USAID-funded Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) has made considerable progress towards the standardization of pond experiments (Szyper 1992). Agustin et al. (1993) have provided some formats for documentation of genetic resources for aquaculture.

Sources

To date, the CULTSYS table contains over 300 records of aquaculture experiments for about 15 species and strains, obtained mainly from the following references: Hopkins and Cruz (1982), Costa-Pierce and Soemarwoto (1990) and Christensen (1994). Most of the data have not yet been checked. However, the data of Costa-Pierce and Soemarwoto (1990) have been entered under the supervision of Barry Costa-Pierce and the fields have been reviewed by him. Similarly, the data of Hopkins and Cruz (1982) have been further verified and analyzed by Mark Prein (Prein 1990; Prein et al. 1993) and entered under his supervision. Other aquaculture datasets such as those of van Dam (1990) and the USAID-funded PD/A CRSP will be included in the future.

How to get there

Clicking on the **Biology** button in the SPECIES window, the **Fish as food** button in the BIOLOGY window, then the **Aquaculture** button in the following window will open the CULTURE SYSTEM form.

Internet

The CULTSYS and CULSPEC tables were not yet available on the Internet in December 2000.

Acknowledgment

We thank Liza Agustin for her contributions to this table and to a previous version of this chapter, while a member of the FishBase Team.

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The CULTSPEC Table

Since culture experiments often involve more than one species, production by species is reported in this sub-table with one record per species used. Included in this table are the stocking practice, culture period, harvesting practice, mortality during the culture period and the gross yield per production cycle. The fields are described below:

Fields

Stocking rate: Refers to the amount of fish at the beginning of the culture period. The choices for the unit are: no./m²; no./m³; no./m³/d; kg/m³. This refers only to the species considered in this record.

Total stocking: Refers to the total initial biomass of the considered species, in kg.

Stocking length: Refers to the modal or typical length of individual fish at the time of stocking, in cm. Type of length measurement is also given (SL, FL, TL or OT).

Stocking weight: Refers to the modal or typical weight of individual fish at the time of stocking, in g live weight.

Stocking age: Refers to the average age of the stocked fish, in days. This is important because of old, stunted fish that might grow very slowly and might start to breed at small sizes.

*The CULTSPEC table
accommodates data from
polyculture experiments*

Method used for estimation: Refers to the method used for growth. Choices include: Ford/Walford plot, von Bertalanffy/Beverton plot, Gulland and Holt plot, non-linear regression, ELEFAN I and other methods.

The von Bertalanffy growth parameters (L_{∞} , K) are given as the preferred measure for growth in length. These are described in more detail in a separate table (POPGROWTH table, this vol.), which distinguishes between fish grown in 'captivity' and in 'open waters' (see also Box 16 and Fig. 21).

Culture period: Refers to the duration of production from, e.g., fingerlings to marketable size, in days.

Harvesting practice: Refers to the method used in harvesting the stocked fish. Choices are: batch culture; continuous stocking and harvesting; periodical stocking and harvesting; periodical stocking and continuous harvesting; variable.

Harvesting length: Refers to the modal or typical length of individual fish at harvest, in cm.

Harvesting weight: Refers to the modal or typical weight of individual fish at harvest, in g.

Mature: Indicates how many fish are mature at harvest with the choices: most; some; none.

Mortality (M%): Refers to the losses encountered during the production period, in %, computed as follows:

$$M\% = (N_0 - N_t) \cdot 100 / N_0 \quad \dots 1)$$

where N_0 is the number of fish at the beginning, and N_t the number at the end of period t.

Also, the Annual mortality rate (Z) is calculated as follows:

$$Z = (\ln(100) - \ln(M\%)) / (\Delta t \cdot 365) \quad \dots 2)$$

where M% is as defined, and Δt = production period, in days.

The Specific growth rate (in %) is calculated as follows:

$$\ln(\text{harvesting weight} - \text{stocking weight}) \cdot 100 / \Delta t.$$

Gross yield: Refers to the total yield per production cycle in wet weight. Yield per cycle here and below can have one of the following units: $\text{kg}\cdot\text{m}^{-2}$, $\text{kg}\cdot\text{m}^{-3}$, $\text{kg}\cdot\text{m}^{-3}/\text{d}$, $\text{kg}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$, $\text{kg}/\text{m}^3/\text{y}$.

Net yield is the Gross yield minus the biomass at stocking.

Extrapolated yield gives the hypothetical gross yield that would have been obtained had conditions remained the same and the production period lasted 365 days.

Comment: A field for miscellaneous remarks not addressed by other fields.

Status

This table currently holds over 550 records. A graph is available which distinguishes the growth patterns of captive fishes from those of fishes in open waters (see Fig. 21).

Sources

There is a huge amount of literature dealing with aquaculture. Extracting usable information from this is quite difficult because there is a lack of standardization in the experiments. Note also that most of the references used in this table deal with freshwater fishes.

How to get there

Clicking on the **Biology** button in the SPECIES window, the **Fish as food** button in the following window, the **Aquaculture** button in the BIOLOGY window and then the **Cultured species** button in the CULTURE SYSTEM window will bring you to this table. A list of species studied (for polyculture systems) is given and selecting a particular species and clicking on the **Production** button will give detailed information on yields. The graph in Fig. 20 is accessible from the Graphs Menu under Population Dynamics.

Internet

The CULTSYS and CULTSPEC tables were not yet available on the Internet in November 2000.

Acknowledgments

We thank Barry Costa-Pierce, Mikkel Christensen, Mark Prein and Anne van Dam for providing their data for distribution through FishBase and for their suggestions on how to improve the CULTSYS and CULTSPEC tables. We thank Liza Agustin, former member of the FishBase Team, for her contributions to this table and to a previous version of this chapter, while a member of the FishBase Team.

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Aquaculture Species Profile

FishBase Team members have found difficulty in presenting, in a concise and standardized format, core information on the use of fish species on aquaculture. The available literature often lacks the quantitative data and the standard protocols, terms and units necessary for straightforward comparisons. Moreover, it often reports research and development trials rather than established farming operations. We have also found that it takes too much time to sort through and to summarize this information for entry in the CULTSPEC and CULTSYS tables of FishBase. Therefore, to broaden the aquaculture coverage of FishBase, we decided to develop Aquaculture Species Profiles: 'mini-essays' of up to 1,000 words for each species, using free text but with a standardized



Mini-essays on aquaculture

structure. Much of this information will later be transferred to dedicated fields in various tables.

An example is given here for a tilapia, *Sarotherodon melanotheron*. We are seeking authors to write one profile for each of the other species of fish that are cultured around the world. Full credit is given to author(s). Pictures of fish and farming operations, etc. can be included. Suggestions for improving the format for profiles and for updating the example below are also welcome.

Write a mini-essay . . .

FishBase 2000 contains aquaculture profiles for seven species, including catla (*Catla catla*), milkfish (*Chanos chanos*), mrigal (*Cirrhinus mrigala*), rohu (*Labeo rohita*) and the tilapias *Oreochromis shiranus* and *Tilapia rendalli*. Prospective authors for profiles on other species should check with FishBase to see whether work on these is already in progress. Please volunteer to cover those species for which you have good knowledge and access to information.

Example of an Aquaculture Species Profile:

Scientific Name: *Sarotherodon melanotheron* Rüppell, 1852.

For aquaculture, note that there are five subspecies with different characteristics: *Sarotherodon m. melanotheron* Rüppell, 1852; *Sarotherodon m. heudelotii* (Duméril, 1861); *Sarotherodon m. leonensis* (Thys van den Audenaerde, 1971); *Sarotherodon m. paludinosus* Trewavas, 1983 and *Sarotherodon m. nigripinnis* (Guichenot 1861); full descriptions and a synonymy are in Trewavas (1983).

Common names: English - black-chinned tilapia (somewhat confusing as melanic patterns on the head and body are variable among and within subspecies); French - carpe (also confusing; used only in Côte d'Ivoire).

History of use: Used for centuries as a food fish; found in West African brackish waters and adjacent freshwaters (mainly lagoons, estuaries, the lower reaches of rivers and neighboring lakes and reservoirs) from Senegal to the Democratic Republic of Congo; a popular aquarium fish, first imported to Europe in 1907; its potential for aquaculture was ignored until recent attempts were made to adapt for extensive aquaculture the highly productive traditional brushpark fisheries or 'acadjas' (brushwood bundles in shallow lagoons, that attract fish and provide shelter and abundant food, especially periphyton) from which large quantities of this species are harvested (7-20 t·ha⁻¹·year⁻¹ of fish from 20 to 560 g) (Hem and Avit 1996); other pond, cage and enclosure trials had proven unsuccessful, except for producing small fish around 50 g (indicative growth data for manured and supplementary-fed ponds, 0.5- 0.7 g · day⁻¹ up to 25-35 g with stunting thereafter, net annual production, 1.9-3.5 t/ha; cages, 0.5 to 0.7 g·day⁻¹ up to 50-60 g and 0.1-0.2 g·day⁻¹ thereafter); such trials, in Benin, Côte d'Ivoire and

Nigeria used *Sarotherodon m. melanotheron*; very recent work in Côte d'Ivoire (Agnèse 1996; Gilles et al. 1998) has shown much faster growth (more than 2 g·day⁻¹) in fish that originated near Dakar, Sénégal, presumably *Sarotherodon m. heudelotii*, or *Sarotherodon m. paludinosus*; these were grown to over 200 g in six months, with a feed conversion ratio (weight of food given : wet weight of fish harvested) of 1.7.

Production statistics: none yet available.

Where farmed: Region - West Africa, FAO Area Africa-01, Inland

Countries: Benin, Côte d'Ivoire, Ghana, Nigeria and Sénégal, and probably others in this region, all on a limited scale.

**Cannot reproduce
below 20 °C**

Climate and Environmental Tolerance: tropics; natural temperature range 17-33°C; cannot reproduce below 20-23°C; wide salinity tolerance, 0-45 ppt, prefers 10-15 ppt; relatively acid-tolerant, grows and reproduces at pH 3.5-5.2 over acid sulfate soils (Trewavas 1983; Campbell 1987); information is lacking on lethal limits; these and tolerance ranges probably vary among subspecies and populations.

Current farming methods: Hatchery methods still under development; reproduces readily in enclosures, ponds and tanks; monthly fry (1 g) production of 200,000 to 250,000 achieved from a raceway system; a spawning female produces 200-900 eggs; size at first sexual maturity is variable among populations, from 4.0-4.5 cm SL for stunted populations to 13.4 cm; male parent normally mouthbroods the eggs and larvae; fry feed mainly on plankton (progressively more zoo- than phytoplankton) detritus and aquatic larvae; diet thereafter is omnivorous, including detritus (Pauly et al. 1988 quantified this detritivory and compared growth parameters), plankton, invertebrates and plant material, especially periphyton; fry readily accept feeds based on cereal bran, peanut cake, fishmeal and vitamins (Campbell 1987).

Grow-out methods are under development for ponds, cage and enclosure systems; adults readily accept agricultural by-products and feeds in powdered, mash or pellet form (Campbell 1987).

***Sarotherodon melanotheron*
could enter global
tilapia markets**

Processing and Marketing: No summary information available; assume main products are fresh, whole, ungutted fish or whole smoked or dried fish; value-added products, such as fillets, are expected if intensive systems are developed; large fish (>350 g) and value-added products could enter global tilapia markets; smaller fish (ca 50 g) are important in domestic markets.

Likely Future Trends: Could become important in aquaculture in West Africa, if systems under development fulfill early promise; of interest for brackish water aquaculture in other regions because of its wide salinity tolerance; for this, adequate appraisals of possible

environmental impacts are essential prior to introductions given former bad experiences with tilapia introductions (*Oreochromis mossambicus*); thorough documentation of the characteristics of different subspecies and populations, and their conservation for use in breeding programs, are needed.

How to get there

You get to this and a few other profiles by clicking on the **Importance** button in the SPECIES window and the **Profile** button in the IMPORTANCE window.

Internet

On the Internet, you get to the Aquaculture Profiles by clicking on the respective link in the 'More information' section of the 'Species Summary' page. You can create a list of all species with available profiles by selecting the **Aquaculture profiles** radio button in the 'Information by Topic' section of the 'Search FishBase' page.

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- Roger S.V. Pullin**

The DISREF and DISEASES Tables

Diseases are a major problem in intensive aquaculture, in the aquarium trade, and in polluted bays, lagoons, or inland waters. Computers can help to diagnose fish diseases, similar to their use in fish identification (see the 'LARVAE table', this vol.).

Sources

The DISREF table was originally developed by Imke Achenbach and Rainer Froese (Achenbach 1990; Achenbach and Froese 1990). It contains 314 descriptions of diseases or stages of diseases extracted from more than 200 references. About 150 macroscopic symptoms have been identified that can be used as diagnostic criteria. It has been shown that the information collected so far can be used to diagnose Northern Hemisphere diseases of marine and aquaculture species (Achenbach and Froese 1990).

Recently Heino Möller gave us permission to use photos from his books and slide collections (Möller and Anders 1983, 1986, 1989),

thus increasing the number of disease pictures from 3 to 267 (see under Pictures).

Status

Two experts, Toshihiko Matsusato and Brian Jones, kindly looked at parts of the information collected so far and we incorporated their suggestions and corrections. However, we feel that the table is still in a prototype stage and do not recommend it for routine use. Rather, we would appreciate if an institution working on fish diseases would take over the responsibility for this and the following table—either completely or for certain groups of diseases only—and subject the tables to thorough testing and further development.

The DISEASES table contains reported occurrences of diseases. For each case it states the affected **Species, Disease, Country and Locality, Year, Prevalence, Intensity, Mortality** and additional information. It contains 218 records of 148 diseases reported for 38 species.

As mentioned for the DISREF table above, the table is still in a prototype stage and is not recommended for routine use. We plan to further develop this table in collaboration with FAO. For more information, please contact the FishBase Project.

How to get there

To get to the DISREF table, you click on the **Biology** button in the SPECIES window, the **Morphology and physiology** button in the BIOLOGY window, the **Diseases** button in the following window and the **More information** button in the DISEASE window.

To get to the DISEASES table, you click on the **Biology** button in the SPECIES window and the **Diseases** button in the BIOLOGY window.

Internet

The DISEASES tables are not yet available on the Internet.

Acknowledgments

We thank Heino Möller and Kerstin Anders for making their collection of disease pictures available through FishBase.

References

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Rainer Froese

The ABNORM Table

Deformities were the focus of the literature review, which this table is based upon. It includes compiled data from both laboratory

experiments and field studies. A review by Weis and Weis (1989) was the source of much of the information from laboratory field studies. The aim of the study was to relate fish abnormalities to environmental quality.

This table was developed to bring together prevalences of specific externally visible abnormalities in fish populations, as reported from field studies, and causal agents of specific abnormalities, as reported from laboratory experiments. The table provides examples of the use of fish abnormalities as environmental indicators, and, where possible, provides information linking these same abnormalities to agents of environmental degradation. Information provided for each record in the table includes species, life stage, geographic location, time of year, locality, type of abnormality, the prevalence (mainly from field studies), stressor or suspected stressor (usually only known with certainty from laboratory studies), concentration (only for lab studies), primary reference (immediate source of information) and a secondary reference (original source of information). In addition, notes are provided to expand on or clarify information given in a record.

How to get there

To get to the ABNORM table, you click on the **Biology** button in the **SPECIES** window, the **Morphology and physiology** button in the **BIOLOGY** window and the **Abnormalities** button in the following window.

Internet

The ABNORM table was not yet available on the Internet in November 2000.

Reference

Weis, J. and P. Weis. 1989. Effects of environmental pollutants on early fish development. *Aquat. Sci.* 1(1):45-73.

Neysa Foy

Other Tables

The ECOTOXICOLOGY Table

This table contains information on the susceptibility of fish to various chemicals, as measured by the concentration that leads within a certain period, to the death of 50% of the test fish i.e., the lethal concentration (LC₅₀).



Fish are commonly used for bioassays

Tests of this sort are routinely conducted to assess the toxicity of various chemicals that are (to be) released into the environment (hence 'ecotoxicology') and fish are commonly used for such bioassays, which are typically conducted for periods of 24, 48 or most commonly 96 hours.

The table was designed to capture the essential features of such experiments, as reported in the ecotoxicological literature, and consists of 3 parts, dealing with (i) the fish, (ii) the substances tested and (iii) the experimental conditions and results. The fields in each of these parts are as described below.

Fields

Species and family: The scientific name and affinities of the test fish.

Number: Indicates the number of specimens used in the experiment.

Sex: A choice field with options: females; males; undefined (default).

Weight: Indicates the minimum, maximum and mean or modal weight (in g) of the fish used in the experiments.

Length: Indicates the mean or modal size. The length type is generally not indicated in the ecotoxicological literature, and is thus omitted here; when available, it is indicated in the **Comment** field (see below).

Stage: Indicates the stage of development of the fish used. The choices are: eggs, larvae, juveniles, adults, juveniles/adults (default).

Fields describing the test substances:



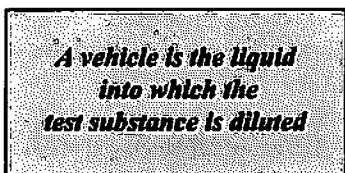
Chemical substances are classified into major groups

Chemical group I: Enables a rough classification of chemical substances commonly tested. The choices are: hydrocarbon, metal, amine, organophosphate, carbamate, organic acid, alcohol, dioxin, dibenzofuran, polychlorinated biphenyl, alkylbenzene, phenol, chloroaniline, cresol, azocompound, bipiridyl, organometallic, inorganic, other group.

Chemical name: A free text field for the precise identification of the test substance.

Common name: A free text field for the generic or commercial name of the test substance.

Chemical group II: Enables a finer classification of test substances and presently consisting of 18 groups (e.g., aliphatic hydrocarbon; aromatic hydrocarbon; polynuclear aromatic hydrocarbon; chloroethane; chlorobenzene; pyrethroids; organochlorines; other groups). More options are likely to be added as the database grows.



Vehicle: A choice field for the liquid into which the test substance is diluted; the choices are: water; acetone; methanol; ethanol; none; other. In case 'other' applies, the vehicle is mentioned in the comment field.

Purity I: Refers to the purity of the test substance in %.

Purity II: Refers to the purity of the test substance, as expressed by the choices: reagent; technical; practical; mixture (see Comments); formulation; other (see Comments).

Use: Describes the use for which the test substance is put or intended: pharmaceutical; food additive; propellant; dielectric fluid; bactericide; fungicide; herbicide; insecticide; antibiotic; other.

Fields describing the experimental conditions and results:

Temperature: A numeric field, with °C as unit.

pH: A numeric field for entries without units and ranging between 2 and 14.

Salinity: A numeric field for entries ranging between 0 and 40 ppt.

Dissolved oxygen: A numeric field for entries, in mmHg and/or mg·l⁻¹.

O₂ saturation: A calculated field for 100% and actual oxygen saturation, based on the entries in the dissolved oxygen, temperature and salinity fields.

Alkalinity: A numeric field for entries, in CaCO₃·l⁻¹.

Flow: Indicates whether or not water flow was maintained through the test chamber.

Flow rate: A numeric field, to be filled, when the Flow field is 'yes', with an entry in ml · hour⁻¹.

Bioassays are often combined with stresses

Applied stress: Describes stresses other than the test substance itself, to which the test fish may be exposed prior to, or during the experiment. The choices are: none specified; temperature (too high or too low); photoperiod; feeding; starvation; toxins; hypoxia; hypercapnia; salinity; high pH; low pH; sedative; transparent; other stresses (to be specified in the Comments field).

LC₅₀: Presents the result of an experiment, and the key information in this table, in mg·l⁻¹.

Exposure time: Specifies the time for which the above LC₅₀ applies, in hr.

MainRef: A reference from which the LC₅₀ and related information were extracted.

Comments: A text field, for complementing the information included in the above fields.

It is hoped that this table will reduce the need for further LC₅₀ experiments

The table presently contains about 1,500 records, pertaining to over 300 substances and involving over 100 test species of fish, extracted from nearly 200 references (see pie charts accessible from the Graph Menu). This is but a small fraction of the available information, and we plan to expand our coverage, notably by inclusion of the many fish records cited in Ramamoorthy and Baddaloo (1995). Also, we would appreciate receiving reprints covering species or substances not yet covered. It is hoped that this table will at some point allow for generalizations that would explain the different susceptibilities of fishes to different substances and thus reduce the need for further LC₅₀ experiments.

How to get there

You get to the ECOTOXICOLOGY table by clicking on the **Biology** button in the SPECIES window and the **Ecotoxicology** button in the BIOLOGY window. The internal name of the table is LC₅₀.

Internet

The ECOTOXICOLOGY table was not yet available on the Internet in November 2000.

Reference

Ramamoorthy, S. and E.G. Baddaloo. 1995. Handbook of chemical toxicity profiles of biological species. Vol. 1. Aquatic species. CRC Press, Boca Raton, Florida. 386 p.

Cristina Bárcenas-Pazos

The CIGUATERA Table

Approximately 50,000 people are poisoned annually by ciguatoxic seafood

Ciguatera, first recognized in the 1550s in the Caribbean (NRC 1999), is a form of ichthyotoxism caused by the consumption of mainly reef fish contaminated with the ciguatoxin class of lipid soluble toxins. An estimated 50,000 victims worldwide annually are reported with 20,000-30,000 cases of ciguatera in the Caribbean in Puerto Rico and U.S. Virgin Islands (Anon. 1997; Bomber and Aikman 1988/89 cited in NRC 1999). Only 20-40% of cases are estimated to be reported (NRC 1999). The toxins

causing ciguatera have been identified by the primary vector, the dinoflagellate *Gambierdiscus toxicus*, an epiphyte living on a range of calcareous macroalgae and other substrates on coral reefs. *G. toxicus* is widely distributed on coral reefs and lagoons but is most prolific in shallow waters (3-15 m) away from terrestrial influences. Herbivorous reef fish browsing on reef algae ingest *G. toxicus* and concentrate the ciguatoxins in the gut and muscle tissue. Piscivorous reef fish may then become toxic through the consumption of herbivorous fishes and the concentration of the toxins up the food web. Other benthic dinoflagellates such as *Prorocentrum*, *Ostreopsis* and *Coolia* are also linked to ciguatera outbreaks (Tosteson et al. 1988; NRC 1999).

Ciguatoxins are not destroyed by cooking and no routine tests are performed to identify contaminated fish, or to predict the timing or occurrence of ciguatera outbreaks on reefs. Ciguatera poisonings are characterized by a range of often severe gastrointestinal and neurological symptoms. Intoxicated individuals may experience diarrhea, vomiting, lethargy, numbness, reversal of temperature perception, itching, tingling and muscular pains. Some of these symptoms such as itching and muscular pain may persist for several months. A recurrence of neurological symptoms may be brought on by consumption of alcohol or certain foods such as other fish, fish-flavored food products, peanut butter, and meat such as chicken and pork. A thorough review of the clinical, epidemiological and ecological aspects of ciguatera has been given by Lewis and Holmes (1993).

Ciguatera is rarely fatal...

The occurrence of ciguatera is documented in the central Pacific and the Caribbean. Ciguatera is rarely fatal and in most areas, local people know where ciguatera 'hotspots' occur and which species of fish are likely to be contaminated at certain times of the year. However, there have been increasing reports of the occurrence of ciguatera poisoning in places especially in Asia, which are outside the range where this disease normally occurs. It is speculated that these cases are caused by fish obtained from local traders in high-risk areas in the Pacific and brought to markets such as Hong Kong without proper verification of its origin. Over 400 persons experienced ciguatera poisoning in 1998 in Hong Kong (Sadovy 1999). Even if such cases remain rare in a large market such as Hong Kong, they pose a real threat to the commercialization of fish as a whole, as wary consumers might become reluctant to purchase any fish, if they cannot be assured that it is free of ciguatera toxin. A number of trade regulations, e.g., United States Food and Drug Administration, 1999 Food Code-HACCP guidelines and the European Communities Directive 91/493/EEC address the trade of species that are affected (Sadovy 1999).

So far, little attempt has been made to document systematically the occurrence of ciguatera. Most information on ciguatera from the Pacific has been reported through epidemiological records from hospitals, which simply report the number of cases of fish poisoning treated in a given year. Accurate documentation of

ciguatera case histories has been confined in the past mainly to French Polynesia, Australia and Hawaii.

In 1990, the then South Pacific Commission (SPC, now called Secretariat of the Pacific Community) commenced collecting detailed case histories of ciguatera poisonings from the Pacific Islands and summarizing these in a database format (Dalzell 1992, 1993). Brody (1972) and Olsen et al. (1984) provide an overview of the ciguatera problem in the Caribbean.

FishBase summarizes published reports on fish species, which have been observed to have caused ciguatera poisoning in given countries. As mentioned above, the occurrence of ciguatera contamination in fish is usually very localized, thus the inclusion of a fish species in the listing should in no way be interpreted as *all* fish of that species in the mentioned country being unfit for human consumption.

In addition to published records, FishBase also has incorporated parts of the SPC database on case histories in the Pacific area to provide more detailed information on the possible causes and effects of ciguatera poisoning. Reporting of these case histories, however, has been uneven, with many case histories reported from Tuvalu and New Caledonia, but with few, if any, from locations such as the Marshall Islands and Kiribati, which are known to have chronic problems with ciguatera outbreaks.

Fields

A ciguatera occurrence record for a given fish species contains the following fields:

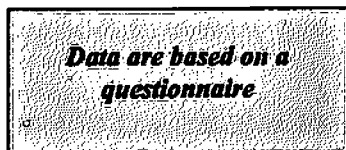
Country: The name of the country where the ciguatera poisoning was observed.

Distribution: An indicator of the geographic dimension of the problem at national level with the options being: nation-wide; regional; localized; or not stated in the absence of any such information.

Frequency: An indicator of the frequency with which the occurrence of ciguatera is observed in the species in question, the options being: frequent; occasional; rare; or not stated in the absence of any such information.

Remarks: Any additional information that allows identifying more precisely the locality within a country from where the specific record originated.

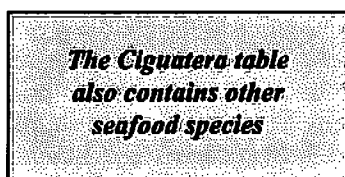
If the selected record is part of the SPC database (Dalzell 1992, 1993), clicking on the button **More Information** gives access to the additional information provided through this database. The various fields in the database contain replies to a questionnaire conducted with persons who have become sick after eating a fish or other marine organism (though records from non-fish species have been omitted from the listings provided in FishBase).



The questionnaire had been structured around the following topics: Type of food, type of locality from where the offending food item originated, how the food item had been preserved, which part of it was eaten, and in what way it was prepared, as well as general information such as date and number of people who became affected.

Clicking on the button **Symptoms & Medical data** provides, if available, detailed information on 18 symptoms reported by patients (such as burning/pain when touching cold water; tingling/numbness sensations; difficulty in breathing, walking; or talking; skin itching; diarrhea; vomiting; etc.).

Status



FishBase contains some 350 records of individual fish species being reported as (potential) carriers of ciguatera in specified countries. These records are comprised of published information in the literature and those from the SPC ciguatera database. The latter includes over 600 records, of which around 10% refer to non-fish species or organisms which have not been identified. These have generally been excluded from the listings as have, for the sake of clarity, multiple occurrences of the same combination of species and location. As stated earlier, the SPC database for the Pacific region is to some extent biased, as reporting has been very uneven, with over 50% of case histories coming from Tuvalu, and most of these from the island of Niutao. Part of the problem in obtaining case history records lies in the blurring of responsibility for ciguatera outbreaks between fisheries and health administrations in the Pacific Islands. Further, ciguatera is not seen as a priority health issue in most locations and only generates concern in fisheries administrations when it has a detrimental influence on export of fish to metropolitan countries.

Where possible, local species names have been translated into their scientific equivalent, although in many instances, a local name refers to a genus or family of fish rather than species. This is one of the reasons why the CIGUATERA table is not only linked with the SPECIES table, but also with the FAMILIES and COUNTRY tables. The SPC will update this database as new cases from the Pacific Islands accumulate. Moreover, the FishBase Team invites colleagues working in the Caribbean to contribute records that would allow this database to expand, and eventually, to cover all areas of the world where ciguatera occurs on the 'Search FishBase' page.

How to get there

In the FishBase CD-ROM version, the CIGUATERA table can be accessed in several ways:

1. By clicking on the **Biology** button in the SPECIES window, the **Fish as food** button in the BIOLOGY window and the **Ciguatera** button in the subsequent window. If more than one record of ciguatera occurrence exists for the selected species, a table will appear from which any of the available records can be selected by double-clicking on the record.

2. By clicking on the **Range** button in the SPECIES window, the **Countries** button in the STOCKS window, double-clicking on a country of interest, then clicking the **Country Info** button in the COUNTRIES window and the **Ciguatera** button in the COUNTRY INFORMATION window.
3. By clicking on the **Family** button in the SPECIES window and the **Ciguatera** button in the FAMILIES window to obtain a list of all species belonging to the selected family that had occurrence of ciguatera contamination reported.
4. By clicking on the **Species** button in the Main Menu, the **Topics** button in the subsequent SEARCH BY window and selecting the **Ciguatera** button in the SEARCH SPECIES BY TOPIC window. The search can optionally be limited to any combination of country, order and family.

When within the CIGUATERA table, clicking on the **Map** button shows all countries highlighted, where the selected species has been reported as carrier of the ciguatera toxin. Note that these countries are usually small island states and thus barely visible on the scale of a world map. Using the zoom function provided in WinMap might be necessary for better viewing.

Internet

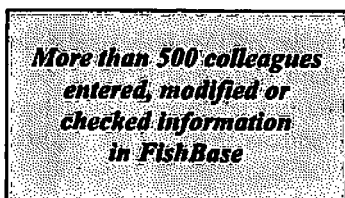
In FishBase on the Web, click on the **Ciguatera** radio button in the 'Information by Topic' section.

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Jan Michael Vakily, Grace T. Pablico and Paul Dalzell

The COLLABORATORS Table



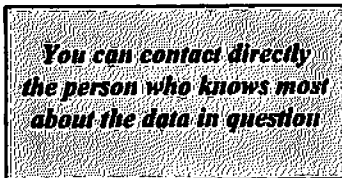
Data in FishBase have been entered, modified, or checked by about 500 FishBase staff and collaborators (see Fig. 2). In order to keep track of who did what and thus be able to give credit and to ask the right person for clarification, each FishBase record has a 'stamp' with the following format:

Entered : 02 19/03/91

Modified: 18 28/04/94

Checked : 01 03/06/94

where, in this example '02' stands for Susan M. Luna who entered the information on 19 March 1991, '18' is Liza Q. Agustin who modified the record on 28 April 1994, and '01' is Rainer Froese who verified the information in the record on 3 June 1994. This stamp can be accessed by clicking on the **Status** button in the footer of any record. Double-clicking on the **Collaborator number** opens the COLLABORATORS table which gives the Name (and photo, if supplied), Institute, Address, Telephone, Fax, E-mail and a description of what the collaborator contributed to the project.



The COLLABORATORS table is also intended to enable FishBase users to directly contact the person who knows most about the data in question, i.e., normally the one who checked or entered it, or the author(s) of the appropriate section of this book.

Help

Remember that to date only about half of the records in the SPECIES table have been checked, and much less in other tables. If you volunteer to help us in this task, please print the record in question, write your corrections or 'okay' on it—preferably in red ink—and mail it to us. We will make the corrections in FishBase and put your name, address, etc. (please provide) in the COLLABORATORS table. If your contribution is substantial, we will also send you a free copy of the FishBase CD-ROM.

How to get there

You get to the COLLABORATORS table by clicking on the **Collaborators** button in the FishBase Main Menu, or in the SPECIES window, or by double-clicking on the **Collaborator number** accessible in any record under the **Status** button.

Internet

On the Internet, you can access the COLLABORATORS table by clicking on the name of a collaborator as shown in the footer of most data pages. You can create a list of collaborators either in the 'Information by Country/Island' or 'Information by Topic' sections of the 'Search FishBase' page, by selecting the respective radio button.

Rainer Froese

The REFERENCES Table

FishBase is a scientific database; this implies that its contents, like that of a scientific paper or book are linked via references to prior scientific knowledge, which enables both verification and the attribution of credit to the cited author(s). The references are usually not directly cited in the body of the FishBase tables. Rather, it is a 'Ref.' number (or **Main Ref.**) that is cited, i.e., a sequential number itself linked with a full reference, consisting of fields for: **Author(s)**' name(s) and initials, **Year**, **Title**, **Source**, **Keywords** and **Cross references**.

Fields

Author(s), **Year**, **Title** and **Source** fields follow scientific conventions for such citations, while the **Cross references** field contains reference numbers of other pertinent references used within FishBase. If you double-click on a cross-reference, the respective record will show up. **Keywords** are summarized into 50 yes/no categories covering the whole range of information that is available in FishBase.

Language fields are available for the text of each cited work. The following lists the languages that are differentiated here, and the percentage (in brackets) of references in each of these languages: English (83%), French (4.1%), Spanish 3.0%), German (1.5%) and other languages with less than 1%. About 4% of the references have not yet been classified according to the language of publication because the citation is incomplete (see below). The language can sometimes be deduced from the source. However, we opted not to assign any language in cases where the reference source was in a series published in more than one language, pending further verification.

Status

Journal articles and books comprise 83% of the references

References are also identified by type of the over 20,000 FishBase references: 62% were derived from journal articles; 14% from book chapters; 7% from books; 6% from reports; 2% from theses; and 9% from other sources.

The STATUS window (click on Status button) provides information on the availability, completeness and status of the reference. Three yes/no fields are provided (go to Status button) to indicate availability of the reference at ICLARM in general or as part of the extensive personal reprint collections of Daniel Pauly (DP) and Rainer Froese (RF).

Further, references are marked as either 'complete' or 'incomplete'. The latter may have one of the major fields blank or flagged as 'missing' or 'to be filled'. This usually pertains to references not seen, i.e., cited in some source material that is usually indicated in the cross-reference field. We shall strive to gradually complete such references, and invite you to assist us with this. Presently, 15% of the FishBase references are tagged as incomplete.

More than 20,000 references have been used in FishBase

In many cases, references were used for only part of the information they contain (e.g., the growth parameters were extracted from a paper also containing an account of say, food and feeding habits), the result of different FishBase staff having to specialize on various tables. A choice field with the options 'used in part'; 'used completely'; and 'not seen', identifies such cases which we will strive to gradually eliminate.

Over 150 publications cite FishBase

References that cite FishBase are also marked as such (not displayed in the user interface). There are over 150 references citing FishBase, 38% of which are publications by FishBase Team members and 62% are those of other colleagues, including in articles in *Nature* and *Science*. Graphs illustrating the cumulative

number of FishBase citations can be displayed by clicking on the **References** button in the Main Menu window, then on the **FishBase citations** button in the REFERENCES menu window and finally on the **Graph** button on the top right corner of the LIST OF REFERENCES CITING FISHBASE window.

The **All species treated** button in the REFERENCE INFORMATION window leads to a list of all the species that are treated in the reference and for which we have extracted information. Note that this list includes the name of the species used as valid in the reference along with its current valid scientific name (see also 'The BIBLIO Table' and section on 'Nomenclatural Changes' under the 'The SYNONYMS Table' chapter, this vol.).

Reports

References are added to long or short FishBase synopses and other FishBase outputs. Moreover, a routine was programmed to output all references by author, title, source, keywords, family or subfamily to facilitate checking and to evaluate the FishBase coverage of various fish groups or areas. This routine is accessible from the REFERENCES menu window (from the Main Menu) through the **Find references** button. You are welcome to send us reprints and reports from which you think we should extract information for incorporation in FishBase.



Note that starting with FishBase 98, we are making W.N. Eschmeyer's REFERENCES table available through FishBase. That table includes all original descriptions of fishes, and all revisions of the last 20 years. It sets a standard for the proper citation of original descriptions.

How to get there

You get to the REFERENCES table by clicking on the **References** button in the FishBase Main Menu, by double-clicking on any reference number within any table, or by making a list of references used for a species in the SPECIES table. The internal name of this table is REFRENS.

You get to Eschmeyer's references by clicking on the respective button in REFERENCES menu, or by double-clicking on the **Author** field in the SPECIES or SYNONYMS forms.

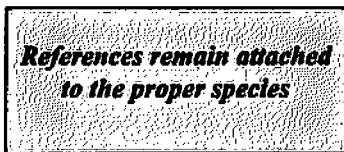
On the Internet, we show references by Author(s) and year in the various data pages. Click on the **reference** to see the full citation. All references used for a species are available if you click on the respective link in the 'More information' section of the 'Species Summary' page. In the 'Search FishBase' page, you can create lists of relevant references if you select the **References** radio button in the 'Information by Family' or 'Information by Country/Island' sections. In the 'References' section you can search several bibliographic databases (FishBase, Eschmeyer, Bibliga (=library of the ichthyology department of the Paris museum (MNHN), ICLARM's library, and the collection of contributions listed in Naga, the ICLARM Quarterly) by Author, Year, Title or Reference number.

Maria Lourdes D. Palomares and Daniel Pauly

The BIBLIO Table

The BIBLIO table provides a many-to-many link between the SPECIES and the REFRENS table, i.e., for each species it lists all the references we have used, and for each publication all the species for which we have extracted information.

We also included a field for the Name Used as Valid for a species in a given reference (not shown in the BIBLIOGRAPHY window but is available from the REFERENCE INFORMATION window through the All species treated button).



This close integration of synonyms and references ensures that publications remain attached to the proper biological species, even if the scientific name changes. It also allows us to print automatically updated lists of nomenclatural changes for our references, from Linnaeus (1758) onwards (see 'Nomenclatural Changes', below).

The BIBLIO table also includes a field for the page number where the species is dealt with and a field for citations, a feature that we have just started to explore.

How to get there

You get to the BIBLIO table by clicking on the **References** button in the SPECIES window. Double-click on a reference to get to the REFERENCE USED window containing details on the reference.

You get to the list of scientific names used as valid cited in the reference by clicking on the **More information on the reference** button in the REFERENCE USED window and then on the **All species treated** button from the REFERENCE INFORMATION window.

Internet

On the Internet, information from BIBLIO (page number, comment, citation, name used as valid) is shown in the 'Reference Summary' page if accessed from the 'Species Summary' page.

Acknowledgment

Credit is due to Emily Capuli for suggesting to record the Name Used as Valid, a very important improvement of the FishBase design.

Reference

Linnaeus, C. 1758. *Systema Naturae per Regna Tria Naturae secundum Classes, Ordinus, Genera, Species cum Characteribus, Differentiis Synonymis, Locis*. 10th ed., Vol. 1. Holmiae Salvii. 824 p.

Rainer Froese and Maria Lourdes D. Palomares

Nomenclatural Changes

A well-designed relational database is a powerful system and one of the few computer-based applications where you get more out than you have put in. For example, when the scientific name of the well-studied rainbow trout was changed from *Salmo gairdneri* to *Oncorhynchus mykiss*, it took us only 5 minutes to change the name in the SPECIES table, change the status of the old name in the SYNONYMS table and to enter a record for the new name.

*The power of
relational databases*

This simple change, however, updated the various checklists for 69 countries where the species occurs or has been introduced and linked 150 references, 57 common names, 21 synonyms and more than 1,000 records in 18 linked tables to the new valid species name.

*Automatic creation
of ERRATA*

FishBase does not only link references permanently to valid names, it also records the names that were originally used in a publication (see BIBLIO above). That allowed us to create a routine that lists all nomenclatural changes that the FishBase Team has discovered so far for important taxonomic works. For more than 400 publications with at least one outdated name, this routine produces a list of invalid names together with the page number where the name is used and provides the current allocation to a higher taxon, senior synonym, correct spelling or proper identification.

[Note that in a few cases, references that do not include species names, e.g., oceanographic atlases, or similar contributions with information relevant to one or several fish species, are linked to these species. Also, sometimes only a common name is mention, which however allows to assign a correct scientific name].

How to get there

You get to the NOMENCLATRURAL CHANGES routine by clicking the **References** button in the Main Menu.

Internet

On the Internet, links to list **All species treated** and **Nomenclatural changes** will be added to the 'Reference Summary' pages.

Rainer Froese

The GLOSSARY Table

*More than 2,600 technical
terms are explained*

The GLOSSARY table contains definitions of more than 2,600 terms related to ichthyology, taxonomy, ecology, conservation, population dynamics, genetics, oceanography, geography and related disciplines. It can be accessed from anywhere within FishBase and is meant to help users in getting acquainted with the terms and concepts used in the database. Terms and definitions are given in English, French, Spanish and Portuguese. Please contact us if you have any comments on our definitions or suggestions for additional terms.

Sources

The glossary was originally derived from the various help messages in FishBase and checked against similar glossaries in taxonomic books and in biological, geographical and other dictionaries (e.g., UNEP/WCMC 1995). It also contains all vernacular names of fish families and the acronyms, addresses and additional information on 200 fish collections. Later we added—with permission—selected terms from glossaries in *FAO Species Catalogues*; the *Zoological Code of Nomenclature* (1985); the *Marine Ecosystem Classification for the Tropical Island Pacific* (Holthus and Maragos 1995); *Fish Population Dynamics in Tropical Waters: a Manual for Use with Programmable*

Calculators (Pauly 1984); *Guide Book to New Zealand Commercial Fish Species* (Armitage et al. 1994); *Field Guide to Trawl Fish from Temperate Waters of Australia* (May and Maxwell 1986); *Trawled Fishes of Southern Indonesia and Northwestern Australia* (Gloerfelt-Tarp and Kailola 1984); *Continental Shelf Fishes of Northern and North-Western Australia* (Sainsbury et al. 1985); *Status of Fishery Resources off the Southeastern United States for 1993* (Southeast Fisheries Science Center 1995); and several others. The definitions were edited and cross-referenced; you can get to the cross-referenced terms by double-clicking on the respective field.

How to get there

You get to the GLOSSARY table by clicking on the Glossary button in the Main Menu or anywhere in FishBase. The GLOSSARY table is also accessible outside of FishBase by double-clicking on its icon in the FishBase Group window.

Internet

On the Internet, the GLOSSARY table is attached to all data pages. You can also access it directly from the 'Search FishBase' page. Note that if a term is not found in the FishBase Glossary, the search is automatically transferred to the search routine of the Encyclopedia Britannica.

Acknowledgments

I thank Daniel Pauly for editing an early version of the glossary and for his valuable comments on the current edition. I also thank the many colleagues who allowed us to use definitions from their respective glossaries. Special thanks to M.L.D. Palomares, J.-C. Hureau, P. Pruvost, N. Bailly, S. Planes, N. Margout and C. Lhomme-Binudin for their help with the French translation.

References

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Rainer Froese

Bodies, Treaties and Conventions

Management of fisheries not only addresses broad ecological and economic issues, but often requires approaches that reach beyond national boundaries. The Agreement on Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks and the Convention on Biological Diversity are but two examples of the kind of legal instruments created to deal with these international issues.

Though these instruments are often cited, e.g., in newspapers, it is difficult to obtain more detailed information on these international bodies, treaties or conventions, especially when it comes to questions such as which country is a signatory to the instrument or what is the legal status of the ratification process in a given country.

***International agreements on
fisheries or biodiversity***

***The full text of the
agreements is available***

Since its 1998 version, FishBase includes a table with information on international bodies and legal instruments dealing, either mainly or peripherally, with fisheries, biodiversity and other environmental issues. These bodies and instruments are international in that they establish mutually agreed rights and obligations between two (bilateral instruments) or more countries (multi-lateral instruments); thus national legislations are not considered. The information provided comprises a general description and classification of the international body or legal instrument; the list of countries that are members or signatories and the status of ratification; the species of fish explicitly covered by the instrument (if any); as well as addresses (both postal and Internet) from where to obtain further information. Where available and limited in scope, the legal text of the instrument has been included.

The information can be accessed either with a country as the starting point, providing an inventory of the bodies and international instruments to which a country is a member or signatory. The other option is to look at specific bodies or instruments and list the countries that are members or signatories. In the latter case, the geographic coverage of each body or instrument can be viewed on a world map which also shows the acronym or short name.

Sources

The information contained in FishBase was primarily compiled from sources made available on the Internet by the Consortium for International Earth Science Information Network (CIESIN), which operates the Socioeconomic Data and Applications Center (SEDAC) for the US National Aeronautics and Space Administration (<http://sedac.ciesin.org>). In addition to this, a number of publications provided a good overview of existing legislation related to the environment (Birnie and Boyle 1992), the precautionary principle as fundamental of law and policy for the protection of the environment (Cameron 1994), and to the conservation and sustainable use of marine resources (McAllister 1995).

Status

At present the table holds information on 45 international bodies and 93 international legal instruments. Where appropriate, this is complemented with information on additional protocols and amendments related to the given instrument.

Fields

Acronym: Provides the acronym or short name (if any) under which the body or instrument is usually known or referred to.

Name: Gives the full legal name of the body or instrument as used in all legal documentation pertaining to the said body or instrument.

Purpose: Displays the global classification, i.e., whether the body or instrument mainly relates to (i) fisheries, (ii) biodiversity, (iii) environment, or is of (iv) general nature. The latter category is primarily used for international bodies such as e.g., the European Commission, which are not primarily established for—but still contain elements pertaining to—the first three categories.

Type: Has the following options: Body; Treaty; Convention; Pact; Agreement; Protocol; Amendment; and whether the body or instrument is bilateral, or multi-lateral.

Established and Locality: Indicate the date when, and the place and country where the body or instrument was established.

Entered into Force, and Expired: Refer to the dates, when a body or instrument entered into force, and when it is scheduled to expire (if this is stipulated in the original documents), respectively.

Coverage: Summarizes in broad terms the goals and objectives of the body or instrument.

Remarks: Provides information on any additional legal instruments (e.g., amendments) signed in a follow-up to the original instrument.

Signatories table: Lists the countries (in alphabetic order), which have become members of or are signatories to the body or instrument, the date when this occurred and the current status in the ratification procedure. The options include (i) member and (ii) observer for bodies on the one hand, and (iii) pending and (iv) ratified for international legal instruments, on the other hand. It should be noted that the term 'pending' is applied to the wide range of juridical terms used in the ratification procedure, in this case denoting everything but full ratification.

Document text: Is a memo field that contains the full text of the legal instrument (if available). The text can be highlighted and then transferred to a word processor through Windows' usual cut and paste procedures. It then can be searched for specific terms and relevant sections can be retained for further use.

Fish species are highlighted

Language table: Lists the language(s) in which the official documentation of the body/institution is written.

The **Species** button is highlighted when a legal instrument explicitly covers certain fish species, whose name(s) appear when the button is clicked on.

Contact table: Provides information on the address of the Secretariat of the body or instrument, as well as addresses of Internet sites that may be visited if more information is needed.

How to get there

You can view the information on bodies/instruments contained in FishBase either from a country perspective or from the view of either a single or a group of bodies/instruments. In the first case, you click on the button **Reports** in the Main Menu, then **Miscellaneous** and finally **Country Information**. After you have selected a country, general information about this country is displayed. Clicking on the button **Int'l Legal. Instr.** will provide a list of instruments to which the country is a signatory or party.

In the latter case, you click on the **Reports** button in the Main Menu and the **International Bodies and Legal Instruments** button in the PREDEFINED REPORTS window.

The legal instruments available in FishBase can be selected using any of the following criteria: (i) a specific body or instrument; (ii) all bodies/instruments having relevance to a specific country; (iii) a pre-defined geographic region (such as Southeast Asia); (iv) a continent; (v) a purpose (e.g., fisheries); (vi) a species covered by international instruments; or (vii) containing a user-provided key term.

Internet

On the Internet, you can access 'Treaties and Conventions' if you click on the respective radio button in the 'Information by Country/Island' section of the 'Search FishBase' page.

References

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Jan Michael Vakily and Grace T. Pablico

Pictures in FishBase

The PICTURES Table

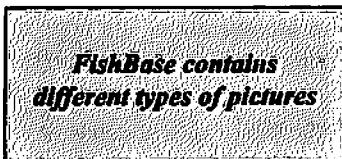
There is an old saying that a picture is worth a thousand words. A compressed picture in FishBase requires about 40,000 bytes of storage space; one word requires about 8 bytes. In FishBase, a picture is thus worth about 5,000 words.

Status

Be that as it may, FishBase presently contains more than 26,000 pictures of fishes. These pictures consist of family pictograms, color drawings of fish, scanned black-and-white (B/W) drawings, scanned color photos or slides, drawings of fish larvae, drawings of fish eggs, rather repulsive representations of fish diseases, and, for philatelists, over 700 fish stamps for over 460 species.

The FishBase fish pictures vary in appearance and quality, due to the different ways they were obtained, viz.:

1. scanned in B/W, without subsequent processing;
2. redrawn (and generally simplified), then scanned, with subsequent 'cleaning up', pixel-by-pixel, of the computerized image;
3. as in (2), but with subsequent coloring of the B/W image;
4. scanned with 16 shades of gray;
5. scanned in true color, 640 * 480 pixel resolution.



The resulting figures rank from (5) to (1) in terms of aesthetic appeal, with category (1) being sometimes so ugly that we not only must apologize for them, but promise that they will all gradually be replaced (most were already).

On the other hand, many of the more than 3,000 underwater photos mostly done by J.E. Randall are of such stunning beauty that some people are using our slide show as screen saver.

We used the GIF format to compress drawings and gray-scale scannings; and the JPEG format to compress scanned color photos about 20-fold. If your hardware supports only 16 colors, the photos will look quite unrealistic; 256 colors already look acceptable and 65,000 colors give you the best display.

Credits

The pictures in (2) and (3) are credited to R. Cada and R. Atanacio or to volunteers to the FishBase Project (notably Magnus Olsson-Ringby), while most of the stamps are credited to Ilya Pauly and R. Rosal, both FishBase volunteers (see 'Fish Stamps', this vol.).

The pictures in (1), (4) and (5) are credited to their original sources in three different ways:

- a) through the name of the source(s) of the picture, i.e., of the artist who originally drew the picture, and/or of the author(s) of the paper or book in which the picture originally appeared;
- b) through the name of the photographer;
- c) through the name as in (a) and (b) and the name of the institution that owns the picture's copyright (e.g., FAO/P. Lastrico);
- d) through the word 'after' followed by a source as in (a).

FAO contributed many black-and-white drawings

Additionally, pictures scanned from FAO publications are labeled 'FAO' in the body of the picture itself.

Items (a), (b) and (c) refer to pictures which we have explicit permission to use. Item (d) refers to pictures for which such permission could not be obtained, such as for the (non-copyrighted) pictures of the late H.W. Halbeisen, a friend to one of us (RF), or pictures from very old publications with lapsed copyright.

This leads, obviously, to an invitation to colleagues to consider sending us picture files for incorporation in FishBase. In addition, we are interested in obtaining permission to use more published photos or slide collections with good identification. We hope that the scheme presented above for giving credit to the author(s) of such pictures is appropriate, and appreciate your suggestions for improvement if you feel differently.

FishBase can hold several pictures for each species

With our current system, we can process up to 50 slides or photos per day, and with JPEG compression storage space is not much of a limitation. Thus, for every species in FishBase, we would like to have one morphological drawing, one 'dead fish' photo, one aquarium photo or drawing showing live colors, and one underwater photo showing the fish in its natural environment. Additional photos can be attached to the OCCURRENCES table (this vol.), if the provided information allows to pinpoint a locality and a date. To date, more than 200 colleagues, most notably J.E. Randall, have provided us with their slides for use in FishBase, on the understanding that they remain the owner of the copyright and that FishBase will contain only low-resolution scans (100-500 dpi) of their photos. Contributors do of course receive a free copy of FishBase and they can actually use an option in the FishBase slide show menu to see (and show!) their photos. In other words, we will have created a computerized archive for them, which is also widely distributed and thus makes their photos known.

How to see pictures

To see a picture of the current species, click on the button with the fish icon in the SPECIES, FAMILY, LARVAE or EGGS window. Alternatively, you can watch different slide shows by clicking on the Pictures button in the FishBase Main Menu, or play the Fish Quiz, which draws on the Family pictograms and on the scanned photos.

Internet

Best photos of the month

On the Internet, a thumbnail sized picture will show in the 'Species Summary' page. When clicked on, it will display a page with all available pictures for a species in thumbnail format. This is useful for comparing, e.g., different color phases. When a thumbnail photo is enlarged, all the related data such as length of fish, locality, date and remarks are shown under the picture. The photographer's name as link to his e-mail, and a URL to his homepage (if any) are shown on top of the picture. Users can 'Add score' to a photo, and these scores are used to create monthly updated pages with '100 Best Photos in FishBase'. The 'Best Photos' page is also accessible from the links at the top of the 'Search FishBase' page.

Acknowledgments

We thank former FishBase artist Roberto Cada for the production of most of the colored drawings, the FAO Fisheries Data and Identification Programme for permission to use the figures in various catalogues and identification sheets, P.C. Young for permission to use photos and drawings from several CSIRO publications, John E. Randall for his permission to let us use low-resolution scans of his more than 10,000 slides; the New Zealand Fishing Industry Board, I.G. Baird, T. Gloerfelt-Tarp, K. Sainsbury, K.-T. Shao, P.C. Heemstra to use the photos in their books on New Zealand, Indonesian, Australian, Taiwanese and South African fishes, respectively; D. McPhail for her drawings of B.C. fishes; D. Cook, D. Faber, R. Field, M. Kochzius, G. Jennings, J. Jensen, R. Patzner and L. Seegers for contributing many fish photos and illustrations, and many other colleagues for permission to use smaller sets of pictures (see general section on Credit). The names of all contributors are shown in the COLLABORATORS table (this vol.) as well as in the 'View pictures by photographer' selection list.

Rainer Froese, Rachel Atanacio and Daniel Pauly

Fish Stamps

Fish are highly decorative

Stamps, whose original *raison d'être* was to only document that a postage fee had been paid, have acquired additional purposes very early, notably for the issuing entities to assert themselves through the dissemination of, e.g., their art, history or natural resources.

Fish being important natural resources in numerous countries, and highly decorative to boot, it was inevitable that they would end up as motif of stamps. Indeed, a stamp-like device, depicting cod (*Gadus morhua*) was issued as early as 1755 in the colony of Massachusetts, while the first true (gummed) stamp depicting a fish—again cod—was issued in 1865 in Newfoundland (Eschmeyer and Bearnse 1974). Nowadays, there are so many colorful stamps of fish that for some countries at least, entire books can be illustrated by them (see, e.g., Hong 1994; Van Tiggelen 1995).

The first global account of fish stamps is that of Bearnse et al. (1977), covering the period 1865 to 1975, and consolidating previous accounts in *Bio-Philately*, a topical journal. Bearnse et al.

(1977), who also covered stamps related to fishing, used a classification that distinguished the following categories:

- a) fish is the central theme (whether or not the stamp also depicts a ruler);
- b) fish is only part of the design (with or without ruler);
- c) fish is a stylized or only minor part of design;
- d) no fish is shown (but a related motif is).

Only stamps belonging to category a) are included in FishBase, with the additional provision that it should be straightforward to assign the fish in question to a valid FishBase species, either because its name or a synonym is stated on the stamp, or because the species can be readily identified from the stamp itself.

Inclusion of such stamps as pictures of FishBase makes it possible for topical philatelists to inform themselves about the fish depicted on their stamps, which range in size from guppies to whale sharks and, taxonomically from sharks to triggerfishes. Philatelists will also appreciate the taxonomic accuracy that FishBase provides, which overcomes a problem that previously hampered fish stamp classification (see Bearse et al. 1977). Also, other users of FishBase will enjoy the beauty of fish stamps, often rivaling that of underwater photos. To this effect, the fish stamps in FishBase have been made nearly screen-filling. The fish stamps included in FishBase 98 (>300), stemming from the Pauly collection, and from the collection of Meryl Williams, which she kindly made available to us, were all individually scanned, and contrast-enhanced using the PhotoStyler software. Stamps from various sources were added later by J.M. Vakily.



We plan to expand our present coverage of fish stamps in FishBase to include eventually all existing stamps that satisfy our selection criteria (see above): i.e., about 2,000 stamps. However, progress may be slow as the FishBase Project does not have a mandate that would allow it to assign regular staff to this activity: how fast the job gets done—if at all—will thus depend on volunteers (such as the first author).

Offers of collaboration on this, including supply of files with philatelic information that could complement the scanned images, or offers to loan stamps for scanning, or to supply scanned pictures of fish stamps should be addressed to Ms. Aque Atanacio (a.atanacio@cgiar.org).

How to get there

Presently, these stamps are accessible in taxonomic sequences through the Pictures button of the Main Menu, or through the SPECIES table, following the fish drawings and photos previously mentioned.

Internet

On the Internet, stamps are accessible by clicking on the respective link in the 'More information' section of the 'Species Summary'

page. Alternatively, lists of fishes with stamp pictures are available by selecting the **Fish stamps** radio button in the 'Information by Family', 'Information by Country/Island', and 'Information by Topic' sections of the 'Search FishBase' page.

Acknowledgment

We thank Adrian Ma. Guerrero for his effort in turning the Paulys' bulging envelopes into an orderly stamp collection, the basis for the work reported upon here.

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- Van Tiggelen, J. 1995. The world down under. Australia Post, Canberra. 40 p.
- Ilya Pauly and Daniel Pauly**

The WinMap Software

*FishBase creates maps for
more than 25,000 species*

Maps are a convenient way to present information on the natural or introduced occurrence of species. In FishBase, maps are created anew from the information in the database whenever they are evoked; this is the only feasible way to deal with the distribution of more than 25,000 species.

Also, FishBase maps are not classical distribution maps but rather present the data on which such maps are based: the countries from which species are reported and the localities (points) where they have been collected. References to such occurrence are available in the COUNTRIES and OCCURRENCES tables under the species in question. Our decision not to show the traditional shaded areas to indicate the distribution of a species has often been criticized because despite our warnings, first-time users tend to interpret the highlighted countries as distribution area, which is of course grossly erroneous, especially for large countries that border more than one ocean. We plan to overcome this problem by including many occurrence points for many species as is done in the Atlas of North American freshwater fishes (Lee et al. 1980). Towards this goal, collaboration has begun with a number of museums. Thus, the current version contains over 600,000 collection records for over 18,000 species, and we expect this number to continue to grow (see the 'OCCURRENCES table', this vol.).

The global map used by WinMap is composed of coastlines/islands, country boundaries, rivers and lakes. These are vector data obtained from Micro World Data Bank (MWDB-II). MWDB-II is a highly compressed version of the full WDB-II, a digital map database of 200 Mbytes initially produced by the U.S. Central Intelligence Agency (CIA), then released for public distribution by the National Technical Information Service (NTIS), U.S. Department of Commerce, and now available in a CD-ROM called Mapping Resources CD-ROM #1 prepared by Micro Doc.

How to display a map

To display a map, click on the button with the globe icon in the SPECIES, GENUS INFORMATION, FAMILY, COUNTRY INFORMATION, INTRODUCTIONS, REPORTS or FISHWATCHER windows.

A dialog box (see Fig. 60) will be displayed allowing you to set several map options. The default settings will mark countries from which a species is reported with light green, countries to which a species has been introduced with orange rectangles and available occurrence points with yellow dots. You can also create maps that, for each fish introduction, show a (red) line ('introduction paths') between the country of origin and the country of introduction. These lines have red dots at either end and clicking on these provides details on the introduction in question. Plotting occurrence points for a genus or a family in addition to the species points is of interest to biodiversity studies.

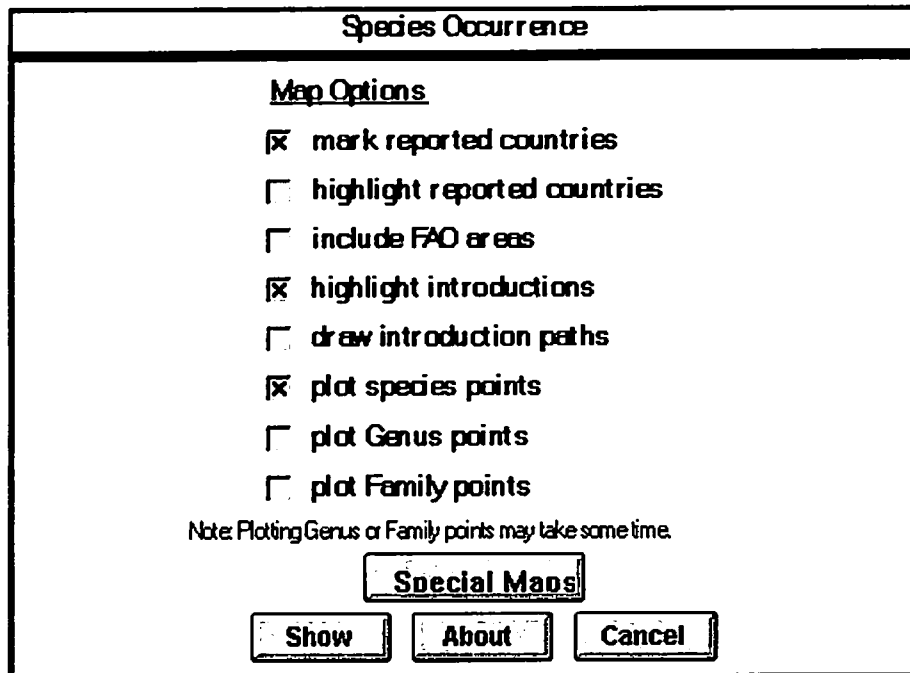


Fig. 60. The WinMap dialog box illustrating default setting. These may be modified, e.g., to highlight reported countries.

Internet

You can also zoom in right away on selected countries or ecosystems, using the **Special Maps** button.

On the Internet, we use two different kinds of maps: a) the xerox map server which plots up to 100 points and allows zooming and overlay of country borders and rivers; and b) static maps for the world and continents, which allow to click on points and see the information behind them. You can access these maps if you click on the **Point map** link in the 'More information' section of the 'Species Summary' page. We have also provided some static biodiversity maps in the respective section of the 'Search FishBase' page. We plan to replace these rather crude maps with high quality maps and a GIS interface by purchasing respective licenses for Internet use from ESRI.

WinMap Options

The remainder of this chapter is very detailed and technical. It is meant for colleagues who want to use WinMap with their own software. Other users may want to skip this section. The following are the functions provided by WinMap:

- **Zoom:** Click on the **Zoom** option in the menu bar, then use the mouse to move the pointer on the screen. WinMap displays the current position of the cursor in degrees and minutes in the lower right corner of the map. To zoom in on a desired portion of the map, select the upper-left corner and determine the size by dragging the mouse. Use the right button to cancel the operation. Note that after zooming in the gray color of the continents sometimes 'floods' the sea. In

WinMap can print high-resolution maps

How WinMap works

You can use WinMap with your own database

such case, please write down the coordinates of the upper left and lower right corner and send them to us, so that we can reproduce and fix the problem.

- **Capture:** If you select **Capture** from the WinMap Menu, you are offered the options to either save the current map to the file C:\FISHBASE\TEMP.BMP or to call PAINTBRUSH (or PBRUSH) where you can modify and print the map;
- **Point info:** If you double-click on an occurrence point (yellow dot), information about locality, coordinates, collector, year of collection, accession number, etc., as extracted from the OCCURRENCES table, will be displayed in a pop-up window.

When WinMap is started from within FishBase, WINMAP.LST is generated in the C:\FISHBASE directory:

WINMAP.LST contains the names of the files to be plotted, including the base map and the overlays. For example, to plot a world map with country boundaries, rivers, lakes, occurrence points and highlighting countries of occurrence, WINMAP.LST will include the following:

WORLD3._FL	(a raster image of the world)
COUNTRY3.DAT	(country borders)
DISTR.DAT	(country where species occurs)
RIVER3.DAT	(major rivers)
LAKE3.DAT	(major lakes)
POINT.DAT	(point data with related information)

The files COUNTRY3.DAT, RIVER3.DAT and LAKE3.DAT are existing overlay files, while POINT.DAT and DISTR.DAT are generated by FishBase. WORLD3._FL contains vector map data. The files for the base map and other overlay files are found in the WinMap directory while the generated files are in C:\FISHBASE directory.

In general, the format for the WINMAP.LST file is as follows:

```
<._FL file> [/X | /S][, x1, y1, x2, y2[, ratioFlag]]  
<overlay file | user file> [legendFlag]  
.  
.  
.
```

where,

._FL file	Vector file of a base map which has a corresponding ._FR file. The ._FR file contains the map boundaries and the fill points used to 'flood' the land with gray;
------------------	--



- /X* An option to automatically create a TEMP.BMP file, exit from WinMap and continue printing, e.g., reports that use the TEMP.BMP file to include maps. With this option, colors will be changed to black and white (see Fig. 61);
- /S* An option that controls zooming in on high resolution maps. If the */S* flag is not specified while plotting a world map and a zoom operation is done, world map files of different resolution will be used depending on the size of the zoom area. There are three world map files: WORLD1_FL, WORLD2_FL and WORLD3_FL. The WORLD1_FL file has the highest resolution and is used when zooming in on small areas;
- x1, y1, x2, y2* A different map boundary to overwrite the default map extent specified in the *._FR* file, where *x1* is the minimum longitude; *y1* is the minimum latitude; *x2* is the maximum longitude; and *y2* is the maximum latitude. Longitude and latitude are expressed in degree-decimal. This option allows zooming in on an area when calling WinMap, instead of starting with a world map (see Fig. 61).
- ratioFlag* An option to maintain the aspect ratio. Specify '1' to keep the aspect ratio of the original map or '0' to disregard the aspect ratio. '1' is the default value. If '0' is selected, the aspect ratio will be determined by the map boundaries (see above);
- overlay file* Vector files overlaid on the base map. See Overlay Files section for different types of overlays;
- user file* Special type of overlay file (refer to User Files section for more information);

For example, in changing the first line of WINMAP.LST to:

WORLD3_FL /X, 30.0, -35.0, 120.0, 23.0, 0

WinMap will plot the portion of the world map from 30°E to 120°E and 35°S to 23°N without maintaining the aspect ratio of the world map. The */X* option tells WinMap to create a TEMP.BMP file then quit from WinMap.

Note: WinMap always expresses coordinates in degree-decimal. Use positive values for north and east, and negative values for

south and west. For example, 12°33'N 174°45'W becomes 12.55, -174.75.

The Base Map

Plotting a base map requires a map file (.FL) and a range file (.FR). The map file contains the vector data and the range file gives the boundaries of a map. The map file has the following format:

```
Latitude, Longitude, P  
Latitude, Longitude, L  
.  
.  
.
```

Here is an example of a .FL file: the vector type P denotes the start of a new line and L the continuation of a line.

```
65.0405, 180.0000, P  
64.7750, 179.4825, L  
64.8167, 179.4833, L  
64.5833, 178.5000, L  
64.7000, 178.7333, L  
.  
.  
.
```

The first row of a range file (.FR) consists of a map description, minimum longitude, minimum latitude, maximum longitude and maximum latitude. It may also contain points to fill the land with gray. For convenience, the fill points may be grouped by country. See the description of the DISTR.DAT file on how to fill countries with different colors. A range file looks as follows:

```
Map description, MinLongitude, MinLatitude,  
MaxLongitude, MaxLatitude  
*CountryName, CountryCode  
Latitude, Longitude  
.  
.  
.  
*CountryName, CountryCode  
Latitude, Longitude  
.  
.  
.
```

For example, the WORLD3.FR file corresponding to the world map contains:

```
WORLD MAP, -30, -70, -30, 90  
*AFGHANISTAN, 004  
33.75, 65.7167  
*ALASKA, 840A  
65.4667, -143.9833  
68.4833, 161.7167
```

65.4667, 164.5667
61.6833, 162.85

.
.
.

Overlay Files

There are three types of overlay files that WinMap can use: POINT, LINE and POLYGON. These files have a .DAT file extension and have a header in the first row to distinguish what type of overlay they contain. Here are the different formats for each type:

The POINT Overlay

The POINT overlay allows the placing of colored symbols on a map. It has the format:

**POINT, DATA n xx[, [*PointSize*][, *RedValue*, *GreenValue*,
BlueValue]]**
***Latitude*, *Longitude*, "Year", "Place", "LongDescription"**

.
.
.

Here is an example of an occurrence data file for *Oreochromis niloticus niloticus*:

POINT, DATA

**32.067, 34.800, "1927","Ras-el-Ain","Bewsher, BMNH
1927.10.17.8-14, Ras-el-Ain, near Jaffa (Tel Aviv)."**

**32.000, 35.000, "1984","Yarkon River","Fishelson, not
catalogued, Probably Yarkon River"**

**32.000, 35.000, "1984","Yarkon River","Fishelson, P 628,
927, Probably Yarkon River"**

Note that the data above represent three rows. Latitude and longitude are given in degree-decimal. The points plotted by this file are 'active dots', i.e., the information in quotation marks is displayed upon double-clicking on the left button of the mouse.

DATAnxx is used to specify the data type: *n* - for the types of symbols; *xx* - for the color codes. The values of *n* are: 1 - filled circle, 2 - unfilled circle, 3 - filled square, 4 - unfilled square. The values for *xx* are: 00 - black, 01 - blue, 02 - green, 03 - cyan, 04 - bright red, 05 - magenta, 06 - brown, 07 - light gray, 08 - gray, 09 - light blue, 10 - light green, 11 - cyan, 12 - red, 13 - light magenta, 14 - yellow, 15 - white. If the file header does not specify the data type, the default will be used which is yellow points with the four different types of symbols.

***You can use other colors
and symbols***

If you want to use different symbols and/or colors, these have to be stored in separate POINT files (see USER FILES below).

Indicating a pixel value in the *PointSize* parameter which is expressed in device units can change the size of the symbol. The

actual point size is double the value indicated. The default *PointSize* = 4.

WinMap uses the 16 standard VGA nondithered colors. These colors are represented by a combination of 8-bit *RedValue*, *GreenValue*, *BlueValue* variables. Each value can be 0 to 255. Table 3 shows the different combinations for each color.

Table 3. Colors available for use with WinMap.

Red	Green	Blue	Color Code	Color
0	0	0	00	Black *
0	0	128	01	Blue *
0	128	0	02	Green
0	128	128	03	Cyan *
255	0	0	04	Bright red
128	0	128	05	Magenta
128	0	0	06	Brown
192	192	192	07	Light gray *
128	128	128	08	Gray
0	0	255	09	Light blue *
0	255	0	10	Light green
0	255	255	11	Light cyan
128	0	0	12	Light red
255	0	255	13	Light magenta
255	255	0	14	Yellow
255	255	255	15	White

*The colors marked with an asterisk are already used by the base maps.

To be able to change the default colors that WinMap uses, different values can be given for *RedValue*, *GreenValue* and *BlueValue*, especially if the display board supports more than 16 colors. For a 256-color display board, we recommend four additional colors (see Table 4). The 24-bit color display boards can display $256 \times 256 \times 256 = 16.7$ million nondithered colors.

The above example of a POINT overlay used the default point size and color. To use larger dots in light magenta, the user may change the file header into the following line:

POINT, DATA, 6, 255, 0, 255

Table 4. Additional colors for display with more than 16 colors.

Red	Green	Blue	Color
192	220	192	Pale green
166	202	240	Light blue
255	251	240	Off-white
160	160	164	Medium gray

The option to change the default colors also applies to LINE and POLYGON overlays.

The LINE Overlay

The LINE overlay allows the drawing of vector lines on a map. It has the format:

LINE, *LineCode*[, [*LineStyle*][, *RedValue*, *GreenValue*, *BlueValue*]]

***Latitude*, *Longitude*, P**

***Latitude*, *Longitude*, L**

.
.
.

Here is an example of a LINE type of overlay with *LineCode* = LAKE,

LINE, LAKE
44.7333, 61.4500, P
45.0500, 61.9667, L
45.0500, 61.7167, L
.
.
.
44.7333, 61.4500, L
46.4333, 74.1833, P
46.7667, 74.6167, L
46.8500, 75.0667, L
.
.
.

LineCode is used to set default colors and can have the following values:

COUNTRY	Code for country boundaries, default color red;
RIVER	Code for rivers, default color blue;
LAKE	Code for lake, default color light blue;
BATHY	Code for bathymetry; default color light cyan;
COREEF	Code for coral reefs, default color white;
ROAD	Code for roads; default color brown;
STATE	Code for state boundaries; default color magenta;
OTHER	For other types of lines with default color yellow;
OTHERxx	For other types of lines where xx is the assigned color; see color codes under POINT type of overlay.

Standard FishBase maps use three LINE type overlays:

COUNTRY3.DAT, LAKE3.DAT and RIVER3.DAT

LineStyle can have the following values:

- 0 Solid lines;
- 1 Dashed lines;
- 2 Dotted lines;
- 3 Line with alternating dashes and dots;
- 4 Line with alternating dashes and double dots.

The POLYGON Overlay

The POLYGON overlay allows the placing of polygons filled with colored patterns on a map.

POLY, *PolyCode* [, [*PolyPattern*] [, *RedValue*, *GreenValue*, *BlueValue*]]

Latitude, Longitude, P

Latitude, Longitude, L

.
.
.

Lake can also be defined as a polygon. Below is an example of POLY type of overlay with *PolyCode* = LAKE. Take note that the last point of a polygon vector is automatically connected to the first (P) point.

POLY, LAKE

44.7333, 61.4500, P

45.0500, 61.9667, L

45.0500, 61.7167, L

.
.
.

44.7333, 61.4500, L

46.4333, 74.1833, P

46.7667, 74.6167, L

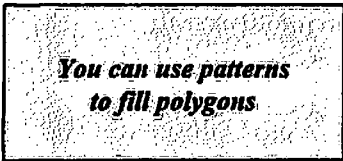
46.8500, 75.0667, L

.
.
.

44.7333, 61.4500, L

PolyCode is used to set default colors and can have the following values:

- | | |
|----------------|---|
| LAKE | Code for lakes; colored light blue; |
| COREEF | Code for coral reefs, colored white; |
| OTHER | For other types of polygons with default color yellow; |
| OTHERxx | For other types of polygons where <i>xx</i> is the assigned color; see color codes under POINT type of overlay. |



If *PolyPattern* value is not specified a solid color will be used to fill up the polygon; otherwise you can specify any of the following patterns:

- 0 Horizontal lines;
- 1 Vertical lines;
- 2 Downward diagonal lines (left to right) at 45 degrees;
- 3 Upward diagonal lines (left to right) at 45 degrees;
- 4 Horizontal and vertical cross lines;
- 5 Cross lines at 45 degrees.

User Files

WinMap supports the following user files: POINTxxx.DAT, LINExxx.DAT, POLYxxx.DAT, LABEL.DAT, FILL.DAT and DISTR.DAT, where the string xxxx can consist of any valid characters in naming a file under DOS.

The LABEL.DAT file

All the labels in a map are stored in the LABEL.DAT file. The format for this file is:

Latitude, Longitude, "Label", [{"FName"}], [FSize], [FBold], [FItalic], [ColorCode]]]]]

The user has an option to change the font style. The parameters for changing the font style are:

<i>FName</i>	The default is the 'System' font name which can be changed to different Windows fonts (i.e. 'Arial', 'MS Sans Serif', 'Times New Roman');
<i>FSize</i>	The default value is 0 (zero). With 0-value, a reasonable default size is used. Otherwise, specify the desired font size which can be a number between -100 and 100;
<i>FBold</i>	The value is either 1 - for bold characters, or 0 - for regular characters. The default is 1;
<i>FItalic</i>	The value is either 1 - for italicized, or 0 - for regular characters. The default is 0;
<i>ColorCode</i>	Providing a value for color code will change the color of the text. See Table 2 for the list of codes.

An example of a label file is:

```
0.5, 10.5, "Test default"  
10.0, 40.5, "Test italics red", "Arial", , , 1, 12  
-15.5, -100.0, "Test font size 14", "Arial", 14
```

The FILL.DAT file

The FILL.DAT file provides an option to flood-fill an area with a certain color and pattern. Only pixels that have the same color as and are connected to the starting point will be 'flooded'. The file has the following format:

Latitude, Longitude, ColorCode[, FillPattern]

.
. .
.

Latitude and *Longitude* specify the starting point for the flooding. See Tables 1 and 2 for the color codes. For *FillPattern*, refer to *PolyPattern* under the POLYGON Overlay section. In adding the FILL.DAT file in the list of overlay files in WINMAP.LST, the previously plotted overlay files will determine the boundaries for the flood-fill.

Here is an example of a FILL.DAT file wherein there are two types of polygon fill. One type of polygon will be filled white solid and the other will be filled with brown crosslines:

```
0.0, 50.0, 15
-15.0, 30.0, 06, 5
20.0, -90.0, 15
-40.0, -112.0, 06, 5
```

The DISTR.DAT file

The DISTR.DAT file is a special type of a FILL.DAT file that facilitates flood-fill of countries with different colors and patterns. The format is as follows:

CountryCode, [ColorCode] [, FillPattern]

.
. .
.

Country codes follow the UN standard. Below is an example of a DISTR.DAT file which fills countries without color code with the default color (dark green = 02 in color code) and the other countries with the specified color (light green). Codes for other colors are: 04 - red, 05 - magenta, 06 - brown, 08 - dark gray, 10 - light green, 11 - light cyan, 12 - light red, 13 - light magenta, 15 - white. For color codes not in this list, the default color will be assigned. This is to avoid using colors that WinMap already uses for other objects. If *FillPattern* is not specified, countries will be filled with solid colors. Below is an example of a DISTR.DAT file with the countries 174 and 716 filled with light green:

```
174, 10
818,
230,
716, 10
566,
```

Like the FILL.DAT file, the DISTR.DAT file uses previous overlays to define the boundaries for filling colors. WinMap assumes that the overlay file listed in WINMAP.LST (see section above) prior to DISTR.DAT is a LINE overlay of COUNTRY type.

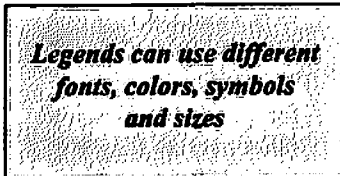
The LEGEND.DAT file

You can fill the rectangular space below a map with legend information such as symbols and text.

To place legends for the different symbols that were used in the displayed map, include the LEGEND.DAT file in the list of overlays in the WINMAP.LST file. The LEGEND.DAT file follows the format below:

```
"SDesc"[, ["FName"]], [FSize][, [FBold][, [FItalic][, [SType][, [SSize][, [SColor][, [SPattern]]]]]]]]
```

where



SDesc The legend text, enclosed in quotation marks;

FName The font name, with default 'System' font (see section on the LABEL.DAT file);

FSize The font size, default is equal to 0;

FBold Has value 0 or 1, where 1 makes fonts bold and is the default value;

FItalic Has value 0 or 1, where 1 makes the fonts italicized and 0 is the default value;

SType The symbol type with the following values: 0 - no symbol, 1 - filled circle, 2 - unfilled circle, 3 - filled square, 4 - unfilled square, 5 - line;

SSize Determines the size of the symbol, expressed in device units. This does not apply to the line type symbol;

SColor The color of the symbol. Values range from 0 to 15 (see Table 3);

SPattern The patterns for different types of symbols. The filled circle and filled square have the same color for the outline and the fill. For the unfilled circle and square, the symbol can be filled with different patterns (0 to 5) or with the background color if the pattern is not specified. See *PolyPattern* under the POLYGON Overlay section. The line type of symbol can have different line styles (0 to 4), where 0 = solid line is the default. See *LineStyle* under the LINE Overlay section.

An example of a LEGEND.DAT file is as follows:

```
"Map Information"  
"Oreochromis niloticus", "Arial", 14, , 1, 1, 1, 4, 14  
"Reported countries", "Arial", 14, , , 3, 6, 02  
"Introduced countries", "Arial", 14, , , 4, 6, 10, 5
```

Legend one will be displayed using the 'System' font and no symbol. Legend two will be in 'Arial', size 14, bold and italicized font type, with symbol yellow filled circle preceding the text. Legend three of the same font type as Legend two, in bold regular characters with a green filled square symbol. Legend four has the same font type as Legend three but with a light green square filled with cross line patterns.

WINMAP.INI

Path information for the various types of files needed by WinMap is contained in the WINMAP.INI file, which can be found in the Windows directory (C:\WINDOWS). By default, if WINMAP.INI is not found, all files are searched in the WinMap directory. If you have problems running WinMap, make sure the entries in WINMAP.INI are correct. The format of this file is:

```
[Settings]
ImagePath=<complete path>   for .BMP base maps;
DataPath=<complete path>    for user files:
                             POINTxxx.DAT,
                             LINExxx.DAT,
                             POLYxxx.DAT,
                             FILL.DAT, LABEL.DAT,
                             TEMP files;
VectorPath=<complete path>  for ._FL/._FR files, and
                             other overlay files, e.g.,
                             COUNTRY3.DAT,
                             RIVER3.DAT,
                             LAKE3.DAT;
UserMapPath=<completepath> contains all user-defined
                             base maps and overlays.
```

For example, for FishBase running from a CD-ROM in drive E: the settings may be as follows:

```
[Settings]
ImagePath=E:\FB\WINMAP
VectorPath=E:\FB\WINMAP
DataPath=C:\FISHBASE
```

Running WinMap

After the necessary files have been created, WINMAP.EXE can be started. WinMap will then read the files specified in WINMAP.LST, and load them from the directories specified in WINMAP.INI and plot the map and overlays. FishBase for example, creates DISTR.DAT and POINT.DAT files through MS Access queries, saves them in C:\FISHBASE, and then calls WinMap with the MS Access command:

```
Shell("WINMAP.EXE") .
```

WinMap, a Public Domain Product

The above section describes how FishBase uses WinMap. Developers of other databases with geographic components are welcome to use WinMap for their purposes; we consider it to be in the public domain. We would, however, appreciate an acknowledgment.

The MakeMap Program

The MakeMap program was developed to assist the user in creating the command files needed by WinMap. You do not need MakeMap if you are displaying maps from inside FishBase. However, if you plan to use WinMap with another application,

MakeMap will assist you in assembling and testing the WINMAP.LST file and the WINMAP.INI file.

Upon executing MakeMap, the form below will appear:

If the 'OK' button is clicked on, the selections will be saved. For the 'DIRECTORIES' section, the selections will be written to the WINMAP.INI file, while the selections for 'BASE MAP' and 'OVERLAY' will be written to the WINMAP.LST file.

The WINMAP.LST file is saved in the DataPath directory and the WINMAP.INI file is saved in C:\WINDOWS.

Choosing the Base Map

Click the arrow at the right of the Base Map field to see the list of available vector maps. The list of files that you can choose from includes those which are in the VectorPath and UserMapPath directories.

The 'Exit & Print' check box when selected will add an /X flag after the base map file. When WinMap is called, it will automatically create a black & white map according to the selections, copy that map to a TEMP.BMP file, and exit. The generated TEMP.BMP file is meant for printing and can be included into database reports and word processor documents.

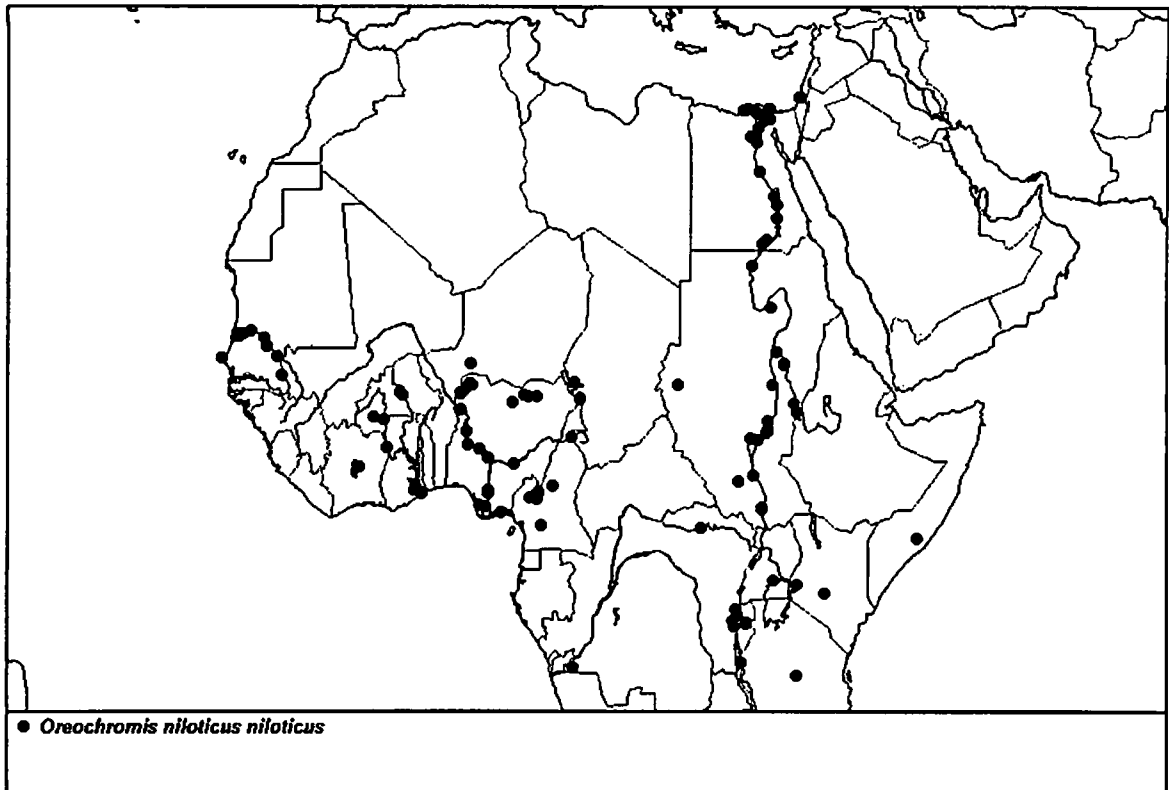


Fig. 61. Distribution map for *Oreochromis niloticus niloticus* as created with the 'Exit & Print' option. Note that WinMap was called and set to zoom in on northern Africa.

The 'Use Special Map' check box, on the other hand, adds an /S flag after the base map file. By default, WinMap uses three sets of world map, i.e., WORLD1_FL, WORLD2_FL and WORLD3_FL, with different levels of detail. The WORLD1_FL file has the highest level of detail. In most cases, WORLD3_FL is used to plot the initial world map. When a zoom operation is done, a world file is chosen depending on the size of the zoom area. Check this option if you want to zoom in on the WORLD3_FL or on a special _FL file.

Different map extents can be indicated to overwrite the default map extents provided in the _FR file and zoom in on an area (see the 'WinMap Software', this vol.). The 'Keep Aspect Ratio' check box will maintain the aspect ratio of the original map, even if new map extents are used.

Choosing Overlay Files

For the overlay files, the list in the right window depends on the selected base map file. If the base map is in the VectorPath, the second column will list all DAT files from VectorPath and DataPath; and if it is in the UserMapPath, DAT files from UserMapPath and DataPath will be listed. Highlight a file in the right window and click on the Add button to add it to the selection of overlay files. See chapter on 'The WinMap Software' for more information on the various DAT files.

Note: Overlay files will be plotted in the same order as they are listed in WINMAP.LST.

Acknowledgments

We thank Edwin de Guzman for helping us with reading and saving BMP files in WinMap. We also thank Eliseo Garnace for helping us with the Windows help system and for other useful hints.

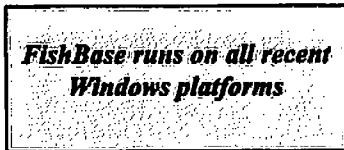
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Grace Coronado and Rainer Froese

Installing FishBase

Getting Started



To be able to run FishBase 2000, you need a computer capable of running Microsoft Windows 95, 98, Me, Windows NT or Windows 2000. For an adequate performance, we recommend a Pentium processor with at least 200 MHz processing speed and at least 64 megabytes of RAM. You will also need a CD-ROM with at least 36X speed drive and a mouse. Picture quality will benefit from a VGA monitor and video card capable of displaying at least 256, better 65,000 colors. FishBase forms are designed for standard VGA resolution, i.e., 640 x 480 pixels. If you use higher resolutions, FishBase will occupy only part of your screen.

For FishBase to run properly, several files have to be installed on your computer's harddisk. The FishBase Setup program will do this for you.

Follow these steps to install FishBase 2000:

0. If you had a previous version of FishBase installed, use the 'Add/Remove Programs' routine of Windows to uninstall it.
1. Make sure your CD-ROM player is properly installed;
2. Put the FishBase Database CD-ROM disc 1 into your CD-ROM player;
3. Click on the Start button and select Run. The Run command dialog box will appear; enter X:\setup.exe, where X is the letter assigned to your CD-ROM drive; press Enter;
4. The FishBase Setup window will appear and guide you through the installation process;
5. Initially, you will be asked to check if there are applications currently open. If this is the case, you have to exit Setup and close all running applications, including virus protection software. The Setup routine will be installing and updating shared files. Other open applications may prevent Setup from installing FishBase properly.
6. The FishBase Setup software gives you four installation options:
 - 1) **Full Installation:** to install everything on your harddisk (about 2,275 megabytes). FishBase may run slower on a compressed drive regardless of compression utility used. Disk compression degrades performance with Access 2000.
 - 2) **LAN Installation Workstation:** to install the minimum requirements on the workstation and access data and pictures from the LAN server.

- 3) **Read from CD-ROM:** to install a minimum of files (about 165 megabytes) on your harddisk and run FishBase from the CD-ROM. This, however, will be relatively slow, with no maps, no Fish Quiz and no pictures;
 - 4) **Run database from harddisk:** to install FishBase software and data on your harddisk (about 590 megabytes). The speed of the application is affected by the speed of the CD-ROM when using the OCCURRENCES table.
7. FishBase Setup will create a C:\FISHBASE directory on your C: drive to store temporary files. Note that you will need at least 49 megabytes free space on your C: drive for FishBase to work properly.
 8. FishBase setup will load the FishBase tools installer. You have the option to install Auxim and Yield (with Popdyn, Keyfacts, Fish on Line and Troph database) and FB advanced, or, install all tools or none. This will require a maximum of 18 MB.

FishBase Registration

Please register your copy of FishBase by providing us with the following information:

Name:

Institution:

Address:

E-mail:

FishBase version:

Approximate number of users:

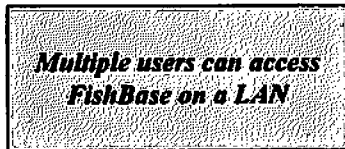
Comments:

Registration will entitle you to receive future updates of FishBase for US\$50, including airmail. It also helps us to know who our users are (see Fig. 1) and what you think about our product. Send your registration and any comment you may have to the following address:

The FishBase Project
c/o ICLARM
MCPO Box 2631
0718 Makati City
Philippines
Fax No. (63-49) 536-0202
E-mail: FishBase@cgiar.org

You can also photocopy the registration form on page *xiv* of this manual and mail or fax it to us.

FishBase on a LAN



You can install FishBase 2000 on a Local Area Network (LAN) to allow several users to access FishBase at the same time from their individual desktop computers. To do so, you have to create a virtual drive on the server harddisk (e.g., H:\) and copy all files and directories from CD1 to CD4 to the virtual drive. To avoid locking problems make sure the file attributes are Read, Write and Share. Users can install FishBase from the LAN by following the installation procedure discussed under the topic Getting Started, with Option for minimum installation and specifying the LAN drive (e.g., H:\) instead of the CD-ROM drive. Note that it may not be possible to run FishBase or the pictures from a LAN CD-ROM server.

Rainer Froese and Meynard Gilhang

FishBase and Microsoft Access

FishBase was originally created under DOS with DataEase (see 'The Making of FishBase', this vol.)



We always knew it would be difficult to move a large application such as FishBase from DataEase to another database software. We knew that we would have to recreate all forms and tables and rewrite the more than 200 procedures of FishBase 1.0. One of us (Portia Bonilla) was a database programmer familiar with DataEase and enthusiastic about Microsoft Access. And we started 10 months before the first planned release date. Still we nearly failed to make it in time.

Also, we were not happy with a number of features of MS Access 1.1 and even Access 2000. Several of our disappointments with Microsoft Access resulted from its limited or awkward use of Windows' graphic capabilities:

Slow pictures

- One of our reasons to move to Windows was the assumption that it would be easy to incorporate thousands of pictures. However, a picture that occupied 30 kilobytes under DOS suddenly grew to 300 kilobytes under Windows and to even more when attached to Microsoft Access. The time to load and display a picture also increased 10-fold and we had to use tricks to include pictures in printouts;

No italics

- Another assumption was that we would be able to display species names in italics, both on screen and in printouts. However, this cannot be done if the name appears in a text string such as a reference title or a remarks field (it is all or nothing in italics). This is the reason for our use of the `<i></i>` sign before and after words that should have been italicized (see Fig. 37).

Demanding layout

- Also, the countless options for screen layout and the high expectations raised by professional multimedia applications make this side of software development much more important and demanding than it used to be, even more so since we have

to cater to inexperienced users and cannot just use the Windows standard interface;

No QBE

- The Query-by-example module that would allow users to create their own queries within FishBase is not contained in the Microsoft Access run-time module. Users have to purchase Microsoft Access to avail of these capabilities.

The Setup blues

Windows has introduced the concept of dynamic link libraries (DLL) supposedly so that different programs can share the same libraries. However, from Windows 95 onward these libraries have to be registered, and newer versions might not work with older programs. This has made proper installation of software a nightmare, because the success of an installation largely depends on which programs and DLLs are already installed. We have tested the current setup on fresh installations of Windows 95, 98, NT4.0, Me and Windows 2000. We also have tested it on a variety of machines with MS Office and other software installed. We have fixed all problems we came across, but we still cannot guarantee that FishBase 2000, and particularly its yield and auxim routines, will install properly on all existing configurations.

The bright side

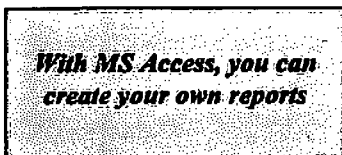
There is also a bright side: a graphical interface is user-friendlier. Windows relieves us of the burden to worry about user hardware (printer, monitor, mouse, etc.). The Windows help system allows us to put this whole manual on disk where it can be accessed from anywhere within FishBase. The continuing development of faster hardware will eventually solve the speed problem; and the availability of Windows on Macintosh, Power PCs and Unix systems will bring FishBase to all of these platforms.

Make it faster

Here are tips to make FishBase (and Microsoft Access in general) perform better with limited RAM:

- close other applications when running FishBase;
- defragment your harddisk.

If you have Microsoft Access



FishBase has grown and now comes in eight databases. The main database is split into four files: FBUSER.MDB, FBAPP.MDB, FBOCCUR.MDB and FBAD.MDB. FBUSER.MDB contains the forms, reports, queries and user-defined functions. FBAPP.MDB contains all main data tables except for the OCCURRENCES table that is contained in FBOCCUR.MDB. FBAD.MDB contains several routines for advanced users, such as the 'Check Names' routine. The FBWRITE.MDB contains tables used for temporary reports and resides in C:\FISHBASE. The USER.MDB contains the FishWatcher table, the NAMES.MDB contains the Local Knowledge tables, and the COUNTRY.MDB contains the National Checklist table. All these databases reside in C:\FishBase. Moreover, the interface for these tables is in FBAD.MDB. If you have a licensed copy of Microsoft Access, you can open the databases and, e.g., create your own queries to combine or extract information.

The Internet tools available with Access 2000 are meant for Intranets and are too slow to make sense on the Internet. Thus, while we still use the MS Access Jet database engine for data tables and queries, we had to create a completely new user interface in the Internet, using Cold Fusion as database web server. As the usage of FishBase on the Internet (over 600,000 hits per month in November 2000) continues to increase, we plan to move to a more stable database backend such as MS SQL server.

Rainer Froese, Portia Bonilla, Alice Laborte and Ma. Josephine France Rius

Credits

Writing the 'ACKNOWLEDGMENTS' for a collaborative project as large as FishBase is a serious matter, and with both of us having mother tongues other than English, we decided to check dictionaries. The Compact Edition of the Oxford Dictionary of 1971 gave six definitions, of which we present the first and the last:

- the act of acknowledging, confessing, admitting or owing; confession, avowal;
- the sensible sign, whereby anything is acknowledged; something given or done in return for a favor or message, or a formal communication that we have received it.

Here, we began to vacillate. Just to be sure, we consulted the Random House Unabridged Dictionary, which is more recent (1993). The nuances matched, and one definition was added:

- public recognition by a man of an illegitimate child of his own.

We decided not to acknowledge anything, but to give CREDIT, instead, to all those who have helped us conceive FishBase, a very legitimate child.



Publications

Wherever possible, we have cited the publications of colleagues who have contributed to FishBase or have in one way or another influenced the design of FishBase. These citations are still somewhat biased towards FishBase Team members, which is understandable, since we are foremost influenced by our own ideas and concepts, as reflected in our publications. However, we expect this bias to become less apparent in the citation count as more and more colleagues actively contribute to FishBase, author their own chapters and then cite their own publications, for the same reasons.

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FishBase tables were reviewed and improved by D. Bartley, G. Bianchi, K. Carpenter, B.A. Costa-Pierce, A.E. Eknath, W. Fischer, A. Jarre-Teichmann, P. Kailola, R.H. Lowe-McConnell, J. McGlade, R.S.V. Pullin, J. Ruesink, K. Ruddle, U. Sienknecht, D. Skibinski and W. Villwock.

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The FishBase Team

Members of the FishBase Team at some point are or were: Belen Acosta, Eli Agbayani, Liza Agustin, Henry Angeles, Rachel Atanacio, Crispina Binohlan, Portia Bonilla, Roberto Cada, Emily Capuli, Christine Casal, Grace Coronado, Maria Teresa Cruz, Anne Johanne Dalsgaard, John Falcon, Rainer Froese, Tom Froese, Cristina Garilao, Meynard G. Gilhang, Emmanuel Kaunda, Sari Kuosmanen-Postila, Alice Laborte, Susan Luna, Jaime Mendo, Mamaa Entsua-Mensah, Grace T. Pablico, Maria Lourdes D. Palomares, Analyn Palomares, Daniel Pauly, Ilya Pauly, Rodolfo B. Reyes, Jr., Magnus Olsson-Ringby, Ma. Josephine France Rius, Pascualita Sa-a, Drina Sta. Iglesia, Dominador Tioseco, Armi Torres, Jan Michael Vakily and Shen-Chih Wang.
Rainer Froese and Daniel Pauly

List of Symbols and Abbreviations

- %BWD** : a measure of the dry weight of feed provided daily to fish held in captivity, in % of their weight.
- λ_{\max} : “lambda maximum”: the wave length of light (in nm) to which the visual pigments in fish eyes are most sensitive.
- β : “beta”: exponent in a relationship linking K_1 and W . Also Bunsen coefficient for oxygen.
- A** : aspect ratio of the fish’s caudal fin, used as index of its level of activity, and defined by h^2/s , where h is the height of the caudal fin, and s its surface area.
- BL** : body length: reference length for the swimming speed of fishes ($BL \cdot S^{-1}$). Also: an undefined measure of length, which may refer to SL, FL or TL.
- BMP** : generic Windows bitmap files.
- B/W** : black-and-white: refers here to pictures of fish.
- C** : parameter of the von Bertalanffy equation, modified to express seasonal growth oscillations, and expressing the amplitude of such oscillations. In practice, C ranges from $C = 0$ (no oscillations) to $C = 1$, when $dl/dt = 0$ at the winter point (WP).
- $^{\circ}\text{C}$: degree celsius, used for expressing temperature.
- CaCO₃** : calcium carbonate.
- CD-ROM**: Compact Disc-Read Only Memory; a standard for compact disc used as a digital memory medium for personal computers.
- C.V.** : coefficient of variation (=standard deviation/mean); often expressed as % of the mean.
- D** : duration of a larval stage; also, in eggs: time to hatching (in days).
- dl/dt** : growth rate in length; first derivative of the VBGF for length.
- dw/dt** : growth rate in weight; first derivative of the VBGF for weight.
- Δt : delta t: a time interval or period.
- ΔT : difference within an annual cycle of the highest mean monthly temperature (summer) and the lowest mean monthly temperature (winter).
- DOS** : Disk Operating System.
- F** : instantaneous rate of fishing mortality (time^{-1}), i.e., $F = Z - M$. Also: absolute fecundity.
- FL** : Fork length; the length of a fish, measured from the tip of the snout to the tip of the shortest central rays of the caudal fin.
- G** : specific growth in weight, defined by $\ln W_2 - \ln W_1 / \Delta t$ where W_1 and W_2 are successive weights, and Δt the growing period; used for fish larvae;
- GIF** : Graphic Interchange Format, used to store black-and-white pictures in FishBase;

- h** : hour, a unit of time. Also: height of a fish's caudal fin.
- h²** : measure of genetic heritability; also height squared of caudal fin, used to compute its aspect ratio.
- ha** : hectare (100 m x 100 m).
- Hg** : used to express partial pressure as millimeters of mercury; e.g., in 'mmHg of oxygen' (from Latin *'hydragyrum'* name for mercury, liquid silver).
- JPEG** : Joint Photographic Experts Group; an image compression standard; a format used to compress color photos.
- K** : parameter of the VBGF, of dimension time⁻¹, and expressing the rate at which the asymptotic length (or weight) is approached.
- K₁** : gross food conversion efficiency; ratio of growth increment/food ingested during a given period.
- kg** : kilogram.
- l** : liter.
- L** : symbol for the individual body length of a fish.
- LC₅₀** : median lethal concentration, i.e., concentration of a substance sufficient to kill 50% of the fish exposed to it during a specified period.
- L_∞** : asymptotic length (also L_{inf}): a parameter of the VBGF, expressing the mean length the fish of a given stock would reach if they were to grow for an infinitely long period.
- L_m** : mean length at first maturity of the fish of a given population.
- L_{max}** : maximum individual length on record for a species or one of its populations (depending on context).
- ln** : base e logarithms (also log_e).
- log** : base 10 logarithms (also log₁₀).
- L_t** : mean length at age t predicted by the VBGF.
- M** : instantaneous rate of natural mortality (time⁻¹), i.e., M = Z - F.
- MDA** : file extension denoting a Microsoft Access file holding user and security information.
- MDB** : file extension denoting a Microsoft Access data file.
- mg** : milligram.
- M%** : natural mortality in % (as recorded in aquaculture experiments).
- m·s⁻¹** : meter per second: used to express swimming speed of fish.
- n** : number of specimens used to derive length-weight, fecundity-length, or other relationship, or included on a graph.

- NG** : not given; refers here to length type.
- N_t** : size (number) of a population of fish at a given time t.
- nm** : nanometers (thousandth of a millimeter).
- OT** : length Other than FL, SL, TL or WD; used to express size in fish.
- pH** : a measure of the acidity (pH<7) or alkalinity (pH>7) of a liquid.
- ppt** : parts per thousand, used to express salinity (though salinity doesn't really require such symbol).
- Ø** : a growth performance index, equal to $\log_{10} K + 2/3 \log_{10} W_{\infty}$, where K and W_{∞} are parameters of the VBGF.
- Ø'** : a growth performance index, equal to $\log_{10} K + 2 \log_{10} L_{\infty}$, where K and L_{∞} are parameters of the VBGF.
- Q** : amount of food consumed by a population of fish over a specified period; also: metabolic rate, i.e., O₂ consumption.
- QO₂** : weight-specific oxygen uptake.
- Q/B** : amount of food consumed per unit weight of an age-structured population of fish; generally expressed on an annual basis.
- r** : coefficient of (linear) correlation; where appropriate, this refers to linearized variates, e.g., $\log_{10} W$ vs. $\log_{10} L$.
- r_m** : maximum intrinsic rate of population increase, in year⁻¹. A measure for the resilience of a population to withstand fishing pressure.
- RAM** : Random Access Memory; a set of chips in the computer in which information can be held for rapid access by the microprocessor.
- R_d** : daily ration, i.e., the amount of food consumed by a fish of a given weight in one day, and often expressed as % of its own weight.
- ROM** : Read-Only Memory: a form of computer memory in which information is permanently recorded so that it cannot be erased or changed.
- s** : second, a unit of time. Also: surface area of a fish's caudal fin.
- S.D.** : standard deviation (of a number of variates).
- S.E.** : standard error (of a mean).
- SL** : standard length; the length of a fish, measured from the tip of the snout to the tip of the hypural bone, or of the fleshy part of the caudal peduncle (i.e., excluding the caudal fin).
- SL/s** : standard lengths per second; used to express the swimming speed of fish.
- T** : temperature (in °C).

- t_0** : a parameter of the VBGF expressing the theoretical 'age' the fish of a given stock would have at length zero if they had always grown as predicted by that equation. The parameter t_0 , which usually takes negative values, is often omitted from stock assessment models incorporating the VBGF.
- TL** : total length; the length of a fish, measured from the tip of the snout to the tip of the longest rays of the caudal fin (but excluding filaments), when the caudal fin lobes are aligned with the main body axis.
- t_m** : mean age at first maturity of the fish of a given population.
- t_{max}** : maximum age reached by the fish of a given species or population (i.e., longevity); hence also: age at exit (or de-recruitment) from a population.
- tr** : Troph, i.e., trophic level
- t_r** : age at entry (recruitment) into a fish population.
- t_s** : parameter of the VBGF, as modified to express seasonal growth oscillations, and expressing the time difference between $t = 0$ and the start of a sinusoid oscillation.
- VBGF** : Von Bertalanffy Growth Function, used to describe the growth in length or weight of fish.
- VGA** : Video Graphic Array: a graphics display system for computer monitors with a resolution of 640 x 480 pixels at 16 colors. We recommend using at least 256 (better 65,000) colors with FishBase
- W** : symbol for the individual body weight of a fish.
- WD** : width; the length, in rays, and skates from the tip of the left to the tip of the right 'wing'.
- WP** : winter point: the period of the year, expressed as a fraction, where growth is slowest, i.e., $dl/dt = 0$ when $C = 1$.
- W_∞** : asymptotic weight (also W_{inf}): a parameter of the VBGF expressing the mean weight the fish of a given stock would reach if they were to grow for an infinitely long period. Also: the weight corresponding to L_∞ .
- W_{max}** : maximum individual weight on record for a species or one of its populations (depending on context).
- W_t** : mean weight at age t predicted by the VBGF.
- Z** : instantaneous rate of total mortality (time^{-1}), i.e., the sum of natural mortality (M) and fishing mortality (F).

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