Sustainable Fish Production in Lake Nasser:

Ecological Basis and Management Policy

Edited by John F. Craig

ICLARM
International Center for Living Aquatic
Resources Management

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CONTENTS

FOREWORD

The freshwater fisheries of Africa account for 54% of the total yield or 64% if upwelling fisheries are excluded. The rapidly expanding human population on the continent has substantially increased the demand for fish. The demand has not been matched by increased catches from the fisheries. The actual yields from many bodies of water are below predicted levels although catch statistics on which the yield estimates are based are usually highly inaccurate and incomplete. There is a requirement to develop the methods for the rational and sustainable harvest of fish resources and to unify national systems of fisheries data collection and analysis and the implementation of international fisheries management policy. The successful management of aquatic resources is dependent on the availability of data on the status of the resources, their rate of exploitation, the socioeconomic components affecting the 'harvesters' and external factors such as pollution which impact on the resources. To these data, state-of-the-art ecological modelling, initially developed for marine ecosystems, can be applied as well as an evaluation of socioeconomic impacts. ICLARM and the Fisheries Centre of the University of British Columbia, Canada, working in partnership, have been leaders in the evolution of these applications which included ECOPATH and ECOSIM.

In Egypt the scarcity of water means that the first priorities given to the resources are for drinking and irrigation. The building of the Aswan High Dam and the formation of Lake Nasser provided a 'water tank' for the country. Other uses of the reservoir include power production, navigation and fishing. The integration of the requirements of different users and the development of a common, holistic management policy could optimize output for all including the fishery. With this in mind, ICLARM developed a research strategy with the High Dam Lake Development Authority, Egyptian Ministry of Agriculture. The first stage of this strategy was a planning workshop in June 1998 which was attended by national and international experts. These proceedings clearly outline what is known and what is not known about Lake Nasser and its fishery, define its major constraints and suggest further studies and work. These include determining industry and local community requirements; increasing knowledge of the ecosystem; evaluating enhancement, in particular, the introduction of a species to utilize the open water; and improving the capabilities of local scientists, fishers, processors and managers.

Although the present plan for Lake Nasser represents a case study, the development and application of techniques have a much wider application in other lakes and reservoirs on the African continent. Knowledge developed for one system can be extrapolated and used to model another. This approach is a significant improvement on the mainly site-specific studies carried out in the past.

Meryl J. Williams
Director General
International Center for Living Aquatic Resources Management

PREFACE

Many fisheries of the world have not been adequately managed and catches are in decline. This is having considerable impact not only on the consumers in the riparian countries but also on the local people, most of whom are in the lower income group and whose livelihood depends directly on the sustainability of the fishing industry.

The inland waters of Egypt supply a considerable proportion of the nation's fish protein and Lake Nasser's contribution is significant. However, the full potential for fish production from the lake, based on its size and level of fertility (nutrient status), has not been achieved. Consumers are not receiving the fish that they require in their diet. In addition, the wealth currently being generated from the lake fishery is not reaching those who need it most, in particular the fishers and their families. Based on an analysis of the Lake Nasser fishery, a comprehensive project, 'Improvement of the Management of the Lake Nasser Fishery to Enhance the Economic Benefit of the Lake Basin Community', is being planned to increase the productivity of the lake in a manner which is sustainable, environmentally sound and socially equitable. As a first step, a workshop was held at the Isis Island Hotel, Aswan, Egypt, on 19-23 June 1998. The workshop was funded and organized by ICLARM with the assistance of the Fishery Management Center, High Dam Lake Development Authority.

These proceedings document the papers presented and the discussions held at the workshop. After an introductory session describing the lake and its users, the aims and objectives of the project and workshop, and the principles behind ecosystem modelling, a series of background papers were presented (19 of which are published here). Following an outline of the main issues identified by the workshop organizer, a thorough discussion on the constraints to the fishery was held. The participants were then introduced to modern techniques to evaluate the sustainability status of fisheries. Each major component—ecosystem, aquaculture, stock enhancement, alien fish introductions, socioeconomics and fisheries management—of the fishery was analyzed by the international experts based on the background papers and the present state of the art. These important contributions are presented here. The final sessions involved identification of tasks for implementing the project and the requirements necessary to carry out these tasks. In the time allowed for the workshop, it was not possible, nor appropriate, to put these tasks into an order of priority. This will be the next step in the project implementation. It was however very satisfying to see the active participation of all, not only in the presentation of papers and the discussions that followed, but also in the group activities and general debate. There were many fruitful dialogues (and informal out-of-session discussions) among ecologists, aquaculturists, engineers, economists, sociologists and laypersons: a good sign for future cooperation in the implementation of the project.

The Editor

ACKNOWLEDGEMENTS

The support of H.E. Prof. Dr. Youssuf Wally, Deputy Prime Minister and Minister of Agriculture and Land Reclamation for Egypt, is gratefully acknowledged. Mr. Hamdy Tolba, Chairman of High Dam Lake Development Authority (HDLDA), has supported the project since its inception and this is very much appreciated. Thanks are due to General Salah Mesbah, Governor of the Aswan Governorate, who kindly closed the workshop. I am indebted to all the participants of the workshop, in particular those who gave presentations and acted as rapporteurs. Ms. Mona Hassan Mahmoud of the Fishery Management Center (FMC) and Ms. Amira Mohamed of ICLARM provided excellent secretarial support in Aswan. A special note of gratitude goes to Mr. Mohamed El Shahat, Director of FMC, and the local organizing committee at Aswan, in particular, Mr. Zakariya Attiya and Mr. Mohamed Koraiyem from HDLDA and Mr. Abdel Wahab Khalifa from FMC. Mrs. Hilary Craig provided considerable voluntary assistance. Ms. Samia Gomaa provided logistical support in Cairo and assistance and artistic flair in page design. Thanks go to Mr. Mohammed Said for giving the permission to use his papyrus for the cover of these proceedings and to Mr. Khalid Nour Eldein for help in redrawing many of the figures. The editor would particularly like to thank Ms. Mohamed and Mrs. Craig for all their help and effort in the preparation of these proceedings. The costs of the workshop, including the publication of this volume and the travel of invited participants, were provided by ICLARM. I am grateful to Ms. Sheila Siar and the Publications Unit in Makati City, Philippines, for their assistance. The workshop was held at the Isis Island Hotel and the efficient support of the hotel management and staff was very much appreciated.

The Editor

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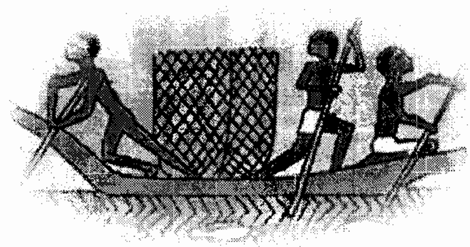

Introduction

Lake Nasser Overview

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El Shahat, M.M. 2000. Lake Nasser overview, p. 3-6. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Lake Nasser, together with Lake Nubia, is the second largest human-made lake in the world and was filled in 1964 after the construction of the High Dam at Aswan. The reservoir is about 480 km long, consisting of 300 km (Lake Nasser) in Egypt and 180 km (Lake Nubia) in Sudan. The only source of water is the River Nile with its inflow in the south. The lake is long and narrow, often with dendritic side areas called khors. There are 100 "important" khors. At 180 m above mean sea level (AMSL), the total surface area of the khors, i.e., areas outside the main valley covered by water, is about 4 900 km^2, 79% of the total lake surface area. However, they contain only 86.4 km^3, 55% of the total lake volume. Lake Nasser is eutrophic and at times the upper layer has a high concentration of chlorophyll *a*. The average water temperature ranges from 15.0°C in February to 32.4°C in August; dissolved oxygen from 0.0 to 10.3 mg l^{-1}, and transparency from 0.2 m in August to 6.1 m in December. The fishes recorded in the lake originate from the River Nile. The predominant species for sale as fresh fish are the tilapias (in particular *Oreochromis niloticus*), *Lates niloticus* and *Labeo* and *Bagrus* spp. The main salted fishes are *Hydrocynus forskalii* and *Alestes* spp. The highest total fish production was 34 206 t in 1981 and the lowest was 751 t in 1966.

Lake Nasser, together with Lake Nubia, is the second largest human-made lake in the world after Lake Volta, Ghana. It was filled in 1964 after the construction of the High Dam (Entz 1974) and extends from Cataract at Dal in Sudan (approximately 20°27'N and 30°35'E) to Aswan in Egypt (approximately 23°58'N and 33°15'E). The reservoir is about 480 km long, consisting of approximately 300 km (Lake Nasser) in Egypt and 180 km (Lake Nubia) in Sudan. It is situated in a desert area where the yearly mean precipitation is very low, ≤4 mm $year^{-1}$, and evaporation is very high, approximately 3 000 mm $year^{-1}$. The air is dry and the sky is almost completely cloudless. The only source of water is the River Nile with its inflow in the south and one outflow in the north at Aswan. This vast impoundment is more like an extremely slow flowing river than a typical lake (Entz 1976). Some of the most important morphometric data of the reservoir are summarized in Table 1.

Table 1. A summary of morphological characteristics for Lakes Nasser and Nubia (after Rashid 1995).

	Lake Nasser		Lake Nubia	
	160 m AMSL	180 m AMSL	160 m AMSL	180 m AMSL
Length (km)	292	292	128	190
Surface area (km^2)	2 585	5 238	472	978
Volume (km^3)	56	133	10	24
Shoreline length (km)	5 400	7 800	647	1 406
Mean width (km)	8.9	18.0	3.7	5.2
Mean depth (m)	21	25	20	26
Maximum depth (m)	110	130	–	–

AMSL = above mean sea level.
– = not known.

The mean slope of the Lake Nasser shoreline is steeper on the generally rocky or stony, mountainous, eastern shore than on the flatter, more open, wider, often sandy, western one. The lake has a long, narrow shape with dendritic side areas called "khors" (Fig. 1). There are 100 important khors in Lakes Nasser and Nubia combined, 58 on the eastern and 42 on the western shores. The total length of the khor systems when the lake is full, i.e., 180 m AMSL, is nearly 3 000 km. The total surface area of the khors, i.e., the areas outside the main valley covered by water, is about 4 900 km^2 (79% of the total

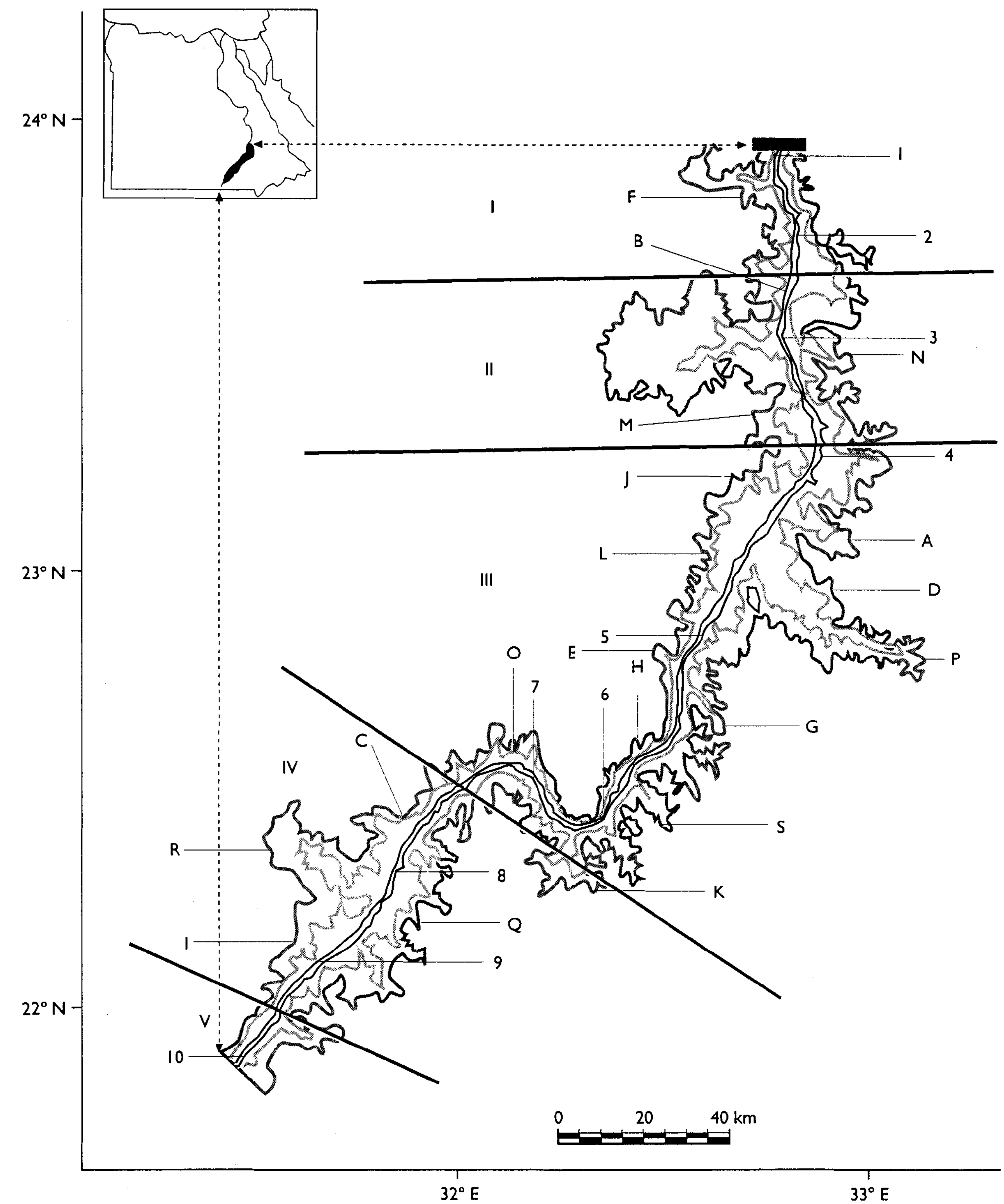

Fig. 1. Map of Lake Nasser. The lake is divided into five fishing regions, I-V. Sampling stations along the main channel are: *1* Aswan High Dam, *2* Dahmit, *3* Kalabasha, *4* Maria, *5* Sayala, *6* Singari, *7* Amada, *8* Masmas, *9* Abu Simbel and *10* Adindan. Khors sampled are: *A* Abesco, *B* Abu Hor, *C* Aniba, *D* El-Allaqi, *E* El-Madiq, *F* El-Ramla, *G* El-Seboa (east), *H* El-Seboa (west) *I* Forondi, *J* Garf Hussein, *K* Korosko, *L* Kourta, *M* Mirwaw, *N* Soliman, *O* Tomas, *P* Turgumi, *Q* Tushka (east), *R* Tushka (west) and *S* Wadi El-Arab.

lake surface). In volume, they contain only 86.4 km^3 water (55% of the total lake volume).

The deepest part of the lake is the ancient riverbed with its adjacent strips of cultivated land which together form the original river valley. The bottom of this central area is between 85 and 150 m AMSL. The side areas of the lake lie between 150 and 180 m AMSL. The speed of the current in the central area is fast at the southern end of the Nubian gorge region (0.5 m s^{-1}). This speed is gradually reduced within a few kilometers to 0.1-0.2 m s^{-1} and in Lake Nasser to 0-0.03 m s^{-1}.

Seasonally, the water level is lowest in July and August, and rises rapidly with the flood in early November (sometimes October or December). The highest levels are reached four months later. In November 1982, the water level reached 173 m AMSL and then it fell gradually to a minimum of 151 m AMSL in July 1988 (Fig. 2). A sharp increase in the water level occurred during the latter half of 1988 to reach the previous high level, and this was maintained during 1989-1997. In November 1996 and December 1997, water levels reached 179 m AMSL.

Lake Nasser is a monomictic subtropical lake with prevalent lacustrine characteristics and with a single circulation period in winter between November and March. Table 2 summarizes some of the surface water characteristics. Water temperature ranges between 15.0°C in February and 32.4°C in August. Transparency (Secchi disc depth) is high during October-April and low during March-September. Dissolved oxygen is usually high during November-April and low during May-October. The pH is normally alkaline.

The upper layer of the water column from the surface to 8 m depth can contain high concentrations of chlorophyll *a*. The maximum chlorophyll *a* concentration recorded was 42.4 mg m^{-3} in January 1984. Lake productivity would indicate that the lake is eutrophic.

The fishes recorded in the lake are indigenous to the River Nile and originated from those formerly living in the Nubian part before impoundment. The 57 species recorded since 1964 belong to 15 families (Latif 1974). The important species are *Oreochromis niloticus, Sarotherodon galilaeus, Hydrocynus forskalii, Alestes dentex, Lates niloticus, Bagrus bayad, B. docmoc, Synodontis serratus, S. schall, Barbus bynni* and *Labeo niloticus*. These together make up more than 95% of the catch. The predominant species for sale as fresh fish are the tilapias and *Lates, Labeo* and *Bagrus*. *Hydrocynus* and *Alestes* spp. are salted.

The fish are caught by trammel nets, gill nets (bottom and floating), long lines and beach seines. The number of boats and fishers varies according to the fishing association operating in the lake (Table 3). The fishing yields (Table 4) have varied from a low value in the late 1960s and early 1970s to a peak in the early 1980s. At present, the yield is about 20 500 t, well below that expected. An unknown quantity of fish landed is poached.

Table 2. Summary of the range of limnological characteristics at the surface of Lake Nasser.

Factor	Range	
	Min	Max
Water temperature (°C)	17.4	31.4
pH	6.1	9.1
Dissolved oxygen (μg l^{-1})	0.0	12.5
Phosphorus (μg l^{-1})	9.8	49.4
Nitrate (μg l^{-1})	0.0	37.6
Chlorophyll *a* (μg l^{-1})	2.0	42.4
Secchi disc depth (m)	0.2	6.1

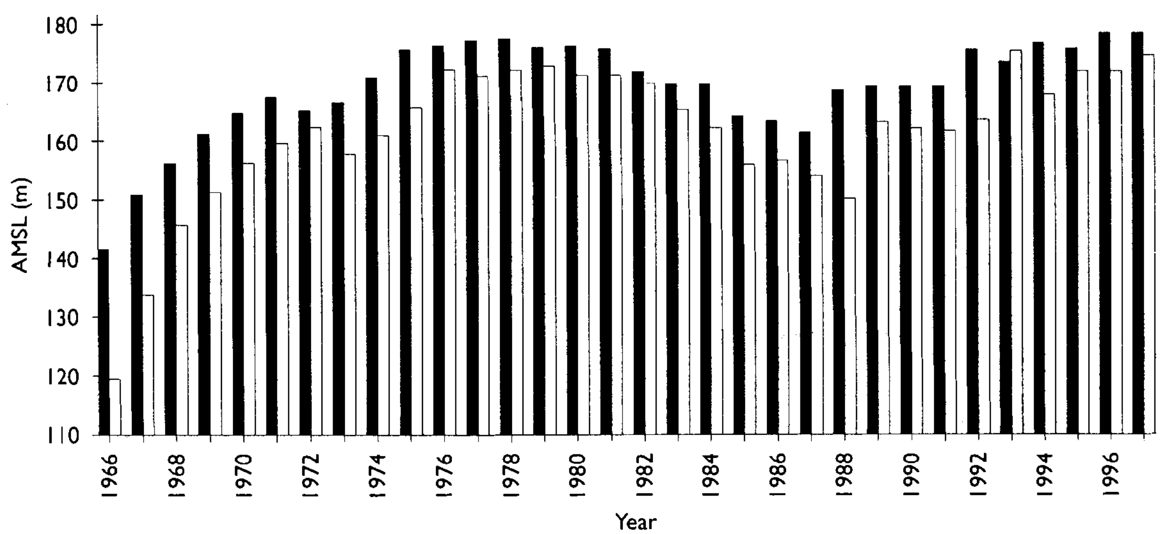

Fig. 2. Water levels at the Aswan High Dam from 1966 to 1997. (Maximum = solid bars and minimum = open bars).

Table 3. Fishery cooperatives of Lake Nasser and the number of boats and fishers employed (1997).

Name of association or public corporation	No. of fishing boats	No. of fishers
Misr Aswan Cooperative Society	228	547
Aswan's Fishermen's Cooperative Society	605	1 452
Mother Cooperative Society	1 431	3 434
Nubian Cooperative Society	526	1 262
El Takamol Cooperative Society	61	146
Total	2 851	6 841

Table 4. Official landed catch statistics (t) of Lake Nasser, 1966-1997.

Year	Fresh	Salted	Total	Year	Fresh	Salted	Total
1966	347	404	751	1982	25 979	2 688	28 668
1967	782	633	1 415	1983	28 885	2 379	31 282
1968	1 152	1 510	2 662	1984	22 069	2 465	24 534
1969	2 802	1 868	4 670	1985	24 975	1 475	26 450
1970	3 370	2 306	5 676	1986	15 023	1 292	16 315
1971	4 316	2 503	6 819	1987	15 287	1 528	16 815
1972	5 303	3 040	8 343	1988	14 579	1 309	15 888
1973	8 027	2 560	10 587	1989	14 031	3 619	15 650
1974	8 030	4 225	12 255	1990	20 129	1 753	21 882
1975	10 384	4 251	14 635	1991	29 642	1 196	30 838
1976	10 929	4 862	15 791	1992	24 721	1 498	26 219
1977	12 279	6 192	18 471	1993	16 723	1 208	17 931
1978	17 852	4 873	22 725	1994	20 491	1 583	22 074
1979	22 649	4 372	27 021	1995	19 693	2 365	22 058
1980	26 344	3 872	30 216	1996	18 159	2 381	20 540
1981	31 295	2 911	34 206	1997	16 546	3 957	20 503

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DISCUSSION

Q. Could you please tell us something about the Tushka Project?

A. The Tushka (New Valley Development) Project will create about 2 500 jobs. It is located near the Sudanese border about 230 km upstream from the Aswan High Dam. It will involve the building of pumping stations and the El Sheikh Zayed Canal which will have four branches. Discharge into the canal will be 300 m^3s^{-1} (25 million m^3 day^{-1}). Reclaimed land will be about 200 000 ha, new communities will be created, and a new demographic distribution of the Egyptian population will be achieved.

Q. What can the fishers do if they leave the lake because of low income?

A. They can work as farmers in their hometowns.

Q. Ninety-five percent of fish production comes from near the shore. Why from this part only? What is the level of technology used?

A. Most fish in the lake inhabit the littoral area. Preliminary results of FMC showed that the pelagic is not used significantly. The catch is not related to fishing technology but to lake level changes. The coastal area is rich in both phyto- and zooplankton.

Q. Why is Lake Nasser not fully utilized by the fishery?

A. Integrated water management is applied to the lake for the benefit of all users. It is important to maintain water quality as the lake is the only 'freshwater' tank for all Egyptians.

Conflicts between Users

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Saad, M.B.A. 2000. Conflicts between users, p. 7-9. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The construction of the High Dam and the formation of Lake Nasser upstream have been among the most important projects for sustainable development in Egypt. The total storage capacity of the lake is 162 km^3. Three types of storage are involved: (1) dead storage which extends from bed level to the water level at 147 m above mean sea level (AMSL) and has a capacity of 31.6 km^3; (2) live storage between 147 and 175 m AMSL which has a capacity of 89.7 km^3; and (3) emergency storage between 175 and 183 m AMSL with a capacity of 41 km^3. The lake ensures that Egypt is provided with Nile water as specified in the 1959 agreement between Egypt and Sudan. The High Dam is the means of controlling sufficient flow for daily demands, which include agriculture, industry, tourism, hydroelectric power, drinking, domestic use and navigation. The development of the lake area is a major source of interest for many sectors in Egypt. Development projects include agriculture, industry, tourism and fishing production. Others are ready for implementation. In this paper, the conflicts between different users of the lake are highlighted and the environmental consequences resulting from development projects are described.

Introduction

The River Nile, the longest river in the world (about 6 825 km), has the oldest and most extensive hydrological records of any water system. It collects the water from three basins: (a) the equatorial lakes plateau, (b) Bahar El Ghayal and (c) the basin of the rivers Sobat, Blue Nile and Atbara, which emerge from the Ethiopian mountains. There are seven dams and their associated reservoirs built on the Nile and its tributaries. Two of them store water all-year round. These are at the outlet of Lake Victoria in Uganda and at the Aswan High Dam on the main Nile in Egypt. Several reservoirs that fill seasonally are situated in Sudan. These are behind the Sennar and Roseires Dams on the Blue Nile, the Khasm El Girba Dam on the Atbare River and the Jebel Awlia Dam on the White Nile. In Egypt, the Old Aswan Dam on the main Nile is used as a regulator for Lake Nasser. The annual yield (volume) of the River Nile differs greatly from one year to another. It may rise to about 151 km^3 as in the year 1878-1879, or drop to 42 km^3 as in the year 1913-1914.

Water in Egypt is predominantly used for agriculture. The total area of cultivated land is about 3.1 million ha, which requires 54.5 km^3 water $year^{-1}$. Domestic use demands 2.9 km^3 $year^{-1}$. In addition to Lake Nasser, water demand is met from ground water and drainage. Several factors have led to a rapid increase in water demand. These include a rapid rise in the Egyptian population, excess cultivation of rice (actual area 650 000 ha compared to the planned area of 283 000 ha), horizontal expansion of the cultivated area, the change from sprinkler and drip to immersion irrigation, industrial development and improved living standards. By the year 2000, it is expected that demands will increase by about 10 km^3 $year^{-1}$, 90% of which will be required for a new 43 million ha horizontal expansion of agriculture and 10% for an increase in domestic and industrial use. In the year 2027, the agricultural demand will be increased by about 5.6 km^3 $year^{-1}$ (810 000 ha will be reclaimed) and the domestic and industrial demands will increase by 6 km^3 $year^{-1}$.

Lake Nasser storage basin

The main reason for constructing the Aswan High Dam was to safeguard the Egyptian people from the devastating consequences of droughts, which they have experienced many times in the past. The guaranteed annual flow of water from

Lake Nasser is 55.5 km^3. This volume provides about 96% of the total Egyptian demand. The outflow is carefully controlled on a daily basis, according to actual needs. The High Dam is 111 m above the riverbed level. The bed level is 85 m AMSL, while the roadway level is 196 m AMSL. The maximum level of the upstream reservoir reaches 182 m AMSL. The spillway at the west side of the river has been designed to release whatever exceeds this level with a maximum discharge amounting to 2 400 m^3 s^{-1}. The water held upstream of the High Dam at its maximum storage level comprises an artificial lake, extending 480 km to the south with an average width of 13 km, and a surface area of about 62 500 km^2. This lake is considered to be the second largest human-made lake in the world. It is evident that the storage of floodwater behind the dam will lead to the sedimentation of most of the suspended materials held in the lake. However, it was considered while designing the High Dam that the reservoir would be spacious enough to hold large amounts of sediment over many years before the reservoir capacity was affected.

The reservoir storage capacity is 162 km^3, distributed as follows:

- 31 km^3 is the capacity for sediments deposited over 500 years. It lies between the bed and the 147 m water level.
- 90 km^3 is the live storage capacity, which lies between the 147 and 175 m water levels.
- 41 km^3 is the flood room (emergency storage) for protection against high floods. It lies between the 175 and 182 m water levels.

Lake Nasser hydrology

Water levels

The water level of the lake changes both between months and years depending on the rates of inflow and outflow. The highest water levels reached were in November 1996 and December 1997 at 179 m AMSL, and the lowest occurred in 1988 at 151 m AMSL.

Water velocity

The water velocity of the lake decreases as it approaches the High Dam. The magnitude of the velocity depends on the inflow rates and the lake water level. At the entrance to the lake the flow velocity is about 0.5 m s^{-1} and close to the dam it is about 0.03 m s^{-1}.

Sedimentation

After the construction of the High Dam, the sediment movement changed completely. The average yearly deposition is about 134 million t based on the average yearly inflow of 84 km^3. Based on recent studies, the accumulated sedimentation inside the lake is 2.76 km^3. The coarser material of the sediment is usually deposited at the inflow to the lake in the south and fine material is deposited when the flow velocity is reduced further in the central and northern parts. Since the lake was created, a new submerged delta is being formed within it. However, due to the recent drought, the upper layers of the delta have degraded and moved with the flow towards the dam. The fine sediment can be traced to 200 km below the dam.

Water quality

Factors such as climate, watershed characteristics, geology, nutrients and thermal stratification have seasonal impacts on the quality of lake water. Generally, from samples collected before and after the flood, the lake water has good physical and chemical characteristics for use. The high temperature in the region accelerates evaporation and weathering processes. In addition, the production of CO_2 from aquatic plants helps in the transformation of calcite and dolomite into soluble calcium and magnesium bicarbonate. Such biological activity may considerably affect the chemical properties of the water.

Evaporation and other water losses

The lake lies in a hot and extremely arid climatic area, so evaporation represents a significant loss. Evaporation is difficult to measure accurately. The whole lake's annual evaporation losses for the period from 1964-1965 to 1990-1991 have been estimated at 9.6 km^3 by bulk aerodynamics. During the same period, losses due to seepage were calculated at 0.05 km^3. Extensive drilling of boreholes was carried out along cross sections on the Nile within the reservoir area and Darcy's law was applied to these data. Most of the reservoir basin consists of Nubian sandstone that is known to have low permeability.

Conflicts

There are many conflicting factors affecting the users of the lake and its water quality.

Due to the importance of the lake as a strategic water reservoir for Egypt, the following should be considered and methods of reconciliation developed:

- Agricultural development on the lake banks will increase crop production but will also add low quality drainage water to the lake.
- An increase in power generation will require more water extraction from the lake that may be needed during maximum agricultural demand.

- An increase in navigation will enhance transportation but will also add a new source of pollution.
- The fishing industry is important to the national income but must not cause lake pollution.
- Urbanization and industrialization around the lake will develop the economy of the region but the lake will be the recipient of all the drainage water of such activities resulting in lower water quality.

Development of the Lake Nasser area

In 1995, the National Water Research Centre organized a three-day seminar in Aswan. The seminar was entitled "Development of the lake area—visions and constraints". In this seminar, many papers were presented dealing with the desired developments for the lake area including industry, tourism, agriculture, mining and fishing. The participants at the seminar recommended the development of the lake area, but with the following considerations. Egypt's share from the Nile water is limited by the agreement of 1959. This share has been used completely for the last five years. Any development for the lake area would require water and it would affect the water supply for the Nile valley and delta. There is a need for identifying criteria for developing the lake. These should be applied strictly in order to prevent undesired effects such as pollution.

The water resources of Egypt are very limited and the lake area should be kept as a natural protected area. Future development in the lake area should not adversely affect water quality.

Summary and conclusions

Lake Nasser represents the national freshwater bank of Egypt. Since the construction of the Aswan High Dam in 1964, Egypt has been able to release water downstream as demanded. The lake is a relatively closed ecosystem with a water retention time of 20 years. The water quality of the lake is affected by many factors including inflows, water circulation, thermal stratification, loadings and sedimentation. The water resources of Egypt are very limited, therefore any future activities and perturbations on the lake should be carefully considered before implementation. The area around the lake should be kept as a natural desert.

DISCUSSION

Q. The sediment entering the lake especially during the yearly flood will fill the lake in 30 years. What is your comment?

A. This is false. The lake is designed to receive material for 500 years.

Q. As a result of the sedimentation, a new delta will be formed. Where will this delta be formed?

A. The coarser particles will be deposited at the southern end of the lake while the finer particles will settle further north.

Aims of the Lake Nasser Project and First Planning Workshop

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Craig, J.F. 2000. Aims of the Lake Nasser Project and first planning workshop, p. 11-13. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The aim of the Lake Nasser Project is to integrate social, economic and ecological factors in the formulation of a management policy for sustainable fish production. The workshop was held to review the present state of knowledge, identify constraints, evaluate existing information and state of the art techniques, and determine future research objectives and strategy.

Introduction

The successful management of aquatic resources is dependent on the availability of data on the status of the resources, their rate of exploitation, the socioeconomic factors affecting the 'harvesters', and external factors such as pollution that impact on the resources. In many countries, particularly in this region, the problems of acquiring suitable and sufficient data are compounded by the wide diversity of species, by the multiplicity of fishing techniques, by the dispersed and often inaccessible landing sites, by decentralized markets, by interaction and often competition among traditional, artisanal and commercial fisheries, and sometimes by political and/or civil unrest.

Historic fisheries data collected from the Great Lakes in the African Region have been, in many cases, fragmented and analyzed only at the national level despite the resource being shared by more than one riparian state. Perhaps, what has been missed is a unified theme and the establishment of a goal to which data can be harnessed.

Some of the problems outlined above may be overcome by developing a consolidated, holistic approach using data from several sources to model a target lake. The modelling will depend on the exchange of good and reliable information. The need to develop a unified approach to the management of fish resources in the African region has been recognized for some time (Annala 1997).

Several parts of Africa are endowed with lakes, both large and small, and natural and artificial. The freshwater fisheries of the continent account for 54% of the total catch or 64% if upwelling fisheries are excluded. The lakes provide food and livelihood for millions of people. Small-scale fishers who tend to be the poorest members of the population take a large proportion of the catch in many of the areas. These fishers often live in remote areas making it difficult to monitor their catch or control their fishing techniques. Rapidly expanding human populations have increased the demand, both locally and for export, for fish production. The demand has not been matched by increased yields from the capture fisheries. The actual catches from many bodies of water are below predicted levels although statistics on which the yields are based are usually highly inaccurate and incomplete. There have been many capture fisheries' research projects carried out in the region that have had specific objectives in ecological, sociological and/or economic disciplines. Rarely have these areas of research been integrated to formulate a common management policy for a shared fishery and, moreover, rarely have ecological considerations been integrated with the social and economic structures in which they are embedded (Fig. 1).

There is an important need to accumulate and share present knowledge concerning specific fisheries and to identify the data that are not available but are required to model the fisheries. Two phases in the African Lakes' Program are envisaged. The first phase (Years 1-5) will focus on lakes where

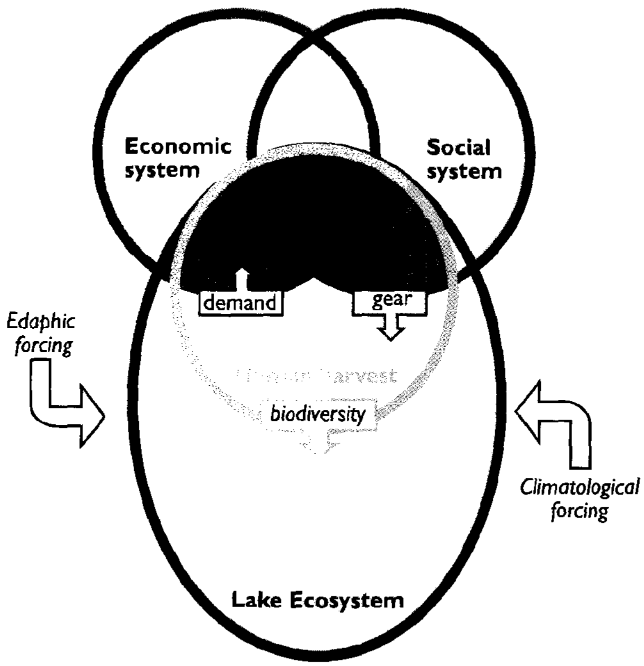

Fig. 1. Generalized conceptual diagram for ICLARM's African lakes' program.

considerable data have already been collected. Missing data will be gathered or further research performed so that modelling of the fisheries resources can be developed. It will be concluded with a synthesis and presentation of data at a conference. The second phase (Years 6-10) will concentrate on less well-studied but economically important aquatic systems using the methods developed during the first phase. The program will provide an overall and unified approach to fisheries prediction and management in the region. A major international meeting organized by the International Center for Living Aquatic Resources Management (ICLARM) will bring the results of this program together. Both the meeting and synthesis work will be incorporated into a book, published by ICLARM, as the principal scientific output. Training and transfer of "know-how" will be the development output.

Lake Nasser

This is the first lake to be considered in ICLARM's African Lakes' Program. 'The ecological basis and management policy for sustainable fish production in Lake Nasser' was established through the cooperation between the High Dam Lake (Nasser) Development Authority and ICLARM. The Authority has approved ICLARM's four-year workplan that aims to maximize fish production and utilize the high lake productivity.

Lake Nasser – background

This is given by El Shahat (this vol.). The main points are as follows:

- Shared by Egypt and Sudan.
- Used for water storage, electricity generation, navigation and fish production.
- Present reservoir formed in 1964 by the construction of the Aswan High Dam.
- At High Dam (Egypt), fish catch statistics (catch, number of boats, type of fishing gear, fishing effort, etc.) have been collected since 1966.
- About 1 000 people are involved in the fishery, which has a gross income of about US$30 million.
- Potential yield thought to be about 80 000 t (derived from a catch and primary production model). Actual recorded landings <43% of the potential.

Objectives of the Lake Nasser proposal

- Improve the current management of the lake fisheries based on sound biological, social and economic factors and thus provide sustainable production and maximum revenue for the people of Egypt.
- Acquire a better understanding of the Lake Nasser ecosystem.
- Determine the benefit of fish enhancement, cage culture and the introduction of fish to utilize the pelagic.
- Enhance the capabilities of local scientific staff and fishers.

First planning workshop

The objectives of the workshop were as follows:

Background review

- Determine national objectives.
- Investigate the current status of knowledge on the system.
- Analyze the development of the project to date.

Constraints analysis

- Analyze the constraints that prevent the realization of development objectives and potential.

Evaluation of existing research results

- Assess the research (both within Egypt and externally) that can be used to address the constraints identified.

Determination of research objectives and strategy

- Determine future research objectives and strategy based on the constraints tree, the evaluation of existing results and the perception of research opportunities.

Identification of research subprojects

- Specify subproject details including their objectives, major activities, location and the human resources required.

Priority setting

- Identify the criteria and methods to be used.
- Apply the above to define a priority set of subprojects.

Acknowledgements

I am grateful to Tony Pitcher for providing Fig. 1, drawn from an idea we developed during my visit to the Fisheries Centre, University of British Columbia, Canada, in 1997.

Reference

Annala, J.H., Editor. 1997. Fisheries and aquaculture research planning needs for Africa and West Asia. ICLARM Conf. Proc. 50, 80 p.

DISCUSSION

Q. You mentioned in your presentation that the target of the project is to obtain optimum sustainable production from the lake. How could this target be achieved if the production depends on the water level in the lake which the fishery manager has no control?

A. The project's aim is to focus on all the constraints against fish production then develop a management policy which will take into consideration those factors that will lead to the sustainable production even if the water level changes.

The Use of Ecosystem Modelling in Comparative Policy Analysis: Maximizing Sustainable Benefits from Lake Nasser's Aquatic Resources

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Pitcher, T.J. 2000. The use of ecosystem modelling in comparative policy analysis: maximizing sustainable benefits from Lake Nasser's aquatic resources, p. 15-22. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Single-species approaches to fishery assessment are not sufficient to avoid the changes to ecosystems caused by fishing. These changes include the replacement of high trophic level, generally high-value species, by low trophic level and lower-value species. Commercial fisheries' practices and ecosystem effects interact producing serious depletion that is usually detected too late to avert, and may result in fishery collapses and the failure of stocks to rebuild. Multispecies management is required. Multispecies virtual population analysis (MSVPA) is one technique that can be used to assess species of fish for which good catch and diet data are available, but whole ecosystem modelling is required to evaluate the impacts of fishing on nonharvested groups. Ecosystems and their embedded fisheries can now be effectively modelled using the mass balance system of ECOPATH, which is briefly introduced. A new development, ECOSIM, allows simulation of "what if" questions that can be used to explore changes by the fishery sector. Beyond the limits of numerical simulation, ECOVAL comprises a new set of techniques for the comparative evaluation of alternative ecosystems. Ecosystem models of current, unexploited and alternative ecosystems are drawn up and their benefits to society assessed. In natural aquatic ecosystems, the state of ecosystems in the past provides the alternatives: a process termed BACK TO THE FUTURE. In human-made systems, a wide range of possible ecosystems, including present and unfished systems, may be compared. Benefits evaluated include total catch, economic value and diversity of fishery products, employment, biodiversity and sectoral conflict. Using ECOVAL, the ecosystem and associated fisheries that maximize total benefit to society may be adopted as a policy goal, taking into account the costs of shifting from the present system.

Introduction

Fisheries management has a history of unpleasant surprises that has dismayed the founders of this quantitative science (e.g., Larkin 1996; Beverton 1998; Holt 1998) and has led some prominent fishery scientists to consider that no fishery has ever been managed in sustainable fashion (Ludwig et al. 1993). For example, the unexpected collapse of the Newfoundland cod caused economic and social hardship on a vast scale. At one time vaunted by the Canadian government as the "best managed fishery in the world" (Finlayson 1994), the cod were historically one of the most prolific fish stocks anywhere on the planet (Kurlanski 1997). Environmental and predator changes have been ruled out as a cause of the collapse (e.g., Myers and Cadigan 1995), and serious mistakes have been identified in stock assessment (e.g., nonexplicit and unachievable policy goals and instruments: Matthews 1995; failure to use spatial data: Hutchings 1996; and errors in biomass estimation: Walters and Maguire 1996). There is also a suspicion that political goals compromised scientific management of the cod (Hutchings et al. 1997). Even today, the Newfoundland cod resource has not begun to recover despite five years of closure, suggesting that all of these analyses have missed the vital factor of ecosystem change. Moreover, the lessons have not been fully learned by fishery managers, as we find that now North Sea cod stocks are also in danger of collapse (Cook et al. 1997).

Unlike rocket science, where a disaster can usually be traced by diligent engineers to faulty O-rings or other defective hardware or software, fisheries are embedded in aquatic ecosystems that are very imperfectly understood. One contributory reason underlying fishery disasters like this is that management has generally not been designed to adapt and learn in the face of errors in data, uncertain assessment and ineffective control instruments, despite the long availability of sophisticated quantitative methods for adaptive management (reviewed by Walters 1986; Punt and Hilborn 1997; Bundy 1998; Hilborn and Liermann 1998). Moreover, the generation of excess catching power (= overcapacity) has been identified as a major worldwide bioeconomic problem that is out of control and which no one can yet see how to arrest (Mace 1997).

There is, however, a second and more fundamental reason for fishery collapses, that unfortunately presages future disasters occurring at an increasing rate. This is the long-term effect of fishing on the species composition of aquatic ecosystems. The ecological processes leading to these changes in ecology seem to be ratchet-like, difficult to reverse and, as yet, imperfectly understood (Pitcher, in press: a). Some recent evidence supports this conjecture: there has been a progressive decline in the trophic level of fish caught in all areas of the world, including freshwaters (Pauly et al. 1998a), as fishers maintain their income by switching to species lower down the food web when higher trophic level fish become depleted. A consequence is that "trash" fish have come to replace high-value table fish, a process that has reached disaster levels in the South China Sea, the Gulf of Thailand and the Black Sea, and is proceeding unchecked almost everywhere else (Pauly et al. 1998b). Moreover, changes in cephalopod fisheries independently support the notion of such a worldwide shift in the nature of exploited marine ecosystems (Caddy and Rodhouse1998).

Avoiding these profound changes in aquatic ecosystems wrought by fisheries requires no less than a paradigm shift in fisheries management (Pitcher and Pauly 1998). Single-species fish stock assessment, although necessary for computing the details of age structure and population biomass, is simply incapable of providing the information to remedy or reverse this process (Pitcher, in press: a). What is needed is an evaluation of the impacts of fishing on aquatic ecosystems, and the adoption of policy goals that aim to maximize profits or total benefits to society, by comparing the fisheries in alternative exploited ecosystems (Pitcher 1998b). This agenda requires multispecies, ecosystem-based stock assessment models, and is an essential requirement for evaluating and maximizing the benefits from fisheries in the African lakes (Pitcher 1997).

Approaches to multispecies assessment

Although multispecies methods for assessing the exploitation status of fisheries have long been recognized as being critically needed (e.g., Larkin et al. 1984), there are no methods yet generally accepted by the fisheries research community. Sissenwine and Daan (1991) comprehensively reviewed multispecies methods that showed promise at that time, but recent developments in ecosystem modelling have superseded their conclusions. Two approaches to multispecies assessment that might be used in Lake Nasser are briefly introduced here: MSVPA and mass-balance ecosystem modelling.

Multispecies virtual population analysis (MSVPA)

Single-species virtual population analysis (VPA) estimates the population numbers (and hence biomass) that must have existed in each age group from the recorded catch and an assumed fishing rate (actually the instantaneous fishing mortality, F). Each cohort is progressively estimated, stepping backwards in time from the present age structure, and VPA methods are sometimes termed cohort analysis (see description of classic method in Pitcher and Hart 1982). Clever ways have been devised to tune the estimation to converge on the correct fishing rate and to adjust the results to known biomass surveys. Recently, more sophisticated "catch-at-age methods" have greatly extended the scope and power of the classic VPA (e.g., CAGEAN: Deriso et al. 1985; stock synthesis: Methot 1990, 1995). For example, Parma (1993) used CAGEAN methods in a retrospective analysis of the Pacific halibut fishery from 1944 to 1990, finding that quotas should be adjusted downwards because halibut biomass had been consistently overestimated in each individual year's analysis. Length-based versions of VPA are also widely used (Pauly 1983; Jones 1984). A weak point of most of these methods is that natural mortality has to be known quite accurately for the method to work well and, in fact, it is usually guessed.

MSVPA uses a similar catch-at-age technique to VPA, except that part of the natural mortality is explicitly modelled as the predation by each predator on each age group of prey. As the numbers of each age group of predatory species are estimated, their impact on prey species ripples through the analysis, age-class by age-class (a little used length-based version is termed phalanx analysis, Pope 1980). MSVPA works best where there are many species of commercial fish that eat other commercial fish, as in the North Sea gadoid community. MSVPA requires a large amount of historical catch data and biomass estimates, in addition to stomach samples that may be used to estimate the predation rate of each age-class of each predator species upon all others (Christensen 1994). MSVPA is reviewed by Magnusson (1995).

MSVPA techniques are helpful in estimating the biomass and harvestable quotas of commercial fish, but they are not capable of addressing the dynamics or impacts of fishing on unexploited groups, such as lower trophic groups, or unexploited top-carnivore animals that feed upon commercial fish, like billfish, seals, whales, aquatic reptiles and sea birds. MSVPA might be used for top carnivores in Lake Nasser's fisheries once sufficient data of age structure of the catches have been accumulated.

Multispecies fisheries and ecosystem modelling

In the past, most forms of ecosystem modelling have generally been of theoretical interest rather than practical relevance. Most are complex, involve many hundreds of parameters, do not encompass the whole ecosystem, and do not usually describe the fishery in sufficient detail, for example by gear sector, to be used directly in management. Some examples are: Ulltang (1995) on the Barent Sea, Andersen and Ursin (1977) and Ursin (1979) on the North Sea, Laevastu and Larkins (1981) and Low (1983) on the North Pacific.

In these models, usually only part of the ecosystem is included, and physical oceanographic or limnological processes that are not necessary for understanding the fishery are often confused with the essential biological features. In general, there seems to have been little advance on Larkin and Gazey's (1982) pioneering attempt to model fish communities by multiple predator prey models. Published models tend to be highly site-specific and so are difficult to adapt to new sites and, moreover, at best, they can often describe, but are not robust enough to make predictions or understand ecosystem processes.

Ecosystem modelling based on ECOPATH

ECOPATH mass-balance and the Law of Maat

In recent years, a series of developments in ecosystem models based on the simplifying assumption of mass-balance have improved the situation described above. ECOPATH is a practical trophic mass-balance model developed by ICLARM (Christensen and Pauly 1992, 1993) based on original work by Polovina at the National Marine Fisheries Service in Hawaii (e.g., Polovina 1984). Recent extensions to this technique have been led by the Fisheries Centre at the University of British Columbia, and comprise ECOSIM (Walters et al. 1997), a dynamic simulation technique, and ECOSPACE, a spatial ecosystem modelling tool. These developments are described below.

ECOPATH tallies the flows of matter within the major components of the system, defines the trophic level of each component and can be used to estimate biomass (B) given information on diet, mortality (production, P, to B ratio, which equals the total mortality rate, z) and consumption rates (consumption, Q, to B ratio). It is not the intention here to provide full details of the method, but the basic ECOPATH approach is to solve a set of simultaneous linear equations, one for each group, i , in the system:

[Production of i] – [all predation on i] –
[nonpredation losses of i] – [export of i] = 0

This may be expressed more explicitly as:

$$[(B_i(P/B)_i * EE_i) - \sum(B_j * (Q/B)_j + DC_{ji}) - EX_i - ac] = 0$$

where,

$\sum$ = summation for j = 1 to n, predator trophic groups;
B_i = mean biomass of group i;
B_j = mean biomass of predator j;
$(P/B)_i$ = production/biomass, or total mortality rate of group i (equilibrium);
EE_i = ecotrophic efficiency, the fraction of the production of i that is either consumed within the system or exported out of the system;
$(Q/B)_j$ = food consumption/biomass of the predator j;
DC_{ji} = fraction of i in the diet of predator j;
EX_i = exports (catches + emigration) of group i; and
ac = accumulated biomass.

An equation like this is drawn up for each component of the system, and the set of simultaneous equations solved using standard algorithms (Mackay 1981). Nonpredation losses include disease, the metabolic costs of assimilation and respiration. The model uses four parameters for each group (derivation of the model equations from the general principle set out above may be found in Christensen and Pauly (1992, 1993) and in the "help" files associated with the ECOPATH software package): the production to biomass ratio, P/B; the consumption to biomass ratio, Q/B; the biomass, B, expressed in t km^{-2}; and the ecotrophic efficiency, EE, expressing the amount of a group that is utilized within the system. In addition, any exports from each group have to be estimated, and the proportion of each group's diet represented by other groups in the ecosystem. Three of these four parameters are required as input, and the remaining one is estimated for each group. As there are short cuts to the estimation of both P/B and Q/B ratios, and EE can be "guesstimated" for most types of organisms; drawing up a preliminary ecosystem model is not so hard as might be imagined, especially where there are considerable background data.

What groups should be included in the ECOPATH model? For a freshwater body like Lake Nasser, the minimum system might be: fish-eating birds, fish-eating reptiles like crocodiles, top predator fish such as Nile perch, medium predatory fish such as tiger fish, benthic fish such as catfish, small pelagic planktivorous fish such as cyprinids, herbivorous fish like tilapias, macrobenthos, meiobenthos, carnivorous zooplankton, herbivorous zooplankton, benthic producers such as algae, macrophtyes, phytoplankton and both organic and inorganic detritus pools. More groups, up to ECOPATH's maximum of 50, may be added to these 16 as information becomes available. The model will become more useful for fishery assessment as group composition becomes closer to the actual species targets of the fishery. Bacteria present a technical problem in ECOPATH modelling as their flows are so large that their errors may swamp other data. They are often considered a separate adjacent ecosystem for this reason. Fisheries for any of the model groups may be included, entered as annual catch per square kilometer. Up to six different gear types and target species can be included in the current software (version 4.0), and there is scope to enter bycatch.

Although quite extensive computationally so that purpose-written software is essential, ECOPATH models are conceptually simple, being little more than accounting sheets for diet, biomass and the import and export of matter (or energy) among predators, prey, grazers and plants. The models are credible because, by using the principle of mass-balance, ECOPATH models are grounded in physics: the first law of thermodynamics (the conservation of energy and matter) is obeyed. The principle of mass-balance in ecosystem modelling may remind Egyptians of the ancient pharaonic Law of Maat, which appears to have meant truth, order and harmony. Maat encouraged all elements of government and administration to be in harmony and balance with human endeavor and with the natural world, especially with the life-giving River Nile.

Many ecologists worry about the mass-balance assumption, but it is not as constraining as it may appear at first sight. It is consistent with the work of most aquatic biologists, whose state and rate estimates represent averages applied to a certain period (although this generally is not stated). Here state and rate estimates are applied during an arbitrary period. In many cases, the period considered will be a typical season or a typical year, but the state and rate estimates used for model construction may refer to different years. For example, ECOPATH models may represent a decade or more, during which little change has occurred. When ecosystems have undergone large changes, two or more models may be needed, representing the ecosystem before, during and after the changes.

The mass balance assumption also has the advantage that model systems can be built without requiring vast amounts of accurate data: many variables can be estimated from inputs and outputs by solving the set of simultaneous linear equations. They are robust in that even preliminary, incomplete models are still helpful and useable and may be improved when more accurate data become available. They are quite easy to explain to nonscientists, and relatively easy to build and validate by junior and student scientists using the software.

Ecologists have also worried that uncertainty was not considered in earlier versions of ECOPATH. The ECORANGER module in the most recent releases of the ECOPATH software now remedies this by allowing input of error distributions (uniform, triangular, normal or log-normal) to be attached to all the model inputs. Random values are drawn from these distributions in a Monte Carlo fashion for one model run, and the process repeated up to 1 000 times. Of the models that pass a selection criteria (such as mass-balance), the best-fitting one is chosen using a least square criterion, and its error bounds evaluated from the runs completed. This process involving prior and posterior distributions is analogous to the Bayesian estimation.

In addition to its use in evaluating fisheries, the ICLARM software guide to ECOPATH states that such modelling has a number of heuristic advantages:

- requiring the modeller to review and standardize all available data on a given ecosystem, and identify information gaps;
- requiring the modeller to identify estimates (of states or rates) that are mutually incompatible, and which would prevent the system from running (e.g., prey productions that are lower than assumed food requirements of predators);
- requiring the modeller to interact with disciplines other than their own (e.g., in order to describe a lake ecosystem, a plankton specialist will have to cooperate with fish biologists and other colleagues working on the various consumer groups in that lake).

In addition, the ECOPATH files for a model can act as a consolidated database, accessible to all, that stores all references and notes about the sources and methods of estimating values.

Simulation of changes in ecosystems—ECOSIM

The need for a simulation version of the static ECOPATH mass-balance model of an ecosystem has long been recognized. ECOSIM is based upon a simple idea, the substitution of rate of change of biomass for the mass-balance equation of ECOPATH, but the resulting simultaneous differential equations are both conceptually and computationally challenging. Walters et al. (1997) have provided a practical solution and their paper lists a range of examples of successful validation of the technique. ECOSIM modelling is based on an ecosystem that is already described by the ECOPATH model, and has proved capable of reproducing changes that have been observed in a number of ecosystems, such as the North Sea and Lake Victoria. The first published examples of the use of ECOSIM are an investigation of the influence of small pelagic fish and their fisheries on ecosystems by Mackinson et al. (1997), and an exploration of the stability of exploited ecosystems by Vasconcellos et al. (in press).

ECOSIM is capable of evaluating the impact of changes in fishing rates on the ecosystem for each of the modelled fisheries, selectively across gear types or sectors of the fishing industry. "What if?" questions may be answered. One of the first examples of the use of ECOSIM at a specific location in this respect has been in evaluating alternative policy options for the Hong Kong fisheries (Pitcher et al. 1998), but this material has yet to be formally published. ECOSIM was used to predict the impact of six scenarios representing changes in the management of six gear type sectors on the relative abundance of eight groups of species. For example, halving the current fishing mortality from trawls provided considerable benefits for all fishery sectors, and for those elements of the ecosystem which needed to be conserved, such as marine mammals. The model suggested that the full benefits of such a policy may, however, take a decade to be realized. Further work in progress on the Hong Kong fisheries is evaluating benefits to the resource of artificial reefs that might be established in areas closed to fishing.

Clearly, ECOSIM has great potential to be used in fisheries management in this way, although it is premature and risky to place great reliance on exact results. Management plans have to be devised in such a way as to learn from the monitoring of changes that result from new policies, and to be flexible enough to adapt to unexpected outcomes.

Simulation of spatial dynamics of ecosystems —ECOSPACE

Another recent development, ECOSPACE, introduces the facility to spatially model ecosystems that have been summarized by ECOPATH (Walters et al., in press). This will be especially useful in the evaluation of the benefits of closed areas. The model enables the layout, on a 50 by 50 grid, of a rough map of the coastline and islands, areas of higher productivity, the habitat preferences of each ECOPATH group of fish, and the shape and size of no-take areas closed to fishing. It includes the movement characteristic of each ECOPATH group of fish and the bioeconomic spatial behavior of the fishers who, in the model, always move to maximize the profit from their catch. The ECOSPACE technique is so new that there are as yet no published examples.

Policy evaluation by comparison of constructed alternative ecosystems—ECOVAL

In the ECOVAL approach, scientific tools are used to construct and evaluate present and alternative ecosystems. The policy objective for management becomes the building of the ecosystem that would, if achieved, maximize economic benefit to society. The approach is fundamentally different from a policy goal of sustainability, which may seek only to sustain present misery (Pitcher and Pauly 1998).

Comparisons among alternative ecosystems cannot be performed using ECOSIM alone, because it is difficult to transform one ecosystem into another using this simulation-modelling tool. This is not a defect of the ECOSIM tool, which can simulate changes credibly up to limits defined by changes in target species biomass no greater than about 50%, but an unavoidable consequence of the inherent uncertainty in ecology. It is virtually impossible to model major changes in ecology, species composition and trophic structure. For example, species either vacate (those going extinct) or exploit (those being introduced to a system) trophic niches. Ecologists cannot predict what will happen to this niche or what the impacts will be on other components of the ecosystem. In addition, many species alter the physical structure of the habitats in an ecosystem by providing refuge for juveniles, breeding sites, or surfaces that may be colonized by primary producers, sessile detritus feeders and their invertebrate grazers.

Although direct simulation modelling is likely to remain unfeasible for the foreseeable future, for the first time, the ECOPATH approach has made it credible to use other information to construct models of alternative ecosystems. The first steps are to draw up probable species compositions and their predation matrices. Introduced species or species that become extinct are easy in this respect. For example, data can be used from similar systems that may exist elsewhere, or may have existed in the recent past. In the last resort, information on diet and metabolic parameters may be borrowed from other models. By 1998, over 150 ECOPATH models had been published (see for example contributions in Christensen and Pauly 1993), and parameters for the same or sibling species can be used as a first approximation. Approximate biomass estimates based on other systems may be given as trial input to the ECOPATH model, which can then be used to adjust the values to be compatible with the newly constructed trophic web. The ability to run checks on the internal consistency of the model, such as respiration rates, is valuable here.

An analogous approach that can be applied to natural ecosystems is termed BACK TO THE FUTURE (BTF), where ecosystems that existed in the past are reconstructed using historical documents, archaeology and traditional or local environmental knowledge (TEK and LEK) (Pitcher 1998a, b, c). For a human-made system like Lake Nasser, BTF is clearly not appropriate, but the essential features of the procedure are very similar.

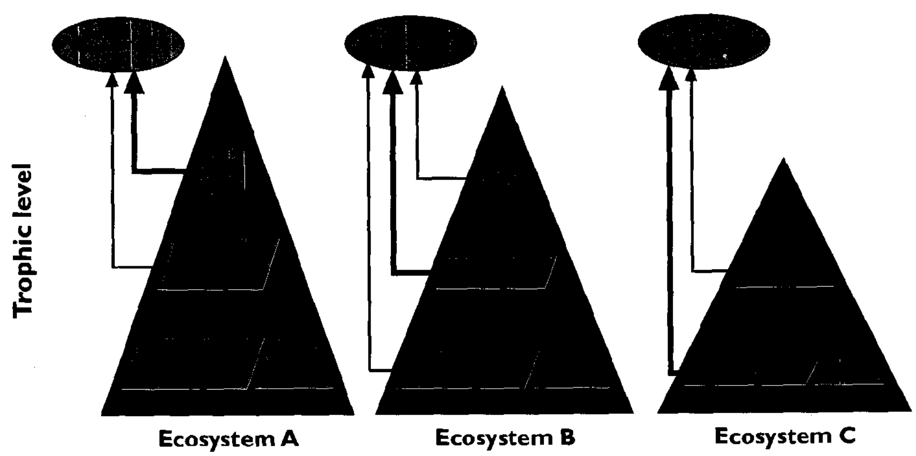
In summary, the ECOVAL method for fisheries management using alternative ecosystem evaluation comprises seven elements:

- ECOPATH model construction of present and alternative ecosystems;
- ECOSIM exploration of the limits to fishing, sector by sector, for each alternate;
- evaluation of economic and social benefits for each system;
- choice of policy goal as the ecosystem that maximizes benefits to society;
- design of instruments to achieve this policy goal;
- evaluation of costs of these management measures; and
- adaptive implementation and monitoring of management measures.

The comparative policy evaluation process is illustrated in Fig. 1. The triangles represent ECOPATH models, which are drawn up for the current ecosystem and its fishery alongside several alternative ecosystems with different fishing regimes. One model, for example, might represent an unfished ecosystem. Triangles are used because the ECOPATH model is conventionally represented in this way, where the vertex angle and height of the triangle are scaled to biodiversity and internal connectance ascendancy (Ulanowicz 1986).

The vertical axis of the pyramid represents the trophic level of resources that might be exploited. Schematic resources are illustrated at three trophic levels. Vertical arrows leading to ovals at the top represent fishery catches. In the ecosystem at the left, mainly top carnivores are exploited. In the center, there are diverse fisheries sectors with most of the catch coming from middle trophic levels. In the ecosystem at the right, catches are mainly from lower trophic levels. In addition, moving from left to right represents a gradient of ecosystem depletion so that organisms available for exploitation are at lower trophic levels. This need not necessarily be the case, but represents what we know has happened to aquatic resources worldwide (Pauly et al. 1998a).

The table below the diagram summarizes suggested evaluation criteria, but the details of the techniques are not given here. Evaluation of the relative benefits to be gained from comparing alternative ecosystems is rather different to conventional stock assessment. First, it is interesting that the



EVALUATION CRITERIA

Total catch	A1	B1	C1
Catch value	A2	B2	C2
Product diversity	A3	B3	C3
Employment	A4	B4	C4
Sectoral conflict	A5	B5	C5
Social benefits	A6	B6	C6

Fig. 1. A schematic illustration of the ECOVAL comparative policy evaluation process. The triangles represent ECOPATH models, which are drawn up for the current ecosystem and its fishery alongside several alternative ecosystems with different fishing regimes. The vertical axis of the pyramid represents the trophic level of resources that might be exploited. Schematic resources are illustrated at three trophic levels. Vertical arrows leading to ovals at the top represent fishery catches. The table below the diagram summarizes suggested evaluation criteria, including costs of implementation. For further details, see text.

potential yield estimation procedure using an ecosystem model automatically provides sustainable yields, since anything greater will alter the nature of the ecosystem as detected by the ECOSIM modelling. Second, in addition to estimating the total catch and catch value, values may be put upon the diversity of the fishery products, the amount of employment and secondary social and economic benefits of the fishery to local communities. Evaluation may also encompass conservation values such as biodiversity, the preservation of endangered species, and benefits and costs for multiple users of the aquatic resource. The procedure has social benefits too. Workshops held to help build models of alternative systems can act as a neutral forum where opposing sectors meet and share knowledge in the interest of long-term conservation. Comparing species levels predicted by the model provides talking points. Focusing on the alternatives highlights what could be achieved, as opposed to fighting over present scarcity. Moreover, when such policy goals are identified, an ecosystem–based agendum means that, during rebuilding, the public can act as sentinels of progress, and many diverse groups, including industry, local people, schools and colleges can have roles in providing data (Pitcher, in press: b). A sense of ownership of the process and goals fosters cooperation and reduces conflict.

Ecosystem modelling, such as that introduced in this workshop, has to be an integral part of the methodology required for this new comparative ecosystem evaluation approach. Mass-balance ECOPATH and ECOSIM modelling has advantages in making clear the impacts of harvest, comparing the effects of alternative gear types, and in being able to provide estimates of unknown biomasses. A disadvantage is that in its present state of development, ecosystem modelling is not itself able to provide single species quotas because, generally, many species have to be combined into one 'box' in the model. Conventional stock assessment methods will continue to be needed, but biomass values for single species will have to be constrained by the results of the ecosystem model. A way of merging current sophisticated single-species stock assessment methods with ecosystem modelling of the impacts of harvest needs to become an active research area.

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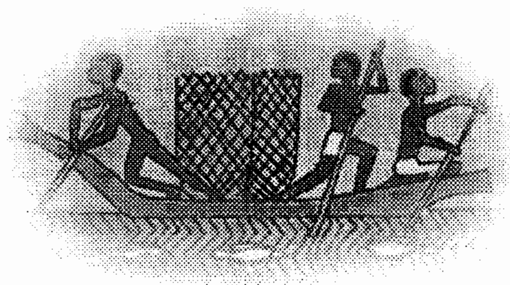

Background

Seasonal Variation in Mean Air and Water Temperature, Transparency, pH and Dissolved Oxygen Along the Main Channel

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Mohamed, A.A. 2000. Seasonal variation in mean air and water temperature, transparency, pH and dissolved oxygen along the main channel, p. 25-27. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Air and water temperature, pH, transparency and dissolved oxygen in Lake Nasser were measured in January, May, August, and December 1996 at nine stations along the main channel. Air and water temperature tended to increase from north to south. The results showed that during January, water temperature was usually uniform from the surface to the bottom and close to air temperature. A thermocline was detected in August. Water transparency in the southern part of the lake was greatly reduced by the incoming, silt-laden water especially during the floods in August (Secchi disc depth = 0.8 m). The pH of Lake Nasser was normally alkaline. Highest oxygen concentrations were found mostly during January and May.

Introduction

This paper reviews seasonal variation in air and water temperature, transparency, pH and dissolved oxygen along the main channel of Lake Nasser in 1996.

Materials and methods

Sampling was conducted in January, May, August and December 1996 at nine locations along the main channel (Aswan High Dam, El-Ramla, Kalabsha, El-Allaqi, El-Madiq, Korosko, Amada, Tushka and Abu Simbel) (see El Shahat, this vol., p. 4). Air temperature and Secchi disc depth were measured at each of these stations and water samples were taken at 1, 3, 6, 9, 12 and 18 m with a Nansen bottle. The water samples were used to measure water temperature, pH and dissolved oxygen (DO) (modified Winkler method, APHA 1992). Means of these variables were calculated across all depths.

Results and conclusions

Air and water temperature

In general, the temperature increased from north to south (Fig. 1). The minimum air and water temperature was recorded in January and December. Water temperature was usually uniform from surface to bottom at all stations at these times. In May, the highest air temperature (35.8°C) was recorded at Amada while the lowest (25.6°C) was recorded at Aswan High Dam. Maximum air and water temperatures were recorded in August. The water temperature was higher at the surface than at the bottom. At Abu Simbel in August, the water temperature at 1 m depth was 36.1°C but decreased to 30.1°C at 3 m depth. Thermal stratification was also detected at Tushka at this time.

Transparency

Fig. 2 shows the seasonal variation in transparency (Secchi disc depth) with station in the lake. There was considerable variation between stations. The highest values were recorded at Aswan High Dam. Transparency decreased gradually towards the south with the minimum values recorded at Abu Simbel. Maximum transparency was observed in the main channel in January, while at most stations, minimum values were recorded in May and August.

The lower values for transparency in the south are related to the effects of turbid floodwater carrying sediment as well as to the abundance of phytoplankton.

Hydrogen-ion concentration (pH)

Seasonal variations of pH at different stations are shown in Fig. 3. The pH was almost always alkaline except in the deep water in the northern part of the lake (Aswan High Dam and El-Ramla) in August.

Dissolved oxygen

Seasonal variations in DO concentration (mg l^{-1}) in the main channel in Lake Nasser are shown in Fig. 4. The DO concentration was highest in January and May, and lowest in August and December.

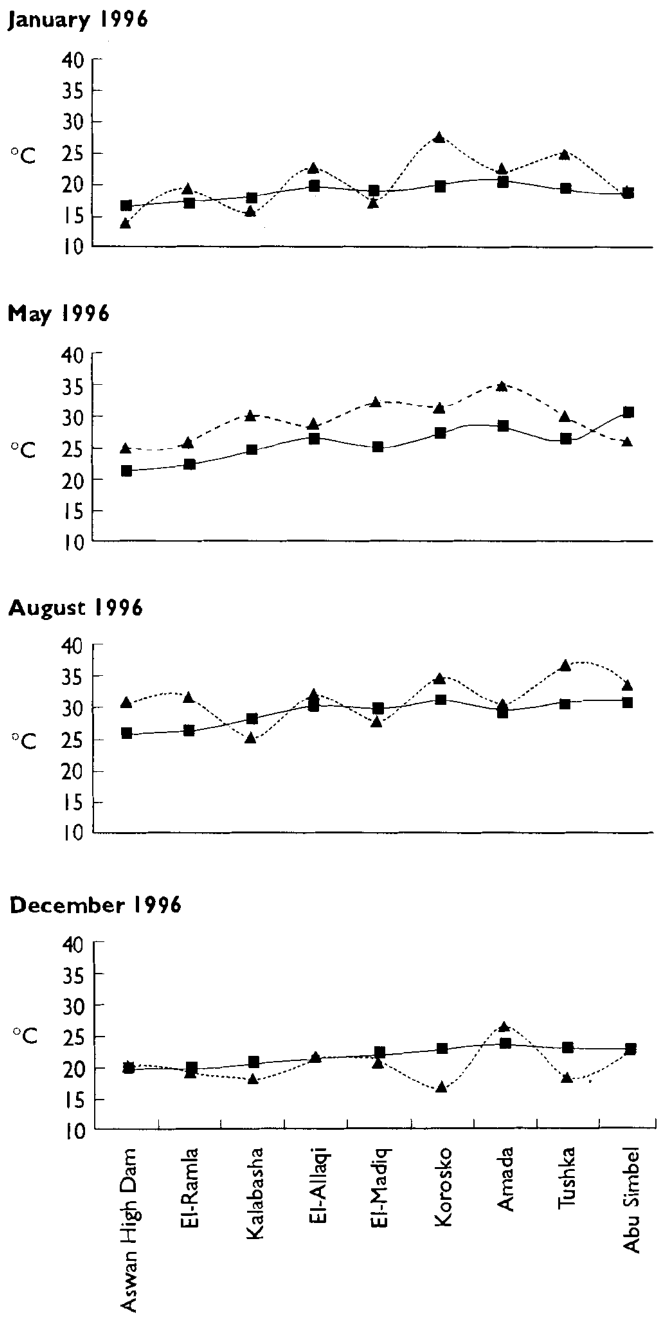

Fig. 1. Mean water column (▲) and air temperature (■)(°C) along the main channel in January, May, August and December 1996. See El Shahat (this vol., p. 4) for location of sampling sites.

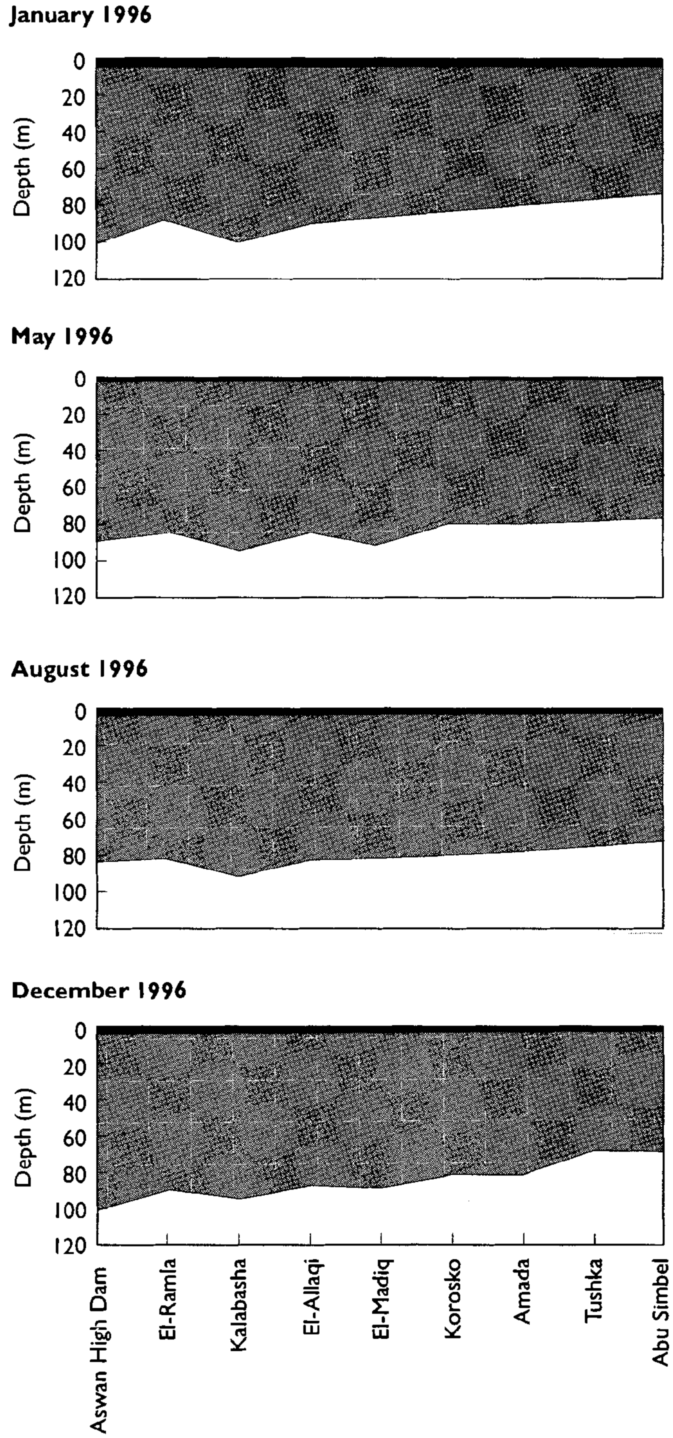

Fig. 2. Total (▒) and Secchi disc depths (■)(m) along the main channel in January, May, August and December 1996.

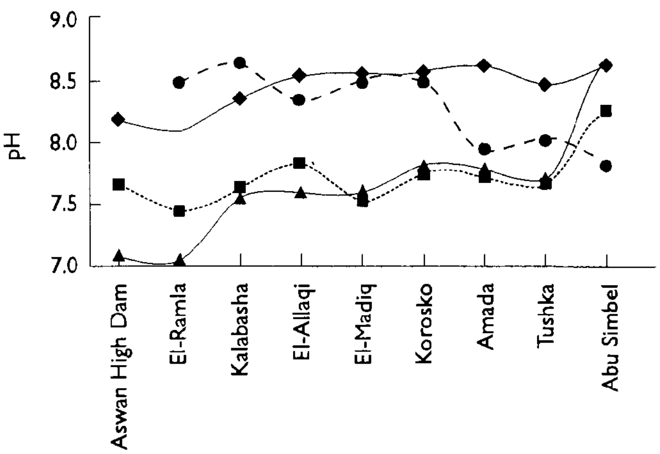

Fig. 3. Average water column pH values along the main channel in January (●), May (■), August (▲) and December (♦) 1996.

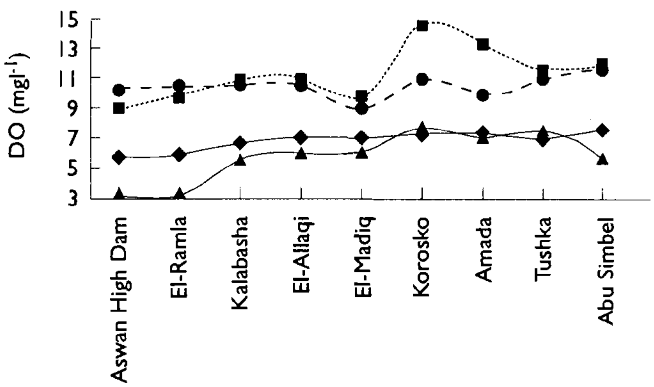

Fig. 4. Average water column DO (mg l^{-1}) values along the main channel in January (●), May (■), August (▲) and December (♦) 1996.

Reference

APHA. 1992. Standard methods for the examination of water and waste water. 18th ed. American Public Health Association, Washington. 1015 p.

DISCUSSION

Q. When and at what depth is the water anoxic?

A. In the summer at about 15-20 m depth.

Seasonal Vertical Variation in Water Temperature and Total Dissolved Solids

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Abd Ellah, R.G., A.E. Belal and I.A. Maiyza. 2000. Seasonal vertical variation in water temperature and total dissolved solidsm, p. 29-31. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The vertical variation in water temperature and total dissolved solids (TDS) along the main channel of Lake Nasser over one year (1993-1994) is presented. The lowest water temperature was observed in winter and thermal stratification was recorded in the summer. The highest value for TDS was found during the summer. TDS concentrations were inversely proportional to the water level. The TDS in Lake Nasser do not reach high levels due to continuous water change, i.e., the inflow of freshwater from the south and the outflow through the Aswan High Dam in the north.

Introduction

This study examined the seasonal variability of water temperature and total dissolved solids (TDS) in Lake Nasser for the period 1993-1994.

Methods

During the period January 1993 to January 1994, five seasonal cruises on Lake Nasser were undertaken. Ten hydrographic stations—Aswan High Dam, Dahmit, Kalabsha, Maria, Sayala, El-Singari, Amada, Masmas, Abu Simbel and Adindan— were established to cover the main channel of the lake (see El Shahat, this vol., p. 4). Water temperature and TDS were measured at the surface and at 5, 10, 20, 30, 40, 50 and 60 m depth and as near the bottom as the depth allowed. Water temperature was measured using a reserving thermometer and TDS were determined according to the standard method of APHA(1992). In addition, TDS data for the period 1975-1992 (Awadallah, pers. comm.; Ibrahim 1984; Tawfik 1993) were also used.

Results and conclusions

Due to vertical mixing, the vertical water temperature gradient was very weak in the winter of 1993. The surface water temperature ranged from 17.0°C in the south to 19.0°C in the middle region (Fig. 1). In the spring, surface warming caused the development of a negative water temperature gradient and there were indications of a thermocline developing. The water temperature was 20.0°C at the surface decreasing to 16.0°C near the bottom.

In summer, thermal stratification was at a maximum. The surface water temperature reached 28.0°C decreasing to <18.0°C near the bottom of the lake. In the autumn, surface cooling and vertical convection currents created a surface isothermal layer (20 m) with a temperature of about 27.0°C overlying a stratified layer similar to that of the summer. During the next winter (1994), the water temperature was similar at all depths (20.0–21.0°C) (Fig. 1).

In general, the vertical water temperature gradient of the lake was dependent on the season of the year, the time of the day, climatic condition and the inflow from the south. The middle part of the lake usually had a higher water temperature throughout the year which may be due to the slower flow of water there.

During the winter of 1993, the vertical TDS concentration increased from south to north (<140 to >155 mg l^{-1}). The concentration of TDS in the spring decreased with depth (Fig. 2). This was probably due to evaporation at the surface. As in the winter, the concentrations were greater in the north than in the south.

The highest concentration of TDS (210 mg l^{-1}) was found in summer in the middle region of the lake. In autumn (flood season), the TDS concentration varied between 180 mg l^{-1} in

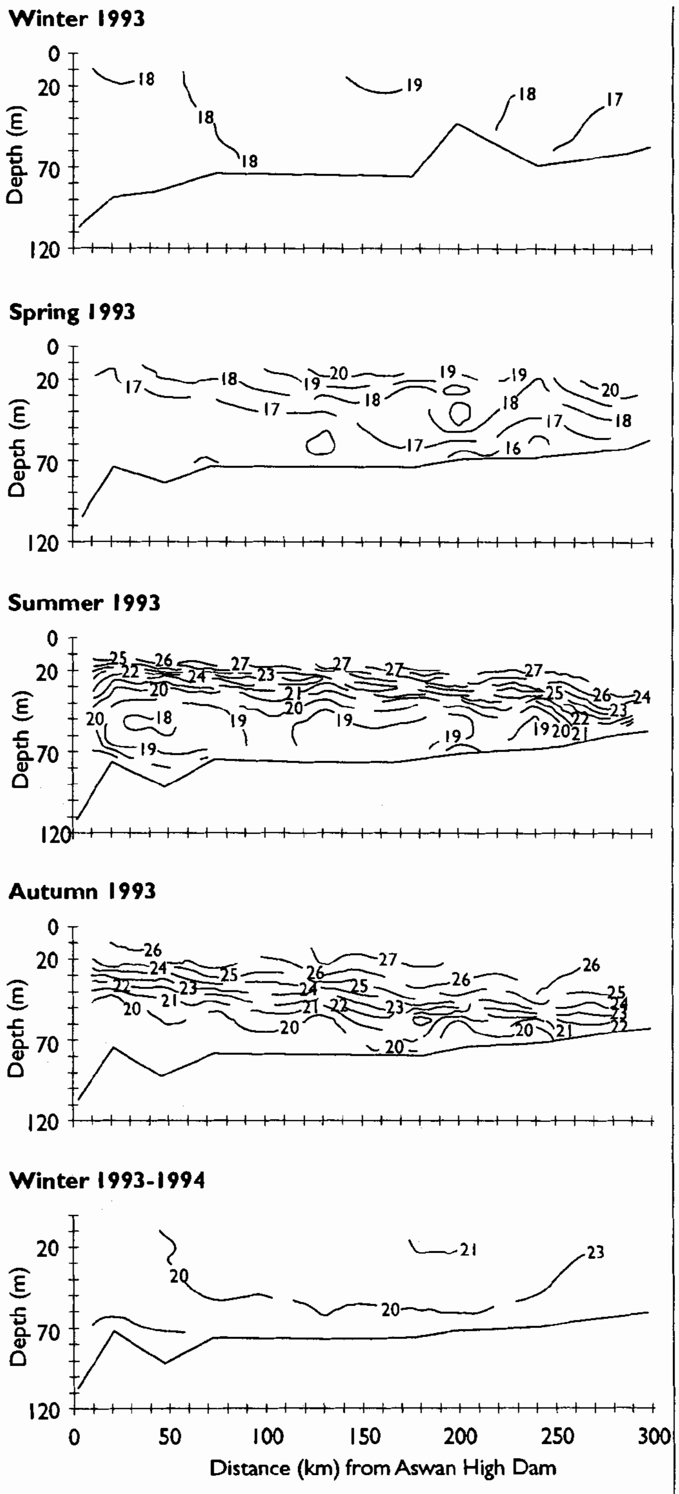

Fig. 1. Vertical (depth, m) variation in water temperature (°C) along the main channel during 1993: winter, spring, summer, and autum, and 1993-1994: winter. Sampling locations are given as distances (km) from the Aswan High Dam. The solid line represents the depth contour.

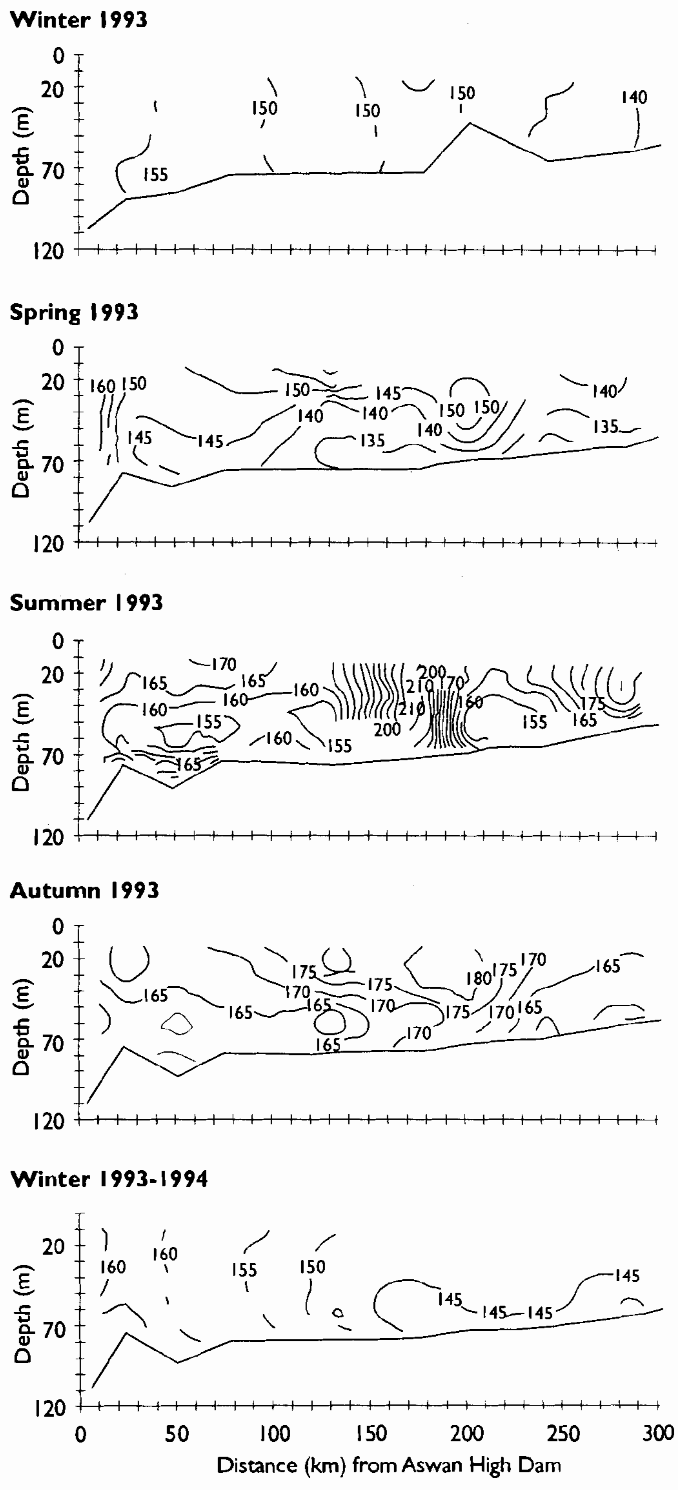

Fig. 2. Vertical (depth, m) variation in total dissolved solids (TDS, mg l^{-1}) along the main channel during 1993: winter, spring, summer, and autum, and 1993-1994: winter. Sampling locations are given as distances (km) from the Aswan High Dam. The solid line represents the depth contour.

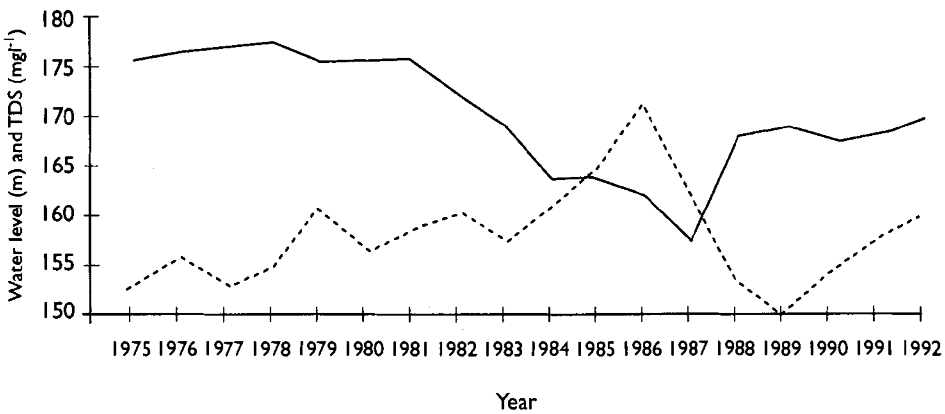

Fig. 3. Water level (–) (m AMSL) and total dissolved solids (--) (mg l^{-1}), 1975–1992.

the middle region and 165 mg l^{-1} in the north and the south, while in the next season (winter 1994), it increased gradually northward (145 to 160 mg l^{-1}).

In the summer, the TDS were generally higher than in the other seasons, which may have been related to a higher water temperature causing higher rates of evaporation. In the flood period, the TDS decreased, as a result of mixing between the lake water and the inflowing water of lower TDS.

The mean annual values of TDS concentrations upstream from the Aswan High Dam were variable, changing from a minimum (150 mg l^{-1}) in 1989 to a maximum (172 mg l^{-1}) in 1986 (Fig. 3). The concentrations were negatively correlated ($P<0.01$) with the water level of the lake.

In general, the storage of water leads to an increase in TDS after a period of time depending on the climate in the area. In Lake Nasser, there is a continuous gain of freshwater from the south and a loss by discharge through the Aswan High Dam and by evaporation. This leads to a fairly constant TDS concentration in the lake.

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DISCUSSION

Q. Why does the TDS value decline in the south of the lake during summer?

A. This is due to mixing between the inflowing and lake waters. The change starts normally in July.

Q. How do the TDS change in the northern part of the lake?

A. There is little change in the northern part that may be due to the continuous outflow of water through the Aswan High Dam.

Seasonal and Spatial Variation of Nutrients

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Goma, R.H. 2000. Seasonal and spatial variation of nutrients, p. 33-38. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

A water quality monitoring program was carried out in the main channel of the lake during the four seasons from 1992 to 1993. The purpose was to evaluate the influence of abiotic factors on the lake ecosystem. The study analyzed and evaluated the spatial and seasonal variation of nutrient nitrogen (nitrite, nitrate and total nitrogen) and phosphorus (orthophosphate and total phosphate). The concentration of nutrients in the reservoir was found to vary from north to south and was usually greater in the south especially in the flood season. The flood had a strong influence on the nutrient variation in lake water as well as on other physical and chemical conditions.

Introduction

Inorganics play an essential role in primary production and thus production of higher organisms up the food chain. Nutrients may be limiting or in excess, causing severe eutrophication and resulting in undesirable effects. The distribution and concentration of many chemical substances will be changed by physical processes such as lateral and vertical movements of water masses, diffusion between air and water or sediment and water, inflows and stratification of the water column. Therefore, as the changes in nutrient availability caused by these physical processes will affect biological productivity in the lake, it is very important to understand these abiotic factors.

Materials and methods

Six stations, El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel, were selected for the survey (see El Shahat, this vol., p. 4). Water was collected with a van Dorm sampler at the surface, at 5 m intervals down to 20 m and then at 20 m intervals down to 2 m from the bottom. The water was stored in carboys. Sampling was carried out in November 1992 (autumn), February (winter), April (spring) and June (summer) 1993. In the laboratory the following chemical analyses were carried out:

Nitrogen compounds

Nitrite nitrogen (NO_2-N) was determined through the formation of a reddish purple azodye produced at pH 2 to 2.5 by coupling diazotized sulphanilic acid with N-1-naphthyl-ethylenediamine dihydrochloride (Strickland and Parsons 1972). The intensities of developed color were measured with a spectrophotometer (UV- Shimadzu type).

Nitrate nitrogen ($N0_3$-N) was determined by the cadmium reduction method (Strickland and Parsons 1972). Nitrate was reduced quantitatively to nitrite in the presence of cadmium coated with copper in a column. The nitrite produced was determined by the same procedure as that of NO_2-N.

Total nitrogen was determined by the persulphate oxidation method (Strickland and Parsons 1972). Sample volume was measured and 10 ml of oxidizing solution (potassium peroxodisulphate and boric acid) was added. The sample was then heated for 30 min in an autoclave under pressure where the organic nitrogen was broken down to inorganic compounds. The nitrite produced was analyzed as mentioned previously.

Phosphorus compounds

Orthophosphate (reactive phosphorus PO_4-P) was analyzed by the ascorbic acid method (APHA 1975). Ammonium molybdate and potassium antimonyle tartarate were reduced in an acid medium with orthophosphate to form a hetropoly acid-phosphomolybdic acid that was reduced to intensely colored molybdenum blue by ascorbic acid. The blue color intensities were measured using a spectrophotometer.

To determine total phosphorus (TP), the persulphate digestion method (APHA 1975) was used to oxidize organic matter effectively to release phosphorus as orthophosphate. Ammonium persulphate (0.4 mg) was added to 50 ml of the sample which was boiled for 30 min in an autoclave at 98 to 137 Kpa. The sample was then treated as described in the orthophosphate procedure.

Results and conclusions

Seasonal and spatial variation of nitrite, nitrate and total nitrogen concentrations at all stations (except in April which shows Station 1 only) are shown in Figs. 1-3. There were marked seasonal changes and spatial differences in nitrite concentration (Fig. 1). Nitrite was the least abundant form of inorganic nitrogen in the lake. High concentrations were observed during the summer season, the highest value of 68.4 $\mu g\ l^{-1}$ at 15 m depth at Station 1 in June. Most nitrite concentrations were <3 $\mu g\ l^{-1}$. At Stations 1 and 2, the highest concentrations of nitrite occurred in the water layers between 10 and 20 m depth where nitrate concentrations were low. These peaks occurred in the upper layers in summer due to thermal stratification and the presence of anoxic conditions.

In November, nitrate concentration ranged from a minimum value of 0.1 $\mu g\ l^{-1}$ at 50 m depth at Station 1 to a maximum value of 611.1 $\mu g\ l^{-1}$ in the surface water of Station 5. The month saw the highest concentration of nitrate through the whole water column in the southern part of the lake (Stations 4, 5 and 6). The south of the lake is strongly influenced during the flood season by the inflow of water containing high levels of nutrients. A relatively high concentration of nitrate (3 mg l^{-1}) has been found in the floodwater of the Blue Nile at Khartoum (Talling and Rzoska 1968). The southern part of the lake has higher productivity than the north. The high content of nitrate in the upper layers (0-20 m depth), after the flood, was probably taken up by phytoplankton (Fig. 2, June 1993). In Lake Nasser, during the summer, the strongly developed thermocline prohibited transfer of nitrate from the hypolimnion.

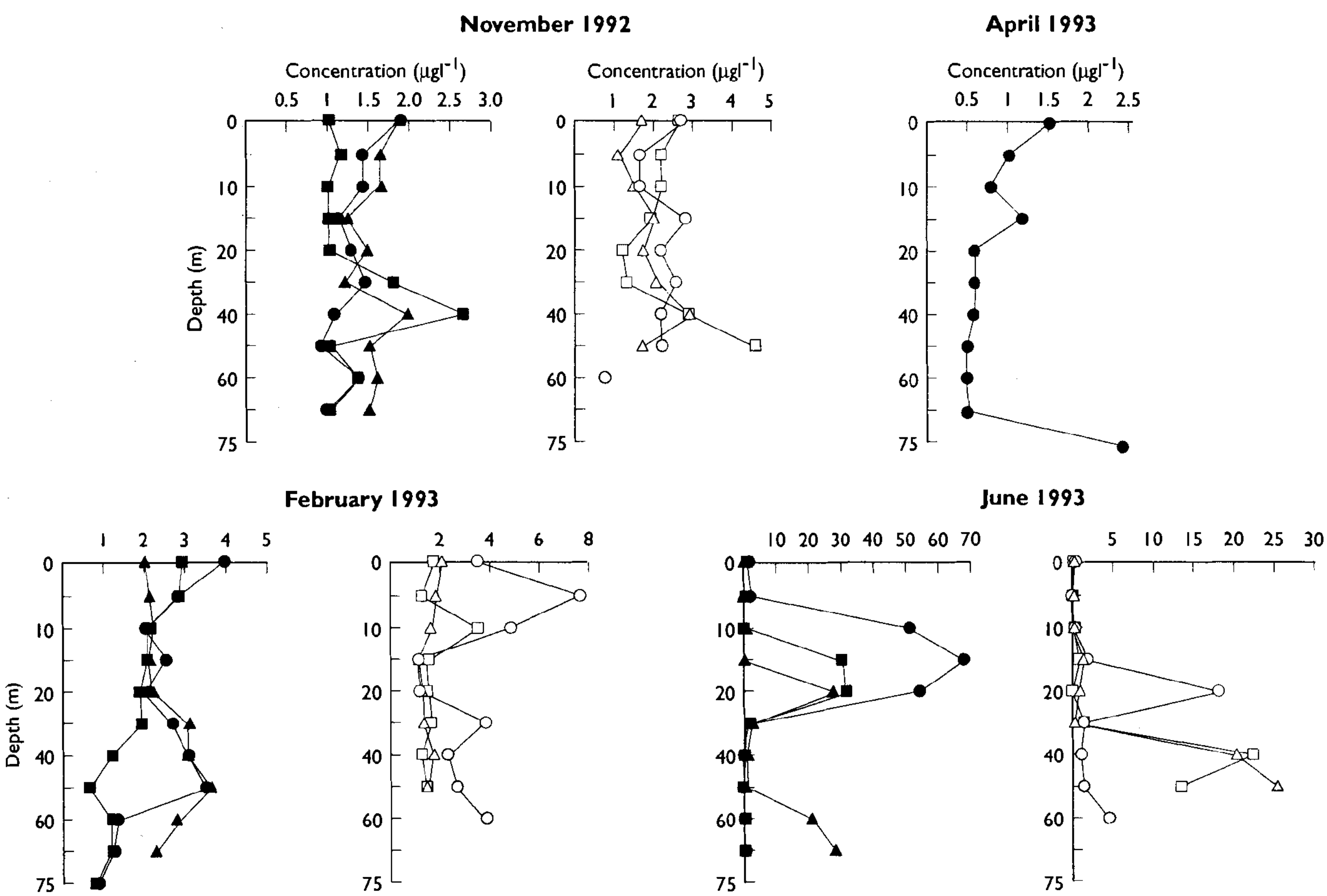

Fig. 1. Vertical (depth, m) variation in nitrite nitrogen ($\mu g\ l^{-1}$) in November 1992, February 1993, April 1993 and June 1993. Note that the concentrations are on different scales. El Ramla (●), Kalabsha (■), El-Allaqi (▲), Korosko (○), Tushka (□), Abu Simbel (△).

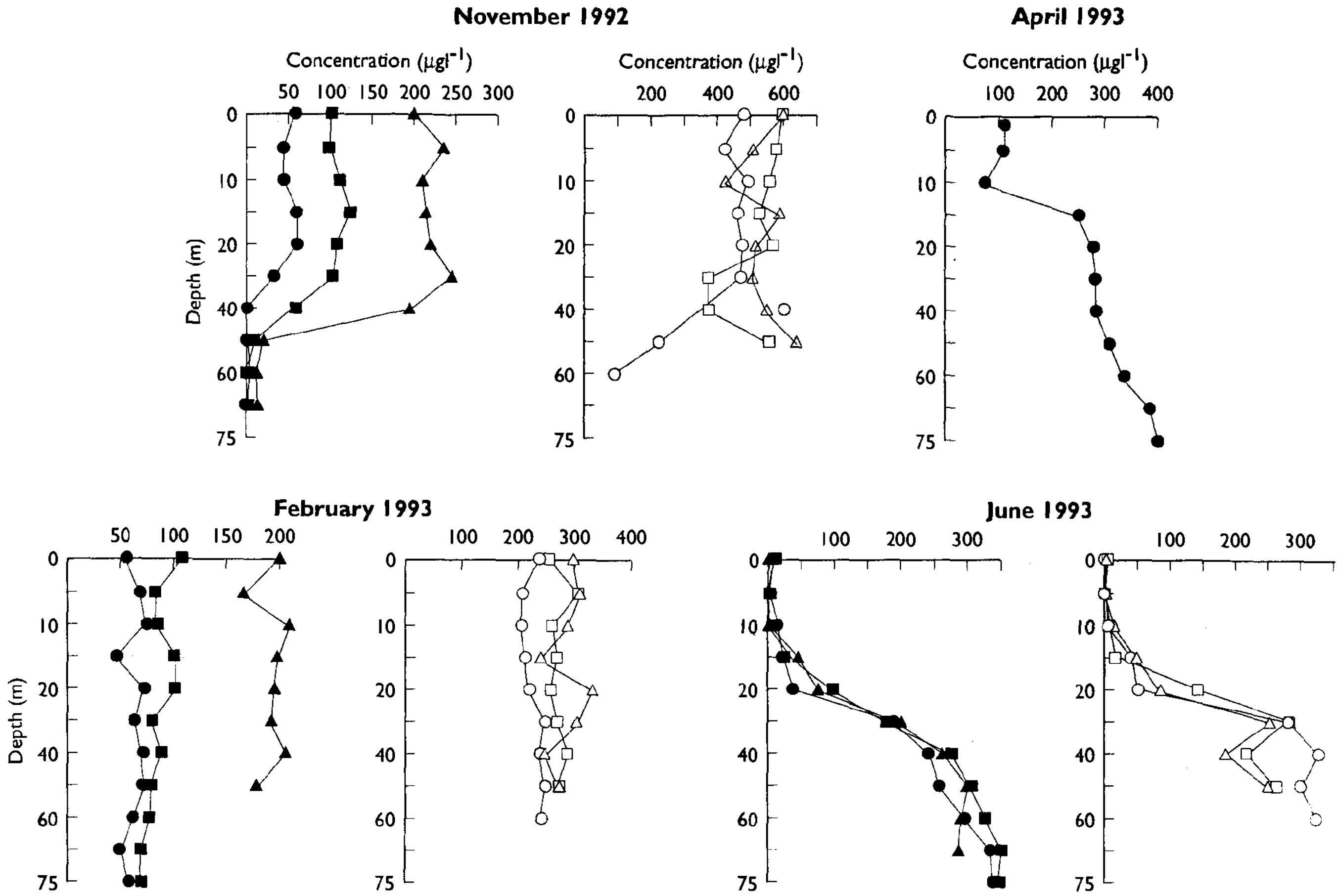

Fig. 2 .Vertical (depth, m) variation in nitrate nitrogen (µg l⁻¹) in November 1992 and February, April and June 1993. Note that the concentrations are on different scales. El Ramla (●), Kalabsha (■), El-Allaqi (▲), Korosko (○),Tushka (□),Abu Simbel (△).

Total nitrogen concentration ranged from 85.3 µg l^{-1} at 15 m depth at Station 5 to 1556.7 µg l^{-1} at 60 m depth at Station 2 during the summer. Seasonal variation in concentrations was not apparent. However, relatively high concentrations were found at Stations 4, 5 and 6 in the autumn and winter. It is noticeable that the vertical distribution of total nitrogen was homogeneous throughout the water column at all stations during different seasons except in the summer when relatively high concentrations were found in deeper layers in the northern part of the lake and irregular variations were found in the south (Fig. 3). This indicated that thermal stratification had little effect on the vertical distribution of total nitrogen. The accumulation of total nitrogen in the water is probably due to input from inflowing water.

Figs. 4 and 5 show seasonal and spatial variation in orthophosphate (PO_4.P) and total phosphorus (TP), respectively, at all stations except in April for Station 1. Orthophosphate concentration varied from the lowest value of 1.4 µg l^{-1} at 15 m depth at Station 1 in November to the highest value of 53.9 µg l^{-1} at 60 m depth at Station 3 also in November. Total phosphorus varied from 5.2 µg l^{-1} at 50 m depth at Station 1 in February to 117.9 µg l^{-1} at 70 m depth at Station 3 in November. Seasonal variations in orthophosphate and total phosphorus concentrations were not clearly observed. High concentrations of PO_4-P and TP were found near the bottom at almost all stations during all seasons. The highest concentration of PO_4-P and TP in the bottom water were measured in the summer season and the values ranged from 7.2 to 47.6 µg l^{-1} for PO_4-P and from 11.9 to 59.9 µg l^{-1} for TP. This may indicate that large amounts of phosphate were released to the lake water from the sediment. Phosphate was probably regenerated when organic matter was decomposed and when ferro-manganese oxides were reduced under the anoxic conditions. The floodwater also increased phosphate in the lake. Low concentrations of PO_4-P and TP in the upper layers were probably due to removal by the growth of phytoplankton.

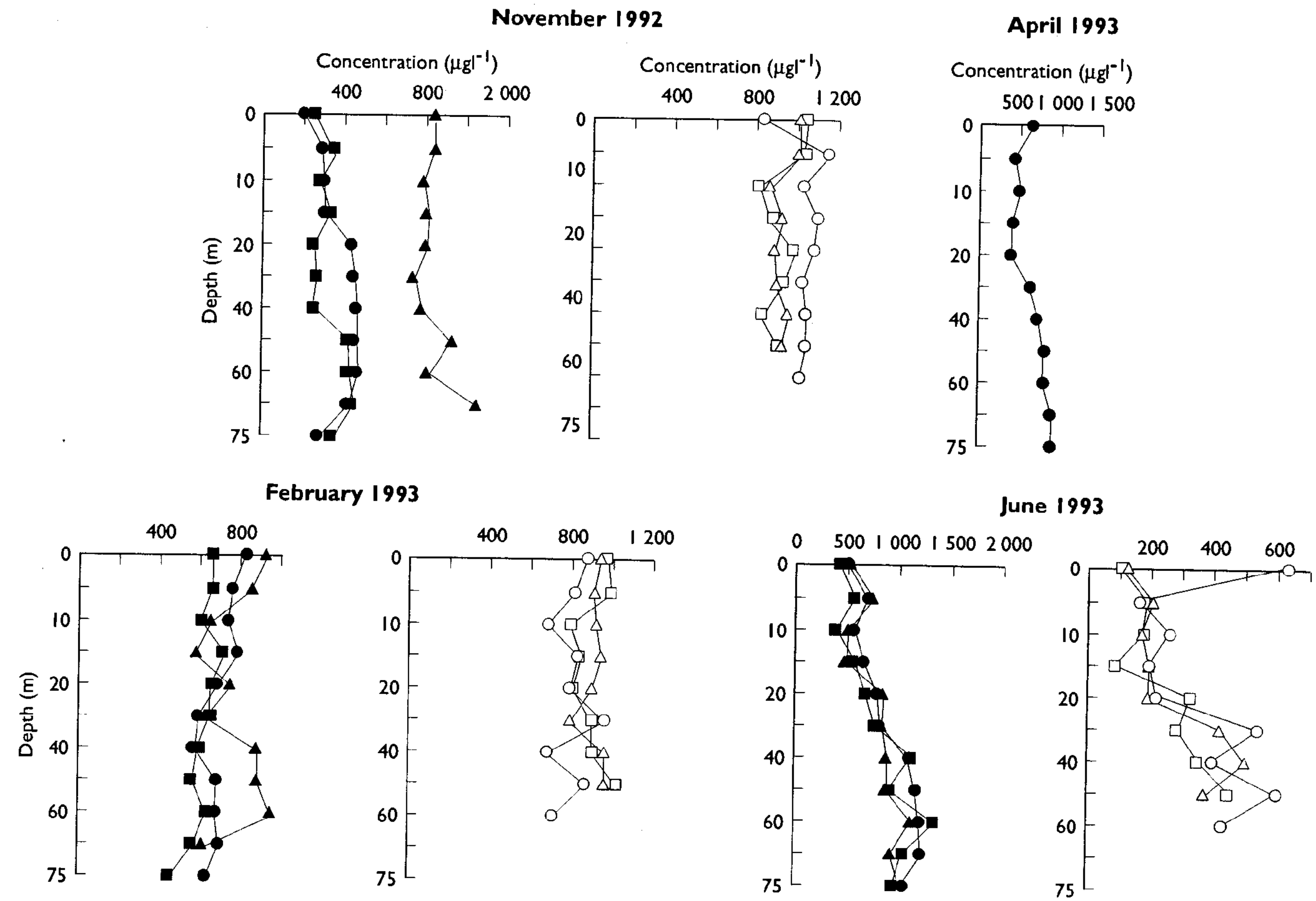

Fig. 3. Vertical (depth, m) variation in total nitrogen (µg l⁻¹) in November 1992 and February, April and June 1993. Note that the concentrations are on different scales. El Ramla (●), Kalabsha (■), El-Allaqi (▲), Korosko (○), Tushka (□), Abu Simbel (△).

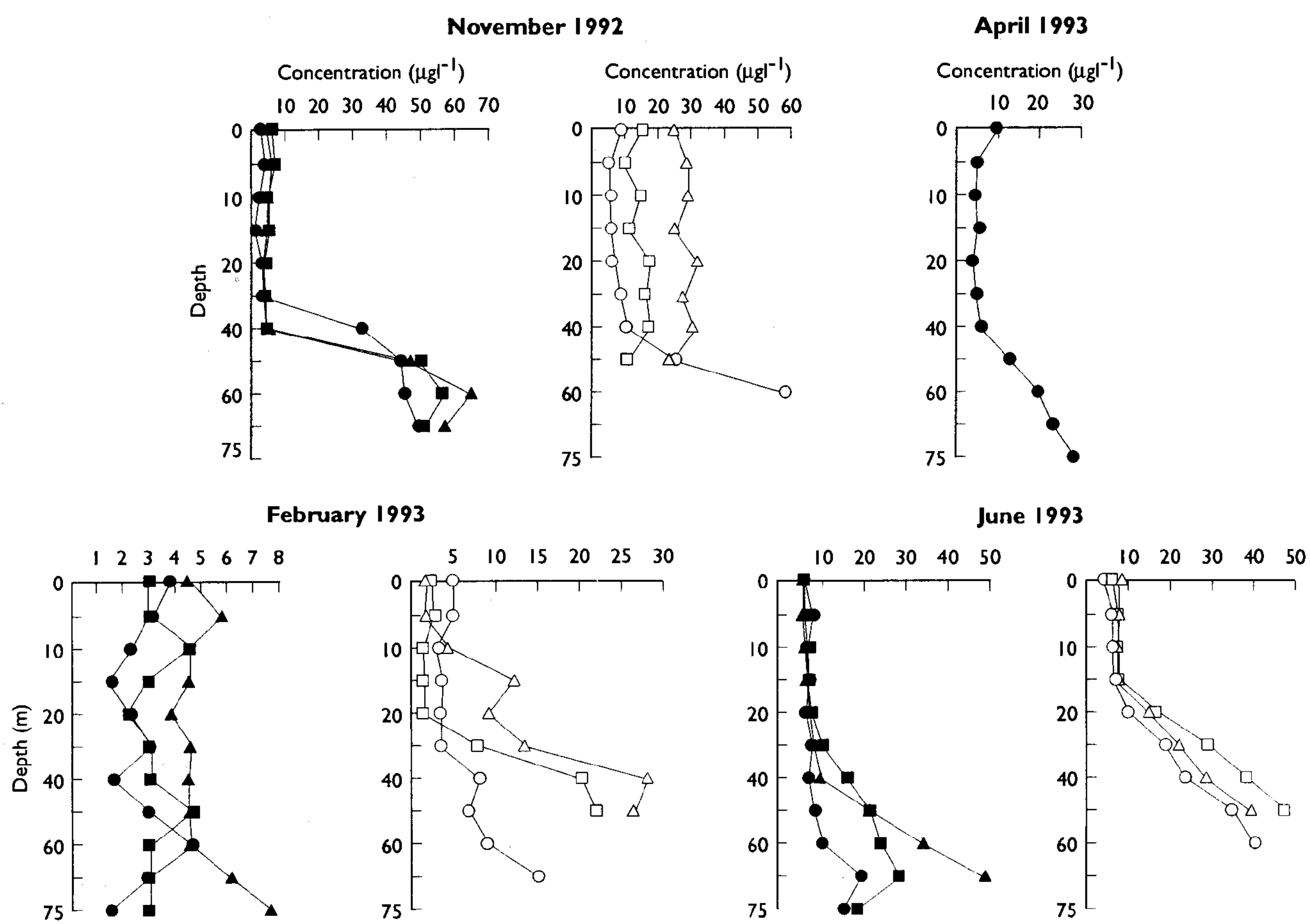

Fig. 4. Vertical (depth, m) variation in orthophosphate (µg l⁻¹) in November 1992 and February, April and June 1993. Note that the concentrations are on different scales. El Ramla (●), Kalabsha (■), El-Allaqi (▲), Korosko (○), Tushka (□), Abu Simbel (△).

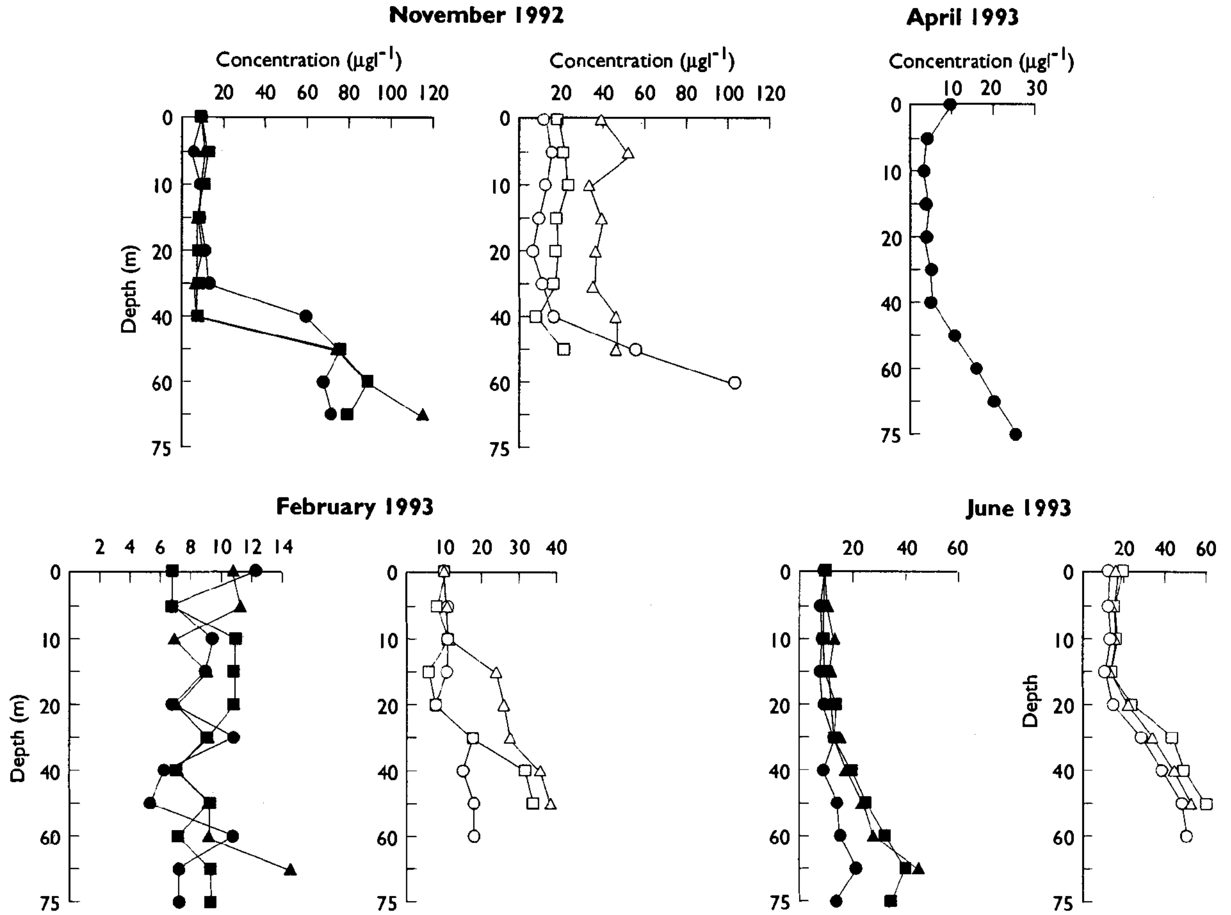

Fig. 5. Vertical (depth, m) variation in total phosphorous (μg l⁻¹) in November 1992 and February, April and June 1993. Note that the concentrations are on different scales. El Ramla (●), Kalabsha (■), El-Allaqi (▲), Korosko (○), Tushka (□), Abu Simbel (△).

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DISCUSSION

Q. Did you calculate N/P ratios?

A. No, we did not. We do have the data to do this although they are not continuous.

Bacteriological Studies

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Rabeh, S.A. 2000. Bacteriological studies, p. 39-41. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The assessment of the sanitary quality of near-surface water along the main channel (nine stations) and of near-surface and near-bottom waters of one station (Tushka) of five selected khors during the winter of 1997-1998 is presented.The water quality was based on the values of total bacterial counts (TBC) at 22.0 and 37.0°C and total and fecal coliforms (TC and FC) as indicators of fecal contamination.The possible presence of sulphate-reducing bacteria (SRB) as the main cause of H_2S production was also examined in near-bottom water and bottom sediments of three stations of the main channel and at one station of each of the five studied khors. Bacterial numbers in the main channel were high in the south of the lake, decreased in the middle and then increased in the north.The highest and lowest numbers of bacteria in near-surface and near-bottom waters were recorded at El-Allaqi and Kalabsha khors, respectively.The highest counts of TC and FC were recorded at El-Ramla and El-Madiq while the lowest counts were recorded at El-Allaqi. Compared with other examined stations, the highest counts of TC and FC were recorded at the source point for the El-Sheekh Zayed Canal in near-surface and near-bottom waters. A complete absence of SRB in almost all tested samples was recorded. It was concluded that there was a small degree of microbial pollution at some sites and recommendations on more stringent measures to prevent further pollution are suggested.

Introduction

As a result of population increase, one of the main objectives of developing countries is to conserve and develop all food sources, especially those that provide animal protein. Lakes are among the most important sources of freshwater fisheries but they are often subject to pollution. The major sources of water pollution are domestic, industrial and agricultural wastes (Hendry et al. 1982). Bacteriological analysis is now carried out with increasing frequency to ascertain the sanitary quality of water. Plate count agar is presently the most valuable and sensitive tool for routine monitoring of water quality and treatment efficiency (Grabow 1990). For many years, coliform bacteria have served as indicators of the degree of fecal contamination in water (Menon 1974).

Sulphate-reducing bacteria (SRB) are environmentally important microorganisms. Their influence can be divided into ecological and economic effects (Postgate 1982). During the hot months, a problem of odor and change in taste has arisen in some areas of Lake Nasser due to H_2S production by SRB (Saleh 1976).

The aim of the present work was a sanitary and bacteriological assessment of the Lake Nasser water by monitoring the number of bacteria (both total and fecal coliforms, TC and FC) developing at 22.0 and 37.0°C. The study also investigated the possible presence of SRB in near-bottom water and bottom sediments of Lake Nasser.

Materials and methods

Sampling and stations

A sterile 250-ml glass bottle fitted with a stopper protected by an aluminum foil cover was used for sampling the near-surface water from nine stations of the main channel and eight stations in five khors (one station for each khor except four in Tushka). In the case of near-bottom water samples taken from three stations of the main channel, Aswan High Dam, El-Madiq and Abu Simbel (see El Shahat, this vol., p. 4), and from eight stations in the khors, a weighted, sterilized bottle on a cord was used. Bottom-sediment samples were collected from the three selected stations in the main channel and from one station in each khor by using a dredge.

Bacteriological analysis

For total bacterial counts (TBC), the surface plate method, sometimes called the spread drop or the streak plate method (Clark 1971), was used. The colonies were counted and computed per 1 ml of the original sample. Counting of TC and FC was carried out by the most probable number (MPN) method. It is known as the multiple tube method or dilution method (APHA 1980). It was carried out by using three dilutions (10, 1 and 0.1 ml) for each water sample (or dilution) in three replicated tubes of MacConkey broth for each inoculum and then incubated at 37°C for 48 hours (± 2 hours). The number of positive tubes (showing acid and gas) within each set of replicates was recorded and the corresponding MPN index was derived from tables. The confirmation and completed tests using eosin methylene blue medium, agar slant, gram stain and MacConkey broth were carried out. Enumeration of FC was performed using the MPN method by inoculating three loops from each positive pressure tube into a tube of MacConkey broth, after incubating at 44.5°C for 24 hours. The frequency of SRB was estimated on modified Starkey's medium (Abdel-Malek and Rizk 1958). Three dilutions were prepared from near-bottom water and sediment. Each dilution was inoculated into five tubes. The presence of SRB was detected at the end of the incubation period by blackening of the medium due to the formation of iron sulphide. Their MPN was read from the tables of Cochran (1950) and their numbers were adjusted to per 1 ml or 1 g (water or sediment, respectively).

Results and conclusions

TBC at 22.0 and 37.0°C during the winter of 1997-1998 are presented in Tables 1 and 2. The 22.0°C colony counts along the main channel ranged from 3.2×10^6 to 6.8×10^6 organisms ml^{-1} at Kalabsha and Aswan High Dam, respectively. Those counted at 37.0°C varied from 3.01×10^6 organisms ml^{-1} at Kalabsha to 6.8×10^6 organisms ml^{-1} at Tushka. The results showed a distinct pattern along the main channel, where high bacterial counts were recorded at the south of the lake (Abu Simbel and Tushka), then decreased in the middle (from Amada to Kalabsha), and increased again in the north (E1-Ramla and Aswan High Dam). This variation may be due to the quantity of suspended matter carrying these microorganisms which is greater in the south than in the middle region. The present results agreed with those of Elewa and Azazy (1986) in finding the association between bacteria and suspended matter in Lake Nasser. On the other hand, the high bacterial counts in the north may be due to wind and turbulence prevailing during the winter. The supply of nutrients and allochthonous microflora with improperly treated wastewater from cruise boats (floating hotels) may also play a role. The ratios of TBC at 22.0 to 37.0°C were <10, which indicated contamination of the lake water (APHA 1980). Such low ratios have also been recorded in water samples collected from different aquatic systems in Egypt (Abo-Sedera 1990; Rabeh 1993).

Table 1. Total bacterial counts (TBC) at 22.0 and 37.0°C and most probable number (MPN) of total coliform (TC) and fecal coliform (FC) and sulphate-reducing bacteria (SRB) along the main channel of Lake Nasser (see El Shahat, this vol., p. 4).

Station	TBC × 10^6 ml^{-1}		MPN × 10^2 ml^{-1}		SRB (MPN) ml^{-1}	
	22°C	37°C	TC	FC	NBW	BS
Aswan High Dam	6.8	5.9	0.2	0.1	0.0	0.0
El-Ramla	6.2	5.5	11.0	0.9	NM	NM
Kalabsha	3.2	3.0	4.6	0.2	NM	NM
El-Allaqi	4.8	4.1	0.2	< 0.1	NM	NM
El-Madiq	3.4	3.3	11.0	0.3	0.0	0.0
Korosko	4.1	4.0	2.1	0.2	NM	NM
Amada	4.0	3.4	0.9	0.1	NM	NM
Tushka	6.8	6.8	0.4	0.1	NM	NM
Abu Simbel	6.4	6.2	0.9	0.1	0.0	0.0

NBW-near-bottom water, **BS**-bottom-sediment, **NM**-not measured.

At El-Allaqi, the highest numbers of bacteria were recorded for near-surface and near-bottom waters from the khor samples for developing at 22.0°C (11.3×10^6 and 78.6×10^6 organisms ml^{-1}) and at 37°C (11.21×10^6 and 77.8×10^6 organisms ml^{-1}). At Kalabsha, the lowest bacterial count at 22.0 and 37.0°C in near-surface and near-bottom was measured. In general, bacteria occurred in higher numbers near the bottom than near the surface in the khors. This may be attributed to the greater quantity of organic matter there. Also, suspended particles tend to sink to the bottom with bacteria adhering to their surface. Resuspension of nutrients and benthic bacteria at the water sediment interface may also play some role.

Along the main channel, the highest counts of TC were recorded at E1-Ramla and E1-Madiq, while the highest counts of FC were recorded at E1-Ramla. The lowest counts of TC and FC were recorded at El-Allaqi. In the khors, the highest counts of TC were recorded in the near-surface water at El-Allaqi and in near-bottom water at Tushka (Station 2). The lowest counts were recorded at the near-surface water of E1-Ramla and at the near-bottom waters of E1-Ramla and Korosko. The highest counts of FC were recorded in the near-surface water of Tushka (Station 1) and in the near-bottom waters (Stations 1 and 2 at Tushka). The lowest counts of FC were recorded at E1-Ramla and Kalabsha in the near-surface water and the near-bottom waters of El-Ramla and Korosko.

Table 2. TBC at 22.0 and 37.0°C and MPN of TC and FC and SRB in the water and sediment of selected khors in Lake Nasser (see El Shahat, this vol., p. 4).

Station	TBC × 10^6 ml^{-1}				MPN × 10^2 ml^{-1}				SRB ml^{-1}	
	22.0°C		37.0°C		TC		FC		MPN	
	NSW	NBW	NSW	NBW	NSW	NBW	NSW	NBW	NBW	BS
El-Ramla	8.6	50.4	8.5	39.9	0.1	0.4	0.1	0.1	0.0	0.0
Kalabsha	6.0	35.3	5.9	34.9	0.3	11.0	0.1	0.3	0.0	0.0
El-Allaqi	11.3	78.6	11.2	77.8	0.5	2.1	0.9	0.2	0.0	0.0
Korosko	7.7	45.0	7.6	44.6	0.2	0.4	0.1	0.1	0.0	13
Tushka 1	6.5	38.4	6.5	38.0	0.4	7.0	0.2	0.4	NM	NM
2	6.8	39.8	6.7	39.4	0.2	9.0	0.1	0.4	0.0	0.0
3	6.3	37.2	6.3	36.8	0.4	43.0	0.1	0.3	NM	NM
Average	6.5	38.5	4.5	38.1	0.4	9.6	0.1	0.4	0.0	0.0
Source point	6.2	36.7	6.0	36.3	4.6	93.0	1.5	1.5	NM	NM

NSW- near-surface water, **NB** - near-bottom water, **BS** - bottom sediment, **NM** - not measured.

Compared with other examined stations, the highest counts of TC and FC were recorded at the source point for the El-Sheekh Zayed Canal both in the near-surface and near-bottom waters. (Tables 1 and 2). Fluctuation in numbers of TC and FC at different stations could be due to localized effects such as discharge of improperly treated human waste from cruise boats.

At almost all stations, SRB were not found in near-bottom waters or bottom sediments during the winter season. The only exception was a count of 13.0 organisms g^{-1} in the sediment at Korosko. The almost complete absence of SRB during the winter season could be attributed to the good aeration of the lake during this season, thus controlling the growth of these anaerobes.

Recommendations

Stringent procedures should be enforced to prevent the disposal of either improperly or partially treated human waste water into the lake. Such treatment should aim at eliminating any additional microbial pollution and minimizing the organic nutrient content. Once these steps have been taken, the microbiologically polluted sites will undergo a self-purifying cycle in a relatively short period of time.

SRB can be a nuisance and may release H_2S under restricted conditions (as those present in the bottom of the lake during hot seasons). However, they do not appear to be a problem in Lake Nasser. Fishing in the lake ensures a gradual decrease in the organic and inorganic load leading to a lower microbiological oxygen consumption and better aeration.

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DISCUSSION

Q. Is there a relationship between bacteria concentrations and the distribution of fishers in some areas?

A. Yes, although there do not appear to be any serious problems to human health.

Seasonal Variation of Phytoplankton Abundance

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Habib, O.A. 2000. Seasonal variation of phytoplankton abundance, p. 43-49. *In* J. F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

In 1991, six stations along the main channel of Lake Nasser were sampled, from Station 1 in the north to Station 6 in the south to estimate phytoplankton abundance. The total number of phytoplankton cells or colonies was high during January-March at Stations 2 and 3 and during July-August at Stations 3 to 5. The number was very low at Stations 1 and 6 except for July at Station 6 where a very high value was observed at the surface. For the water column (0-20 m), the total phytoplankton number as algal units l^{-1} ranged from 2.8×10^3 at 20 m depth in November at Station 6 to $2\ 592.1 \times 10^3$ at the surface in August at Station 5. The phytoplankton community was composed of blue-green algae, diatoms, green algae and dinoflagellates. Blue-greens dominated the community, as a percentage, during spring and summer. Diatoms dominated the community only once in winter (December). Noticeable peaks of green algae were recorded in spring at Stations 1 to 4 and in summer at Stations 5 and 6. Dinoflagellates were very few except for some remarkable peaks in late winter and spring.

Introduction

Planktonic algae occur in all types of water, where environmental conditions are suitable for their growth (Feldmann 1951; Tiffany 1951). Seasonal patterns in phytoplankton periodicity result from the integration of such factors as light, temperature, nutrient concentrations and biological interactions (Fogg 1965; Hutchinson 1967; Round 1971, 1981; Porter 1977; Keating 1978).

Methods

Water samples were collected four times (February, May, August and November) during 1991 at six stations, El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel, along the main channel of Lake Nasser (see El Shahat, this vol., p. 4). One-liter water samples were collected at 5 m intervals from the surface to 20 m depth (0, 5, 10, 15 and 20 m) in polyethylene bottles and fixed with 10 ml of 4% formalin for later treatment. Each sample was left to settle in a measuring cylinder for 48 h, after which 900 ml of the supernatant were carefully siphoned off.

The residue was transferred into a 100 ml cylinder and left to settle again for 48 h. The supernatant was again siphoned off and the final volume of the sample was made up with water to 25 ml in a vial. A counting chamber of 1 ml capacity was used to count the algae with a microscope. Empty and obvious dead cells were not included in the counts. Results were expressed in algal units per liter. Algal units were individual cells of single-celled species and colonies of cyanophytes.

Results

Seasonal variation in the total number of phytoplankton cells or colonies at five depths (5 m intervals from the surface to 20 m depth) is shown in Fig. 1. In general, Stations 2 and 3 had similar trends in seasonal variation of phytoplankton abundance, with high values in February ($2\ 326 \times 10^3$ and $1\ 966 \times 10^3$ algal units 1^{-1} in the surface layer for both, respectively), and August (583×10^3 algal units 1^{-1} in the surface and 993×10^3 algal units 1^{-1} at 5 m depth, respectively). Values in May were low (40×10^3 algal units 1^{-1} at 20 m depth and 98×10^3 algal units 1^{-1} at 15 m depth, respectively). Stations 4 and 5 were also similar to each other in seasonal variation of phytoplankton abundance with high values in August only ($1\ 899 \times 10^3$ algal units 1^{-1} at 5 m depth and $2\ 592 \times 10^3$ algal

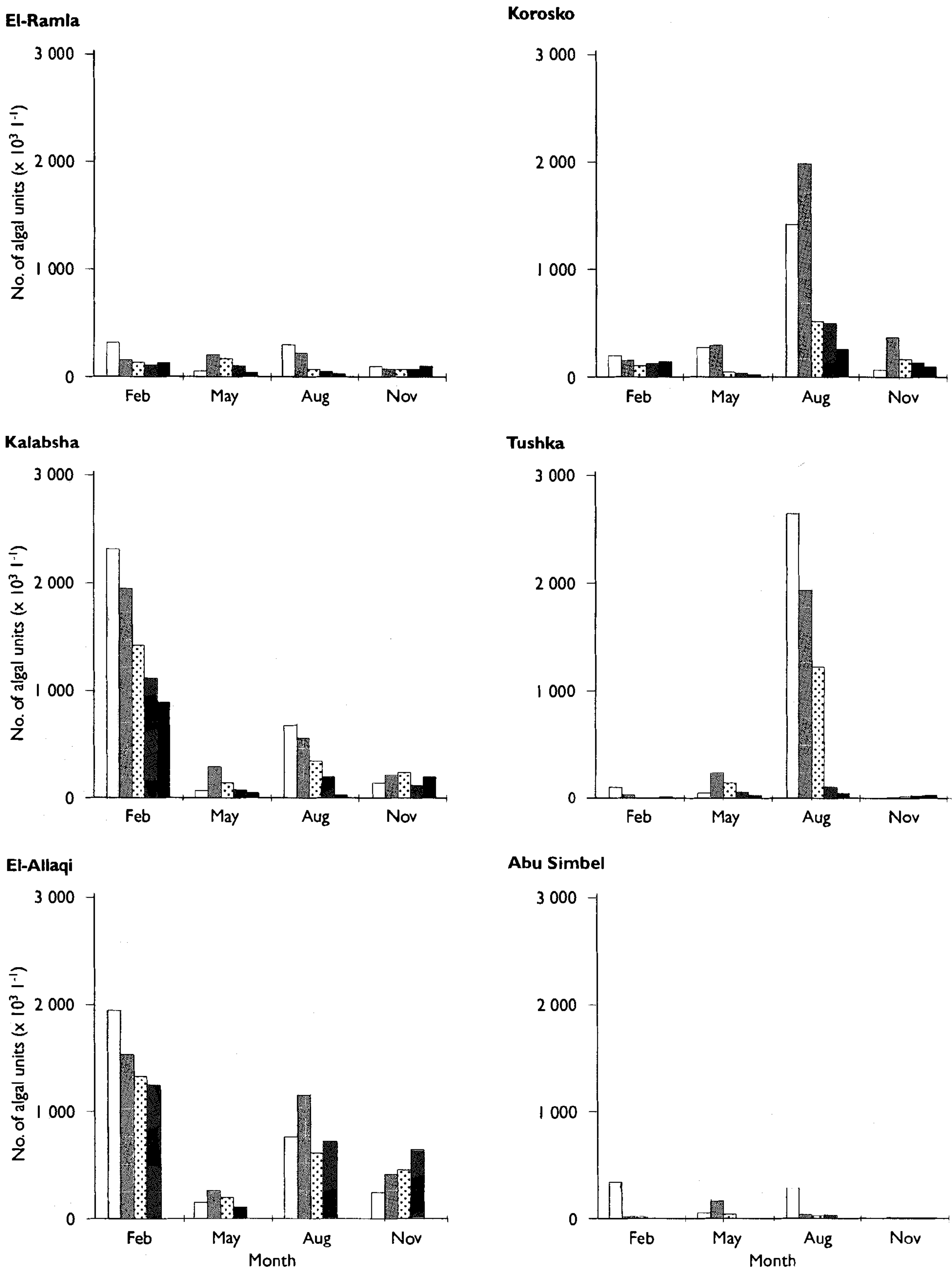

Fig. 1. Seasonal variation in the total number of algal units (x 10^3 l^{-1}) in 1991 at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel from the surface (□) to 5 (▨), 10 (⁙), 15 (▩) and 20 m (■) intervals.

units l^{-1} at the surface, respectively) and low values in February, May and November. The minimum values were 41×10^3 algal units l^{-1} at 20 m in May at Station 4, and 7×10^3 algal units l^{-1} at 5 m depth in November at Station 5. Stations 1 and 6 had relatively low values and no significant seasonal changes. In February, the surface layer showed a maximum of 277×10^3 (Station 1) and 312×10^3 (Station 6) algal units l^{-1}. The minimum values at 20 m were 14×10^3 algal units l^{-1} (Station 1 in August) and 3×10^3 algal units l^{-1} (Station 6 in November).

The percentage contribution (as an average of the five depths) of each group (diatoms, green algae, blue-green algae and dinoflagellates) to the total is illustrated in Fig. 2 for the six stations. Blue-green algae were most abundant in August at all the stations. In general, at Stations 1-3, blue-green algae dominated the community from February to August. There was an increase in November. At Stations 4-6, diatoms dominated the community in February being superseded by blue-green algae from May to August. In November, diatoms and green algae increased. Diatoms were most abundant in November at Stations 1-3 and in February at Stations 4-6. Green algae were most abundant in May at Stations 1-4 and in November at Stations 5 and 6. Dinoflagellates were most abundant in May at all the stations.

Seasonal variation in the composition of blue-green algae is shown in Fig. 3. In general, *Anabaenopsis* dominated the community in February and November at all six stations, and at Stations 5 and 6 in August. In May, *Anabaenopsis* was less

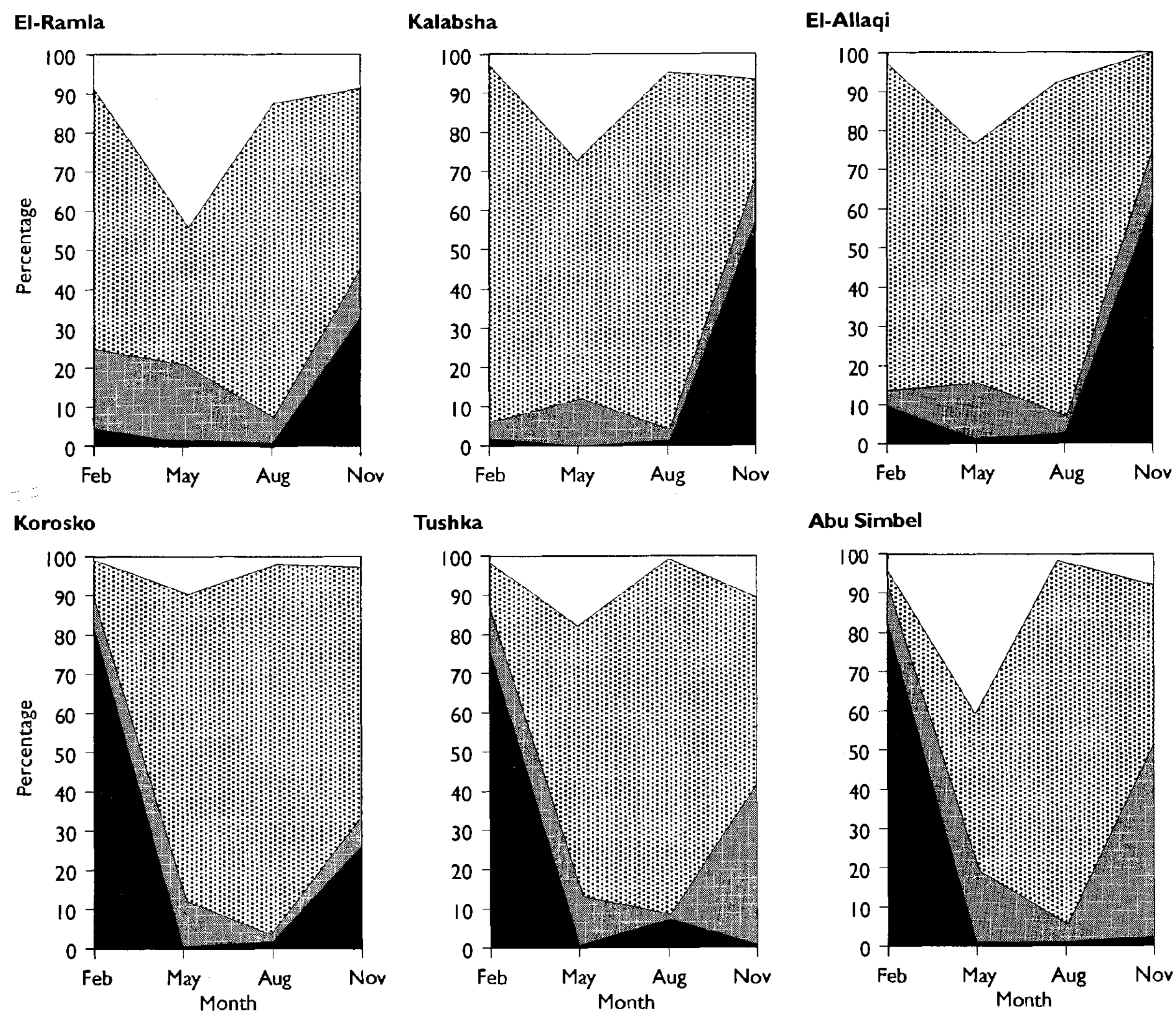

Fig. 2. Seasonal variation (%) in the major phytoplankton groups in 1991 at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel. Diatoms (■), chlorophytes (▨), cyanophytes (⬚), dinoflagellates (□).

Primary Production of the Phytoplankton

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Habib, O.A. 2000. Primary production of the phytoplankton, p. 51-55. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Phytoplankton primary production was estimated at six stations, from El Ramla in the north to Abu Simbel in the south, along the main channel of Lake Nasser from September 1986 to August 1987. Gross and net production (gC m^{-2} day^{-1}) was generally high in September or October and April or May and low in August, ranging from 1.0 in August at Station 5 to 27.4 in April at Station 2 for gross production, and from 0.7 in August to 23.8 in September at Station 5 for net production. Respiration (gC m^{-2} day^{-1}) ranged from 0.3 in September at Station 1 and in August at Station 5 to 12.5 in April at Station 2.

Introduction

Primary production is one of the most important sources of energy input to freshwater ecosystems and has been studied largely to obtain basic information on carbon transfer. Primary production can be measured through carbon uptake, oxygen production or the formation of organic compounds. The classic procedure for determining the oxygen content (oxygen production) of natural water is the "light-and-dark" bottle technique (Vollenweider 1969). This paper describes primary productivity and respiration by the phytoplankton as measured by the light-and-dark bottle technique at six stations in the main channel of Lake Nasser from September 1986 to August 1987. The data given in this paper are the first to be published for Lake Nasser since Samaan (1971).

Methods

Water samples were collected monthly with a van Dorn-type water sampler at six stations: El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel (see El Shahat, this vol., p. 4) from September 1986 to August 1987. The primary production of phytoplankton was estimated by the chlorophyll *a* method according to Ishimura et al. (1962) and Aruga (1966). The photosynthetic and respiratory activities of phytoplankton were measured to obtain photosynthesis-light curves on a chlorophyll *a* basis. The diurnal changes of light intensity were measured with a lux meter and the attenuation of light in water was estimated from the Secchi disc depth. The relative intensity (RLI) at depths of sampling was determined from the light attenuation in water; the depth for 1% RLI (D1%) is approximately three times the Secchi disc depth. The absolute light intensity at each depth for every hour of the day was calculated using the diurnal changes of light intensity in accordance with RLI and the hourly gross photosynthesis at each depth was read from the photosynthesis-light curve according to the respective light intensity. The hourly gross photosynthesis at each depth was summed from sunrise to sunset or from sunrise to noon and multiplied by 2, to obtain the daily gross production at each depth and the daily gross production at each depth was multiplied by the chlorophyll *a* concentration at respective depth to obtain the daily gross production per m^3. Daily gross production at each depth was integrated from the surface to the lower limit of the euphotic zone to obtain the daily gross production per m^2 of the surface. The hourly respiration on a chlorophyll *a* basis was multiplied by the chlorophyll *a* concentration at each depth and by 24 to obtain the daily respiration per m^3 at respective depth. The daily respiration of each depth was integrated from the surface to the lower limit of the euphotic zone to obtain the daily respiration per m^2 of the surface. The difference between the daily gross production and the daily respiration was taken at each depth to obtain the daily net

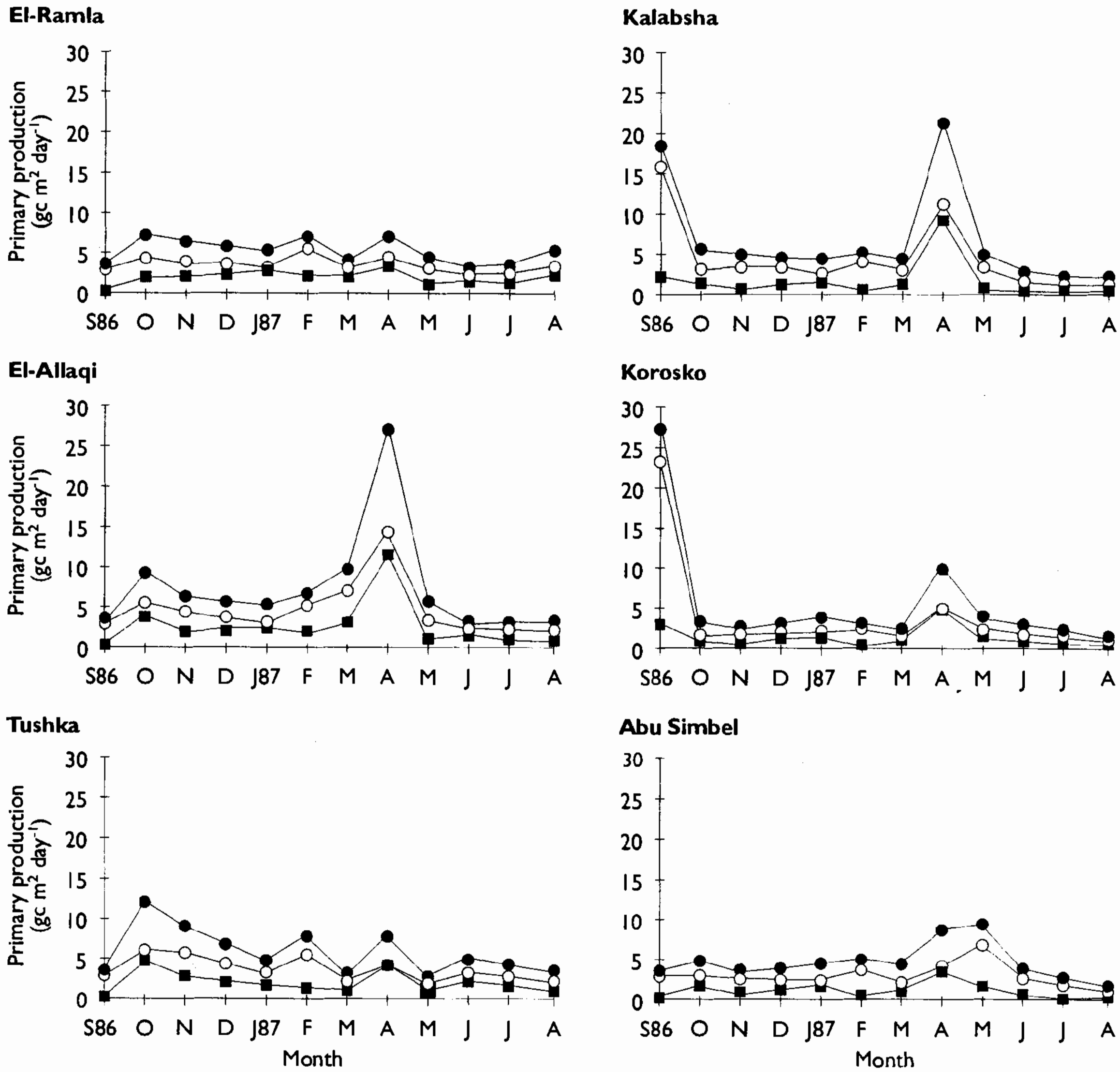

Fig. 1. Seasonal variation in primary gross production (●), primary net production (○) and phytoplankton respiration (■) (gC m^{-2} day^{-1}) from September 1986 to August 1987 at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel.

production. The daily net production of each was integrated from the surface to the lower limit of the euphotic zone to obtain the daily net production per m^2 of the surface. Or, the daily respiration per m^2 was subtracted from the daily gross production per m^2 to obtain the daily production per m^2 of the surface.

Results

Seasonal variation in primary production at Stations 1-6 is shown in Fig. 1, including gross production (Pg), net production (Pn) and respiration (R). Gross production ranged from 1.0 gC m^{-2} day^{-1} in August 1987 at Stations 5 to 27.4 gC m^{-2} day^{-1} in April 1987 at Station 2. There were two periods of high net production. Stations 4 and 5 only showed a high peak in September 1986 of 16.1 and 23.8 gC m^{-2} day^{-1}, respectively, but no peaks were recorded at other stations. Stations 1-3 had peaks in October 1986 increasing from Station 1 to Station 3. Another peak was observed in April at all stations with Station 2 having the maximum peak of 14.0 gC m^{-2} day^{-1} and Stations 1 and 3 the minimum values. Apart from the previously mentioned peaks, net production was constant or decreased from June to August 1987 at all stations. Respiration ranged from 0.3 gC m^{-2} day^{-1} in September 1986 at Station 1 to 12.5 gC m^{-2} day^{-1} in April at Station 2.

Seasonal variation in primary production depended mainly on transparency and chlorophyll *a*. Fig. 2 shows seasonal

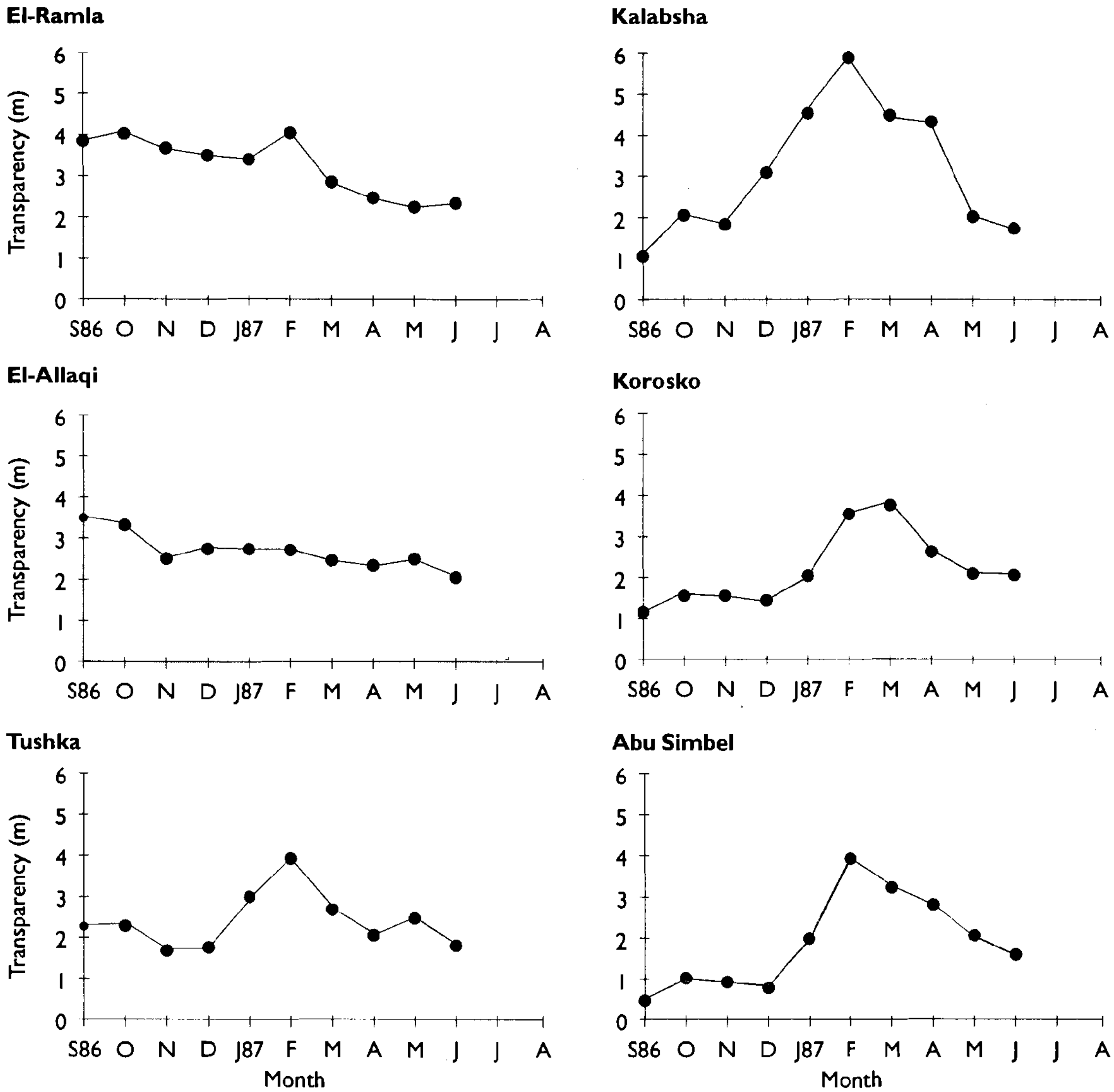

Fig. 2. Seasonal variation in Secchi disc depth (m) from September 1986 to August 1987 at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel.

variation of transparency at Stations 1-6. It is clear that peaks of primary production, especially in April, coincided with low transparency in most cases. The correlation coefficient between primary production and transparency was calculated separately at each station. Only Station 1 showed a high positive correlation. There was no significant relationship, probably due to small sample size (see I.O. Mohamed, this vol.).

Chlorophyll *a* concentration at Stations 1-6 is shown in Fig. 3. It is noticeable that the peaks of chlorophyll *a* concentration normally coincide with those of primary productivity. In some cases, high concentrations of chlorophyll *a* also coincided with minimum transparency (Stations 5 and 6 in August) but minimum productivity was observed. This could be related to the small euphotic zone, which in turn affected the integrated layers. The correlation coefficient between net production and chlorophyll *a* was calculated at each station separately. Stations 1, 4 and 6 showed no correlation at all, while Stations 2, 3 and 5 showed positive correlation ($P<0.01$, $P<0.05$ and $P<0.01$, respectively).

Conclusion

The combination of factors known as the light-climate influences photosynthetic production by the phytoplankton. This includes incident solar irradiance, underwater light attenuation and the proportions of illuminated and dark water in the mixed water column (Bindloss 1976). To estimate total photosynthesis beneath a unit of water surface, all the variations of photosynthesis in the illumination gradient with respect to depth and time must be integrated. The

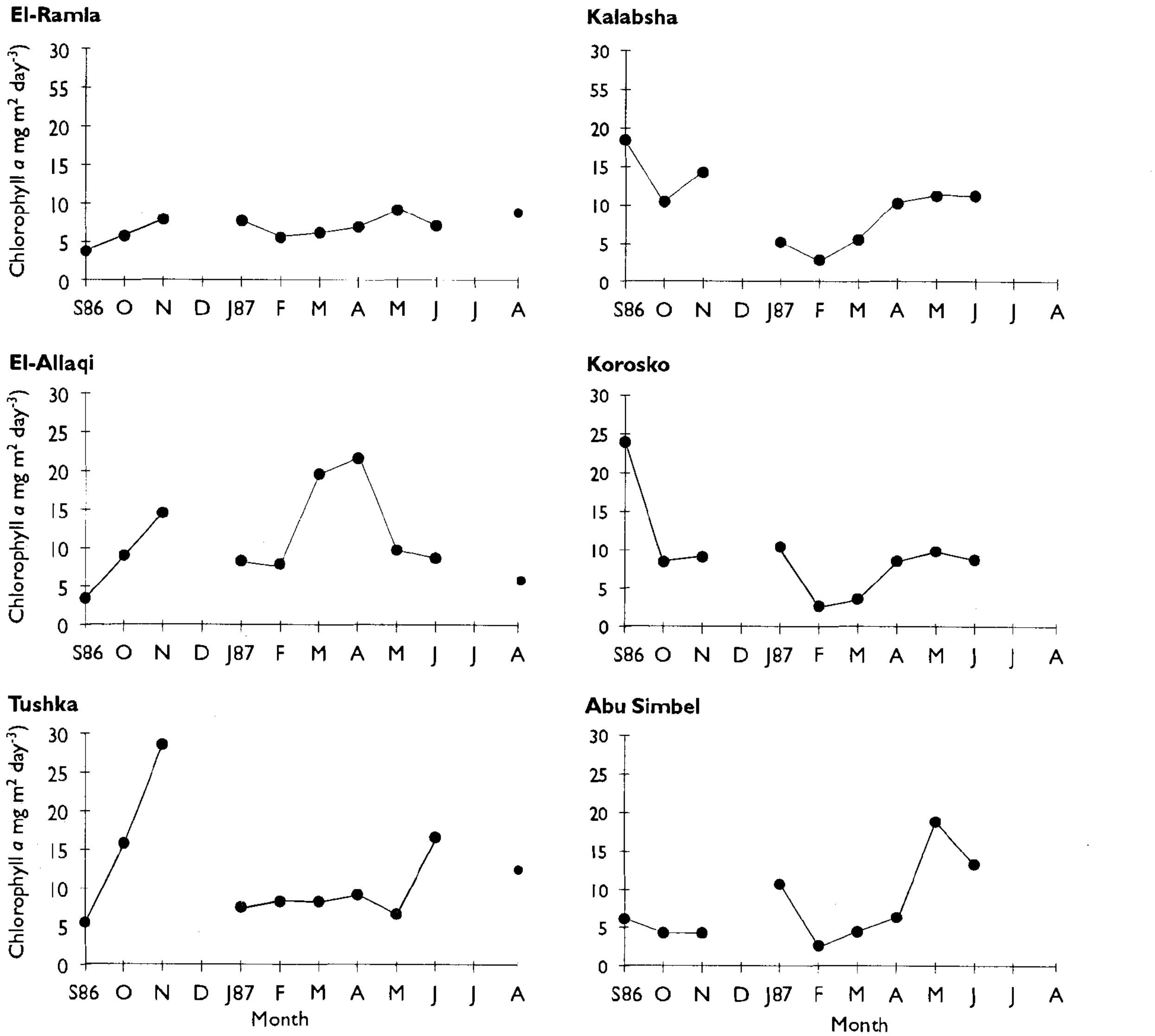

Fig. 3. Seasonal variation in the mean chlorophyll *a* concentration (mg m^{-3}) in the euphotic zone from September 1986 to August 1987 at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel.

integer may be evaluated directly from measurements of photosynthetic rates between sunrise and sunset at depth intervals (Megard 1972). According to Talling (1965), the rate of photosynthesis at any depth is a simple product of population density and the specific rate of photosynthesis by units of the population, which are interdependent: light attenuation increases as densities increase and photosynthesis therefore decreases rapidly with depth when the population density is high.

Despite extensive literature on spatial and temporal variation in phytoplankton primary production in temperate lakes, little information is available on the seasonality of phytoplankton production for most of the tropical lakes. Net primary production of Lake Nasser ranged from 0.7 to 23.8 gC m^{-2} day^{-1} during 1986 and 1987. Few measurements have been published about Lake Nubia-Nasser, but Entz (1972) refers to one high estimate of 15.5 gO_2 m^{-2} day^{-1} (5.8 gC m^{-2} day^{-1}). Similarly high estimations by Samaan (1971) give 3.2-5.2 gC m^{-2} day^{-1}. Kifle and Belay (1990) recorded daily integral photosynthesis for Lake Awasa, Ethiopia, ranging from 3.3 to 7.8 gC m^{-2} day^{-1}. They concluded that their data were very close to those reported for Lakes Naivasha, Olodie and Crescent Island Crater in Kenya (Melack 1979) and greater than those found for Lakes Ziway and Abijata in Ethiopia (Belay and Wood 1984). Lake McIlwaine, Rhodesia (Zimbabwe), is considered one of the most productive lakes in Africa with photosynthetic rates of 1.64 to 6.03 gC m^{-2} day^{-1} (Robarts 1979). In comparison, Lake Sibaya has productivity rates of 0.23 to 1.85 gC m^{-2} day^{-1} (Allanson and Hart 1975) and the upper reaches of Swartvlei rates of 0.013 to

0.017 gC m^{-2} $hour^{-1}$ (Robarts 1976). Talling (1965) recorded daily rates between 4.0 and 6.0 gC m^{-2} day^{-1} in a number of east African lakes, and Melack and Kilham (1974) found rates of 0.3 to 2.0 gO_2 m^{-2} day^{-1} (1.2-7.5 gC m^{-2} day^{-1}) for a number of east African alkaline, saline lakes. Ganf (1975) found that the mid-day integral photosynthetic rate in Lake George, Uganda, was between 1 and 2 gO_2 m^{-2} $hour^{-1}$ (375-750 mgC m^{-2} $hour^{-1}$). Perhaps the most productive lake in Africa is Lake Arangudi, an Ethiopian soda lake, for which Talling et al. (1973) reported a productivity of 43-57 gO_2 m^{-2} day^{-1} (16-21 gC m^{-2} day^{-1}). Lewis (1974) found the average net primary production of 1.7 gC m^{-2} day^{-1} for Lake Lanao, Philippines, which is considered to be one of the most productive lakes. This was similar to Lake Victoria with 1.7-3.8 gC m^{-2} day^{-1} (Talling 1965).

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Average Changes in the Distribution of Phytoplankton Chlorophyll *a* in the Euphotic Zone in the Main Channel

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Mohamed, I.O. 2000. Average changes in the distribution of phytoplankton chlorophyll *a* in the euphotic zone in the main channel, p. 57-58. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Chlorophyll *a* concentrations have been measured in Lake Nasser since 1982. Usually, high concentrations were recorded in the euphotic zone. A stratified vertical distribution was noted from April to September, while the distribution was homogeneous from November to February. The average annual chlorophyll *a* concentrations in the euphotic zone were higher at the three southern stations compared to the three northern ones. The maximum yearly average (13.1 mg m^{-3}) was recorded at Station 3 (El-Allaqi) in 1990, while the minimum (1.8 mg m^{-3}) was measured at Station 1 (El-Ramla) in 1994. The maximum yearly average transparency (Secchi disc depth) among the stations was 4.6 m at Station 1 and the minimum, 1.1 m, at Station 6 (Abu Simbel) in 1994. The maximum yearly average water temperature in the euphotic zone (26.3°C) was recorded at Station 4 (Korosko) in 1995, while the minimum (17.3°C) was recorded at Stations 1 and 3 in 1997.

Introduction

The Fishery Management Center (FMC) has measured chlorophyll *a* concentrations in Lake Nasser since 1982. This paper describes the changes in average chlorophyll *a* concentrations in the euphotic zone from 1986 to 1997.

Materials and methods

The water samples were collected from the euphotic zone (Secchi disc extinction depth × 2.7) with a van Dorn water sampler at six stations, El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel, along the main channel (see El Shahat, this vol., p. 4). Water transparency was measured with a Secchi disc (30 cm diameter) and water temperature was recorded immediately after collection with a standard thermometer. The water samples (1-2 l) were filtered through a glass fiber filter (Whatman GF/C, 47 mm) and the filter stored in a cool and dark place for later analysis. Pigments were extracted with 90% acetone. To check the turbidity of the extract solution, light absorbencies of the extract were measured at 750, 663, 645 and 630 nm with a spectrophotometer. The chlorophyll *a* concentration was calculated by the equation of SCOR-UNESCO (1966):

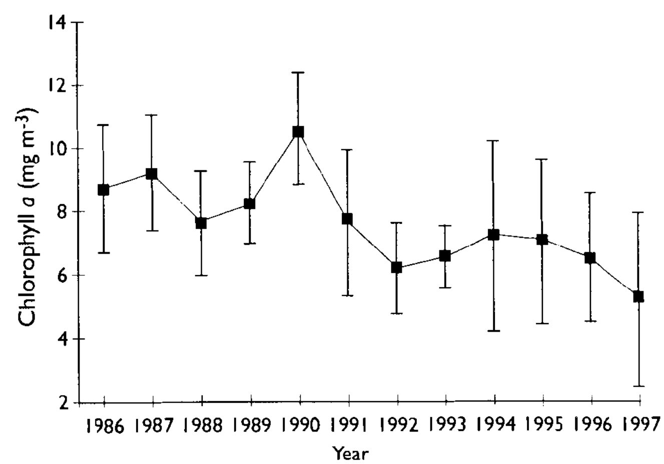

Fig. 1. Yearly average chlorophyll *a* concentrations (mg m^{-3} ± 95%CL) for six stations in the main channel.

Chl. *a* (mg m^{-3}) = (11.64*Abs 663 nm - 2.16*Abs 645 nm) + 0.1*(Abs 630* ext. vol. (ml))/(filt. Vol (1))

Results

A stratified vertical distribution of chlorophyll *a* was noted from April to September, while the distribution was homogeneous from November to February. The average annual chlorophyll *a* concentrations in the euphotic zone were higher at the three southern stations compared to the three northern ones. The annual average (six stations), from 1986 to 1997, of chlorophyll *a* concentrations in the euphotic zone are shown in Fig. 1. The maximum value through the period of study was 13.1 mg m^{-3} measured at Station 3 in 1990 and the minimum was 1.8 mg m^{-3} at Station 1 in 1994.

The maximum yearly average transparency (Secchi disc depth) among the stations was 4.6 m at Station 1 and the minimum, 1.1 m, at Station 6 in 1994.

Transparency and chlorophyll *a* concentrations were inversely related ($P<0.001$) (Fig. 2).

The maximum yearly average water temperature in the euphotic zone (26.3°C) was recorded at Station 4 in 1995, while the minimum (17.3°C) was recorded at Stations 1 and 3 in 1997.

Conclusions

Chlorophyll *a* concentration in the water can be used as an index of primary production of the phytoplankton. (Ishimura et al. 1962; Aruga and Monsi 1963). The transparency in Lake Nasser is caused by two main factors, namely allohtonic silts of riverine origin and authochtonic suspended organic material (plankton and detritus).

The inverse relationship between transparency and chlorophyll *a* explained this phenomenon of authochtonic character. The results agree with the data obtained by Zaghloul (1985). However, other planktonic organisms also played an important role in lowering the water transparency.

Acknowledgements

I would like to express my deep gratitude and appreciation to Eng. M.H. Tolba, Chairman of High Dam Lake Development Authority, and Eng. M.M. El Shahat, Under-Secretary of State for Fisheries, for supporting this survey. I am greatly indebted to Dr. Hussein E. Touliabah, Researcher in the National Institute of Oceanography and Fisheries, Inland Water and Aquaculture Branch, for his help with the graphical and statistical analyses.

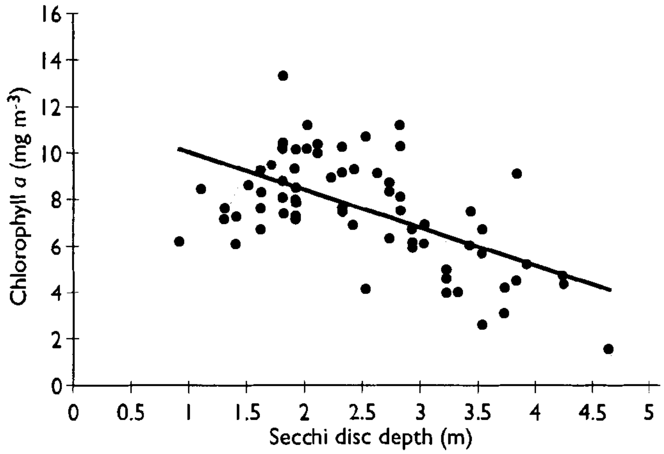

Fig. 2. The relationship between chlorophyll *a* concentration (mg m^{-3}) and Secchi disc depth (m).

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DISCUSSION

Q. Can you give a value for the yearly average biomass?

A. No, I only calculated the maximum and minimum values, not the average.

Q. Did you make any comparison between the chlorophyll *a* data and the composition of the phytoplankton?

A. No comparisons have been made.

Microcystis aeruginosa Kutz Water Blooms

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Mohamed, I.O. and T. Ioriya. 2000. *Microcystis aeruginosa* Kutz water blooms, p. 59-60. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

After the construction of the Aswan High Dam, water blooms of *Microcystis aeruginosa* were observed only at the southern end of the lake between Wadi Halfa and Abu Simbel. Recently, water blooms were observed in the central area of the lake. Very occasionally, they were seen at Korosko in the northern area. Formerly, *M. aeruginosa* water blooms occurred annually for several months before the floodwater period, but now they occur intermittently all the year round.

Introduction

After the construction of the Aswan High Dam, extensive water blooms of *Microcystis aeruginosa* Kutz were common every year, for several months before the flood period, in the southern areas of the lake between Wadi Halfa in Lake Nubia (Sudan) and Abu Simbel in Lake Nasser. An investigation was initiated to monitor the temporal and spatial changes of these blooms.

Materials and methods

Since 1985, monthly surveys have been conducted to identify water blooms in the main channel of Lake Nasser from the Aswan High Dam to Abu Simbel (see El Shahat, this vol., p. 4). When blooms were observed, water samples were collected in plastic buckets, fixed with 10% formalin and stored in sample bottles. In the laboratory, identification and counting of each species was undertaken.

Results

The dates when *M. aeruginosa* blooms were observed are shown in Table 1. The size of water bloom patches varied from a few centimeters to 35 m in diameter and the blooms were usually found to be at <1 cm depth. The largest blooms were observed on 11 December 1989, when patches of plants were distributed over a length of 125 km, from El-Seboa to Abu Simbel. *M. aeruginosa* was the dominant species.

Table 1. Date, location and surface water temperature when water blooms were observed.

Date	Location	Water temperature (°C)
19 Aug 1987	Abu Simbel	33.2
19 Aug 1987	Tushka	30.0
16 Aug 1988	Korosko	33.3
9 Sep 1989	Tushka	31.1
11 Dec 1989	Abu Simbel	20.2
11 Dec 1989	Tushka	20.0
11 Dec 1989	El-Seboa	20.8
22 May 1990	Korosko	26.6
14 Aug 1991	Abu Simbel	29.2
16 Oct 1992	Abu Simbel	28.1
16 Oct 1992	Wadi El Arab	28.4
19 Feb 1993	Korosko	18.5
25 Aug 1993	Tushka	28.5
26 Feb 1994	Tushka	—

On 9 September 1989 at Tushka, *Oscillatoria tenuis* was dominant although *M. aeruginosa* still was >40%. As shown in Table 1, the occurrences of water blooms were not restricted to any particular season, but tended to be more common in the month just before the flood period (from late summer to early autumn).

Conclusions

Reports of water blooms in Lake Nasser are few (Entz 1976). Since 1965, when Lake Nasser was filled, extensive water blooms of *M. aeruginosa* were observed annually for several months before the flood water period only in Lake Nubia and in the southern areas of Lake Nasser, between Wadi Halfa and Abu Simbel (Entz 1976). Before 1987, the occurrence of the water blooms was restricted to the area south of Tushka and Abu Simbel. From the results, 12 occurrences of water blooms were observed in the area between Abu Simbel and Korosko and only two occurrences were seen in the areas north of Korosko. The northern movement of water blooms is gradual. It took about 20 years to move from Abu Simbel to Korosko. Korosko is situated at the Great Bend of the lake, which forms a kind of "threshold" for phytoplankton distribution (Habib et al. 1990). The water bloom has only been observed twice in the region north of Korosko but the spread appears to be accelerating. The seasonality of water bloom outbreaks has disappeared.

At present, Lake Nasser is almost totally devoid of industrial pollution and nutrient enrichment from agricultural runoff. However, monitoring the occurrence of water blooms in Lake Nasser in relation to eutrophication must be continued. Hammerton (1963) pointed out that even a very mild degree of eutrophication from industrial development could have a serious effect on the Nile because of the high temperature and high radiation inputs.

Acknowledgements

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Aquatic Macrophytes in Egyptian Nubia Pre- and Post-formation of Lake Nasser

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Ali, M.M. 2000. Aquatic macrophytes in Egyptian Nubia pre- and post-formation of Lake Nasser, p. 61-65. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The paper gives an account of the dynamic changes in the Lake Nasser aquatic macrophyte communities in relation to water and hydrosoil physical and chemical characteristics. Two types of aquatic macrophyte changes were recognized: changes due to alteration of the Nile system in Egyptian Nubia from "lotic" or "fluviatile" to "lentic" or "lacustrine" and changes due to the continuous alteration in the physical and chemical characteristics of water and hydrosoil. Literature and field surveys suggest that major changes have occurred in the aquatic macrophytes in Lake Nasser following completion of the Aswan High Dam in 1964. However, recent changes in the submerged macrophyte communities in the lake appear to be related to physical factors (e.g., water level fluctuations and human activities).

Introduction

Aquatic submerged macrophytes can cause weed problems by the growth of dense vegetation that interferes with irrigation and hydroelectric schemes, fisheries and/or navigation. On the other hand, they are beneficial to the aquatic system because they produce oxygen, purify the water by trapping silt particles, take up toxic substances and provide habitats for fish fry and other organisms.

Profound changes can occur to the flora of a system after the building of dams and the impoundment of water. Rorslett (1989) summarized the changes in vegetation, following impoundment for hydroelectric schemes as: (a) a decline in species richness; (b) the gradual disappearance of the shallow water and mid-depth communities; (c) a conspicuous absence of submerged vascular macrophytes in storage hydroelectric lakes when lake levels are >7 m annually; and (d) an increase in the incidence of species possessing strategies of the ruderal (R) type.

Morphological changes in the river may occur as a result of changes in the flow regime. An increase in the flow can cause erosion of river banks and result in a reduction of the mean size of particles remaining. Alternatively, reduced flows can result in sedimentation with decreasing substrate diversity (Jeffries and Mills 1990). After impoundment, resulting either in reservoir formation or in raising the level of an existing lake, there is usually an increase in the total biological productivity, with a risk of eutrophication due to leaching of nutrients from the newly inundated ground.

Methods

Information on the past distribution of aquatic plants in Egyptian Nubia before the formation of Lake Nasser is based on literature records. However, data on distribution and ecology of aquatic plants after formation are mainly derived from surveys. Sampling of the euhydrophyte communities was undertaken during three sampling periods, 1984-1986 (at 18 stations), 1988-1990 (at 17 stations) and 1993-1994 (at three stations) (see El Shahat, this vol., p. 4).

Submerged macrophytes were sampled using a replicated grapnel-sampling technique (Murphy et al. 1981). The grapnel was attached to a wooden pole and collected both foliage from the water column and overwintering vegetation and roots buried in the sediment. In the laboratory, plants from each grapnel haul were washed to remove mud, stones, mollusc shells and aquatic invertebrates. Plants were separated into different taxa, identified after Täckholm (1974), Moore (1986) and Triest (1989), and a list of species was recorded.

Standing crop dry weight of each species per grapnel haul was determined after air-drying.

Results

Aquatic macrophytes

In 1962-1964, several expeditions of Egyptian and European botanists explored the Nubian area. The part of the Nile valley, which was to become Lake Nasser, had a relatively rich submerged and emergent flora (57 species, of which six were euhydrophytes: *Alisma gramineum* Lejeune, *Damosonium alisma* Mill. var. *compactum*, *Potamogeton crispus* L., *P. pectinatus* L., *P. perfoliatus* L. and *Zannichellia palustris* L.) (Boulos 1967). Similar data were presented by other authors (e.g., Aballah and Sa'ad. 1972; Ahti et al. 1973; E1-Hadidi 1976) from studies during the same period.

After the construction of the Aswan High Dam, two euhydrophyte species *(A. gramineum* and *D. alisma)* appear to have been lost from the region, but the other four species have colonized the lake, with varying degrees of success.

In 1967, *Vallisneria spiralis* L. was recorded for the first time in Egypt (E1-Hadidi 1968; El-Hadidi and Ghabbour 1968). In 1978-1986, eight species were recorded (Ali 1987; Springuel and Murphy 1991). Five of them (*Potamogeton schweinfurthii, Najas horrida, N. marina* subsp. *armata* and *Nitella hyalina)* were new to the area (see Table 1). Sixteen sites were visited during the 17-month period from November 1988 to March 1990 and the results are given in Table 2. In November 1988, no aquatic vegetation was recorded at any of the Lake Nasser sites.

In February 1989, seedlings of *N. marina* subsp. *armata* appeared in both shallow and deepwater zones. *Z. palustris* was also observed. In May 1989, *Najas marina* subsp. *armata* became more abundant and reached its highest biomass of 507g m^{-2} (Table 3). *N. horrida* and *N. hyalina* were commonly found. In September 1989, *V. spiralis* dominated the aquatic plant community at the Amada site, which is situated in the middle section of the lake. In October 1989, *N. hyalina* disappeared and *N. marina* subsp. *armata* became dominant. In March 1990, the abundance of *N. horrida* increased and became dominant at some sites.

From Table 2, the following may be inferred: (a) *N. marina* dominated the deepwater zone at all sites (except at Amada, where it was dominated by *V. spiralis)* and (b) the aquatic vegetation was more abundant in deep than in shallow water.

In 1993-1994, the author surveyed the northern sector of Lake Nasser from the Aswan High Dam to El-Allaqi. Dense cover of two "nuisance species" was recorded, *Myrophyllum spicatum* L. in Abu Hor and *Ceratophyllum demersum* L. at the Aswan High Dam port in addition to *N. horrida, N. marina*

Table 1. Freshwater macrophyte species recorded in Egyptian Nubia pre- and post-formation of the Aswan High Dam in 1964.

Species	1962-1964	1966-1967	1978-1986	1988-1990	1993-1994
Alsima gramineum	+				
Damasonium alisma var. *compactum*	+				
Potamogeton perfoliatus	+				
P. crispus	+	+	+		
P. pectinatus	+	+	+		
Zannichellia palustris	+	+	+	+	
Vallisneria spiralis		+	+	+	
P. trichoides			+		
P. schweinfurthii[a]			+	+	+
Najas horrida[b]			+	+	+
N. marina subsp. *armata*			+	+	+
Nitella hyalina[c]			+	+	+
Myrophyllum spicatum					+
Ceratophyllum demersum					+

[a] This species was misidentified as *Potamogeton nodosus*.
[b] This species was misidentified as *Najas pectinalis* (Ali 1987).
[c] This species was misidentified as *Chara* sp. in Springuel and Murphy (1990).
Sources: a) Pre-inundation, 1962-1964: Boulos (1967); El-Hadidi (1968) and El-Hadidi and Ghabbour (1968); Abdalla and Sa'ad (1972); Ahti et al. (1973); (b) Post-inundation, 1966-1968: Ghabbour (1972) and El-Hadidi and Ghabbour (1968); 1978-1986: Ali (1987) and Springuel and Murphy (1991); 1988-1990: Ali (1992); and 1993-1994: author's records (northern part of the lake from the Aswan High Dam to El-Allaqi).

Table 2. Dry weight standing crop (g per sample) in shallow and deepwater zones at 15 sites, 1988-1990. (— = not present)

Site	Date	Shallow zone			Deepwater zone				
		N. marina	*N. horrida*	*Z. palustris*	*N. marina*	*N. horrida*	*Z. palustris*	*V. spiralis*	*P. schweinfurthii*
Abesco	Nov 1988	—	—	—	—	—	—	—	—
El-Allaqi	Nov 1988	—	—	—	—	—	—	—	—
Kourta	Nov 1988	—	—	—	—	—	—	—	—
Adindan	Nov 1988	—	—	—	—	—	—	—	—
Soliman	Feb 1989	0.4	—	—	1.6	—	—	—	—
Maria	Feb 1989	0.1		0.3	3.5	—	—	—	—
Kalabsha	Oct 1989	—	—	—	16.3	0.1	—	<0.1	3.9
El-Ramla West	May 1989	3.2	—	—	12.5	4.4	—	—	—
El-Ramla East	May 1989	—	—	—	0.9	4.6	—	—	—
	Oct 1989	—	—	—	<0.1	28.1	—	—	—
Mirwaw West	Feb 1989	—	1.1	0.3	1.2	—	0.2	—	—
Mirwaw East	Feb 1989	—	10.9	0.3	3.9	—	—	—	—
Amada	Sep 1989	—	—	—	—	1.0	—	5.4	—
Abu Hor	Feb 1989	0.2	—	<0.1	2.8	—	0.4	—	—
Kalabsha	Feb 1989	0.5	—	<0.1	0.8	—	—	—	—
	Sep 1989	—	—	—	<0.1	4.6	—	—	—
El-Madiq	Sep 1989	—	<0.1	—	0.3	<0.1	—	0.8	—
	Apr 1990	4.3	—	—	1.0	—	—	—	—
Turgumi	Jun 1989	16.4	—	—	13.5	—	—	—	—
	Oct 1989	—	—	—	7.2	—	—	—	—
	Mar 1990	—	—	—	31.6	—	—	—	—

Table 3. Dry biomass (g m^{-2}) in the shallow water zone at Turgumi, Lake Nasser.

Species	April 89	May 89	July 89	May 90
Najas marina	115	507	121	48
N. horrida	—	—	—	50
Nitella hyalina	103	54	—	38
Zannichellia palustris	—	—	—	1

subsp. *armata* at all sites surveyed and *P. schweinfurthi* at Kalabsha.

Hydrosoil

The physical properties of hydrosoil samples collected during a previous study (Ali 1992) in Lake Nasser are given in Table 4. The hydrosoil varied in texture and could be classified into three categories as sandy, loamy sand and sandy clay loam. Sand was the main constituent of the hydrosoil texture in Lake Nasser. However, the northern section had hydrosoil that was mainly sandy clay loam and the middle section was sand or loamy sand. The hydrosoil is rich in calcium and magnesium and poor in phosphate (Table 5).

Conclusions

Regulated waterbodies have distinct features associated with them. In particular, hydroelectric reservoirs tend to be much steeper-sided than other lakes (Rorslett 1989). This has a direct physical effect on the plant and animal communities. Water level regulation also affects the physical and chemical characteristics of the waterbodies. Erosion of the littoral zone is a natural phenomenon occurring in regulated waterbodies and is often linked closely with water level fluctuations and wave action (Smith et al. 1987).

Hydrosoil characteristics can be important to plant distribution and abundance (Haslam 1978). The causes of this relationship with the substrate may be both indirect, via water movement regimes that create these substrates, or direct due to rooting patterns (Madsen and Adams 1989). The littoral zone is often composed of gravel and has a coarse hydrosoil texture. This is determined largely by the water level regime and by the degree of exposure to wave action (Wilson and Keddy 1986; Weisner 1987). In the Egyptian waterbodies, hydrosoil texture plays an important role in species distribution.

The construction of the Aswan High Dam substantially reduced the amount of silt deposited in the river downstream from the dam. El-Hadidi (1976) stated that the silt, which is necessary for building up the fertile embankments, was no longer available after the construction of the dam. The littoral zone of Lake Nasser has a mainly sand substrate, as the submerged area was previously desert.

Most of the silt, which had been brought by the floods, accumulated behind the dam. Such an accumulation of silt, in

Table 4. Physical composition (%) of hydrosoil samples from Lake Nasser (After Ali 1992).

Site	Physical makeup (%)						
	Gravel	Coarse sand	Fine sand	Silt Sand	Clay	Organic matter	Soil type
El-Ramla	0.49	22.32	42.66	8.52	19.08	1.88	Sandy clay loam
Kalabsha (a)	14.64	14.41	45.31	1.34	22.48	3.91	Sandy clay loam
Turgumi	0.14	84.60	7.64	1.28	10.90	0.75	Sand
Amada	0.56	8.48	77.58	1.55	9.10	1.17	Loamy sand
Kalabsha (b)	0.43	52.76	31.64	4.03	9.09	1.94	Loamy sand

Table 5. Chemical analysis of hydrosoil samples ($\mu g\ g^{-1}$) from Lake Nasser (After Ali 1992).

Site	K^+	Ca^{++}	Mg^{++}	PO_4^{-3}
El-Ramla	34.86	510	39.0	1.54
Kalabsha (a)	21.09	480	31.0	3.16
Turgumi	40.90	400	13.0	1.75
Amada	13.17	410	25.0	0.72
Kalabsha (b)	10.70	410	20.0	1.70

the north section of the lake, gave a hydrosoil texture of sandy clay loam, which provided a favorable substrate for the growth of *M. spicatum* (Haslam 1978). Some of the silt was deposited on the shores and khors on both sides of the lake. Due to the water level fluctuation and wave action, the accumulated silt was washed from the banks and accumulated in the main channel, leaving behind sandy or loamy sandbanks. On these shores, *P. schweinfurthii* and *N. marino* subsp. *armata* were the dominant plants.

Alteration of the hydrology of the River Nile system has not only resulted in a difference in the species that dominated each site but it has also resulted in structural differences in the vegetation. The dramatic changes in macrophyte communities, resulting from the regulation of waterbodies, have been described by several authors (Smith et al. 1987; Rorslett 1989; Wilcox and Meeker 1991).

Water body regulation leads to the selection of a community of submerged aquatic plants, which can tolerate the fluctuating water levels. The abundance of a species alters with different water level fluctuation regimes. An extended range of water level fluctuations often results in mortality of the aquatic vegetation caused by conditions of low or no light. (Rorslett 1989). Extreme changes in water levels therefore give rise to communities that are extremely species poor and so the littoral zone is impoverished (Smith et al. 1987). Some species cannot tolerate the disturbance caused by the fast rate of change in the water level. The capacity to invade new territory successfully, especially after some form of disturbance, to maintain existing populations or to recolonize an area after control and propagate rapidly, are important weed characteristics.

Impoundment and regulation have altered the macrophyte community structure in Lake Nasser. In 1963-1964, *A. gramineum, D. alisma* var. *campactum, P. crispus, P. pectinatus, Z. palustris* and *P. perfoliatus* (which was a new record) were noted (Boulos 1967). In 1967, *V. spiralis* was recorded (El-Hadidi 1968). In this study, two nuisance species, *M. spicatum* and *C. demersum* invaded the lake. Species such as *M. spicatum* have only been recorded in south Egypt during the past decade (Fayed 1985).

Clearly, the degree of control and consequent duration, frequency and extent of water level changes are of fundamental importance to the littoral macrophyte communities. The data presented here indicate that, where there is a high degree of control, there are extensive changes to the plant community, whereas at sites where the water level is less regulated, the plant community has remained close to that present before the construction of the dam.

In Lake Nasser, light attenuation had very little influence on the submerged aquatic macrophytes growing in the 0-3 m zone, because of the clear water (Secchi disc 5 m depth, Ali 1987). However, during the flood season, light attenuation may be a more important factor (Secchi disc <0.5 m).

This study had three primary aims: to characterize the features of a regulated lake; to assess the impact of disturbance on the lake; and to determine the influence of other variables on the macrophyte community. The data presented demonstrate that regulation has a strong influence on the lake because of the disturbance it causes. Plants present before regulation may not be able to exploit the new habitat created, giving the opportunity for introduced (and possibly nuisance) species with broad ecological tolerances to invade the area and compete with or displace the native species.

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DISCUSSION

Q. Do you have any values for the macrophyte biomass in Lake Nasser?

A. I do not have any data.

Zooplankton Distribution

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Habib, O.A. 2000. Zooplankton distribution, p. 67-74. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT
Zooplankton standing crop (individuals l^{-1}) was estimated at six stations from El-Ramla 1 in the north to Abu Simbel 6 in the south along the main channel of Lake Nasser, Egypt, from February 1987 to November 1988. The concentration of zooplankters in the water column (0-20 m) was variable throughout the year, ranging from 0.6 individual l^{-1} (in February 1987 at the surface at Abu Simbel) to 346.2 individuals l^{-1} (in August 1988 at 5 m depth at El-Allaqi). Normally values were higher at Kalabsha, El-Allaqi and Korosko than at El-Ramla, Tushka and Abu Simbel even though several high values were recorded at these stations. The zooplankton community was composed, in order of abundance, of copepods, cladocerans and rotifers. The species composition of each group of zooplankton is discussed.

Introduction

A small fraction of the radiant energy incident on a lake is converted by the phytoplankton into chemical energy in the form of organic matter. Some of this energy will then be transferred to the zooplankton, the so-called primary or herbivorous consumers. The animal components of the freshwater plankton are dominated by Copepoda and Cladocera (Wetzel 1975). Rzoska et al. (1955) began a quantitative survey of the annual cycles of plankton production in the Blue and White Nile south of Khartoum. Their work was continued and enlarged in scope by Prowse and Talling (1958) who gave a detailed account of the seasonal growth and succession of planktonic algae in the White Nile from 1951 to 1956.

The results of these studies, together with those of Brook (1954) and Talling (1957), have revealed the presence of two regular systems of yearly plankton growth and decline, the general timing being determined by biological regimes of the river. This paper describes the vertical distribution and seasonal variation of zooplankton species composition.

Methods

During February, May, August and November 1987 and 1988, 10 l water samples were collected from each of six stations, El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel (see El Shahat, this vol., p. 4) at 5 m intervals from the surface to 20 m depth (0, 5, 10, 15 and 20 m) with a van Dorn water sampler. Only three depths (surface, 5 and 10 m) were sampled at Station 3, a shallow water area. Water samples were filtered through a plankton net (0.1 mm mesh). The samples were preserved with formalin (4%) and kept for later analyses. Each sample was then transferred into a beaker and left to settle overnight. In the case of low numbers, all organisms were put in a Sedgwick-Rafter chamber (1 ml) for counting. Samples with high numbers of zooplankter were left to settle again and the exact volume of the sample was measured. The sample was then shaken, 1 ml was removed and the organisms in the subsample counted. The procedure was repeated at least three times, and the average number of individuals per 10 l was estimated.

Results

The vertical distribution of zooplankton as number of individuals 10 l^{-1} over the sampling period is shown in Fig. 1. The upper layer (surface and 5 m depth) normally contained the largest number of zooplankton (Table 1). The minimum zooplankton numbers were normally at 20 m depth. The exceptions were Stations 2, 3 and 6 (Table 1).

Table 1. Maximum and minimum numbers of zooplankton organisms (individuals 10 l^{-1}) counted at Stations 1-6. Depth and date are provided.

Station	Max	Min
1	1 802 (5 m) in Aug 1987	17 (20 m) in Aug 1987
2	1 918 (5 m) in Aug 1988	42 (15 m) in Aug 1987
3	3 462 (5 m) in Aug 1988	102 (zero) in May 1987
4	2 941 (zero) in Aug 1988	82 (20 m) in Aug 1987
5	1 834 (5 m) in Aug 1987	31 (20 m) in Aug 1988
6	2 578 (5 m) in May 1987	6 (zero) in Aug 1987

Seasonal variation in the total number of zooplankton was clearest (showed a similar pattern in 1987 and 1988) at Stations 1 and 4 (Fig. 1 and Table 2). The number was normally small during the winter (February) and increased towards a maximum in the summer (August). At Stations 2 and 3, seasonal variation was not clear. Station 5 showed clear seasonal variation, but the maximum zooplankton number was recorded at different times in the two years. The first peak was in August 1987 while the second peak was in February and May 1988. The seasonal variation of zooplankton number at Station 6 showed a peak in May 1987 and a lesser peak during February and May 1988.

Table 2. Average number of zooplankton organisms (individuals 10 l^{-1}) over all depths (surface to 20 m).

Date	Station					
	1	2	3	4	5	6
Feb 1987	356	870	1 470	437	360	53
May	404	284	379	543	441	917
Aug	778	670	878	1 333	1 038	272
Nov	609	715	1 585	678	303	210
Feb 1988	239	803	880	432	509	550
May	310	473	314	588	437	520
Aug	1 004	1 066	2 844	1 062	182	177
Nov	125	281	313	685	65	108

The zooplankton community was dominated by three main groups: copepods, cladocerans and rotifers. Copepods were

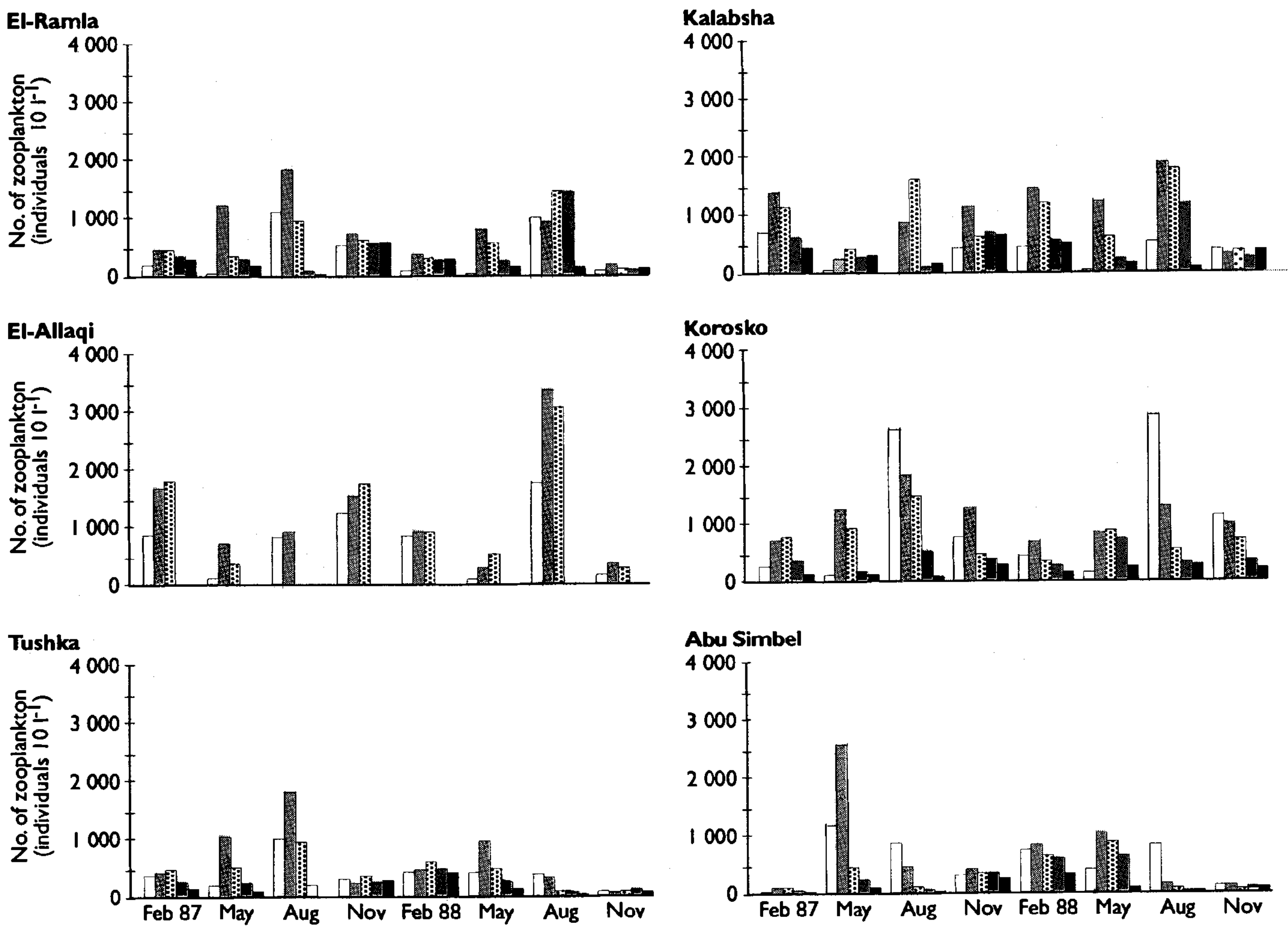

Fig. 1. Seasonal variation (August 1987-November 1988) in the number of zooplankton (individuals 10 l^{-1}) at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel (see El Shahat, this vol., p. 4). Samples were taken at the surface (□), 5 m (□), 10 m (□), 15 m (■) and 20 m (■) depth. Note that only 3 depths were measured at El-Allaqi (a shallow water station).

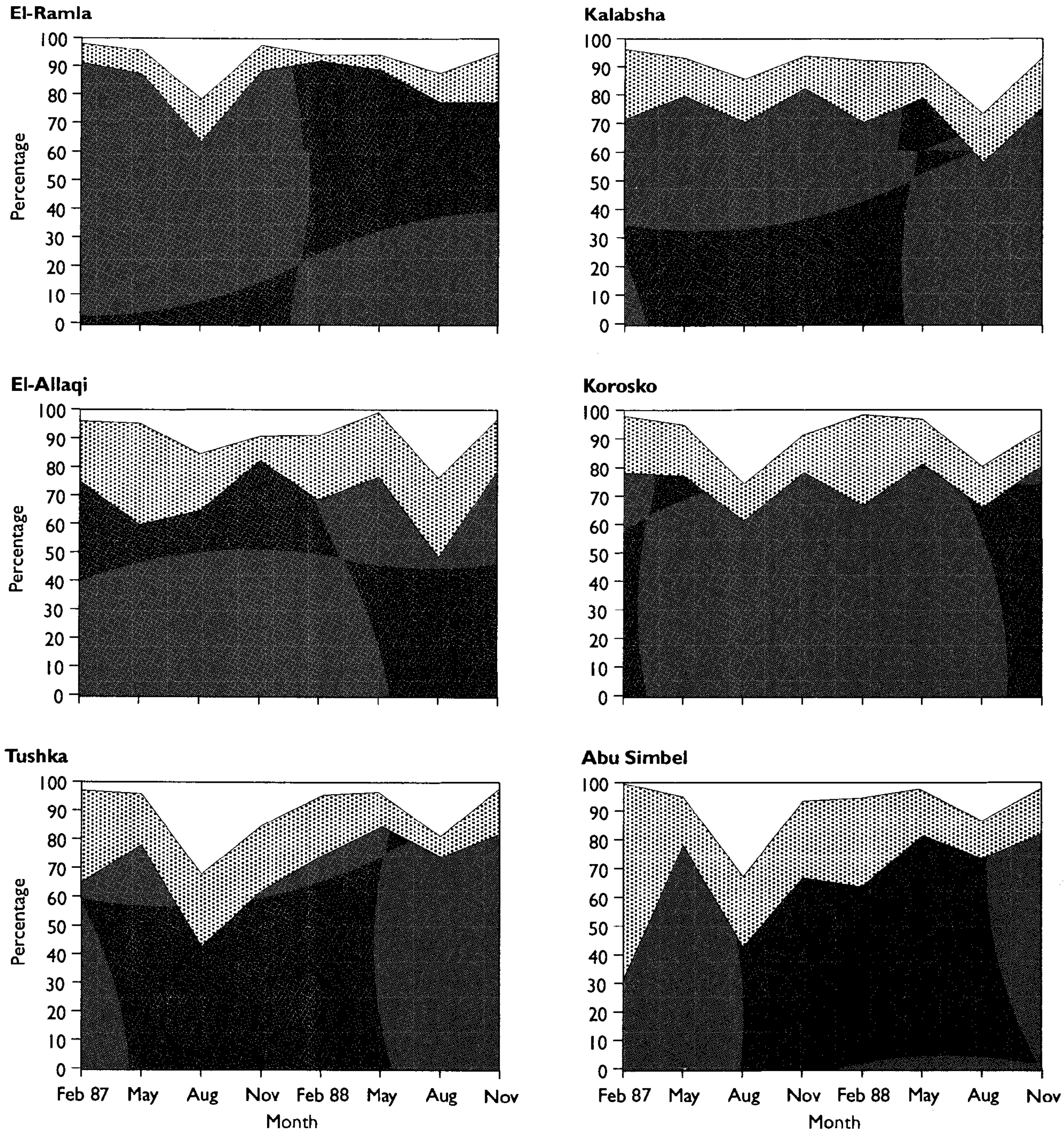

Fig. 2. Seasonal variation (August 1987-November 1988) in the percentage contribution of copepods, cladocerans and rotifers in the zooplankton at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel. Copepods (■), cladocerans(▒), rotifers (□).

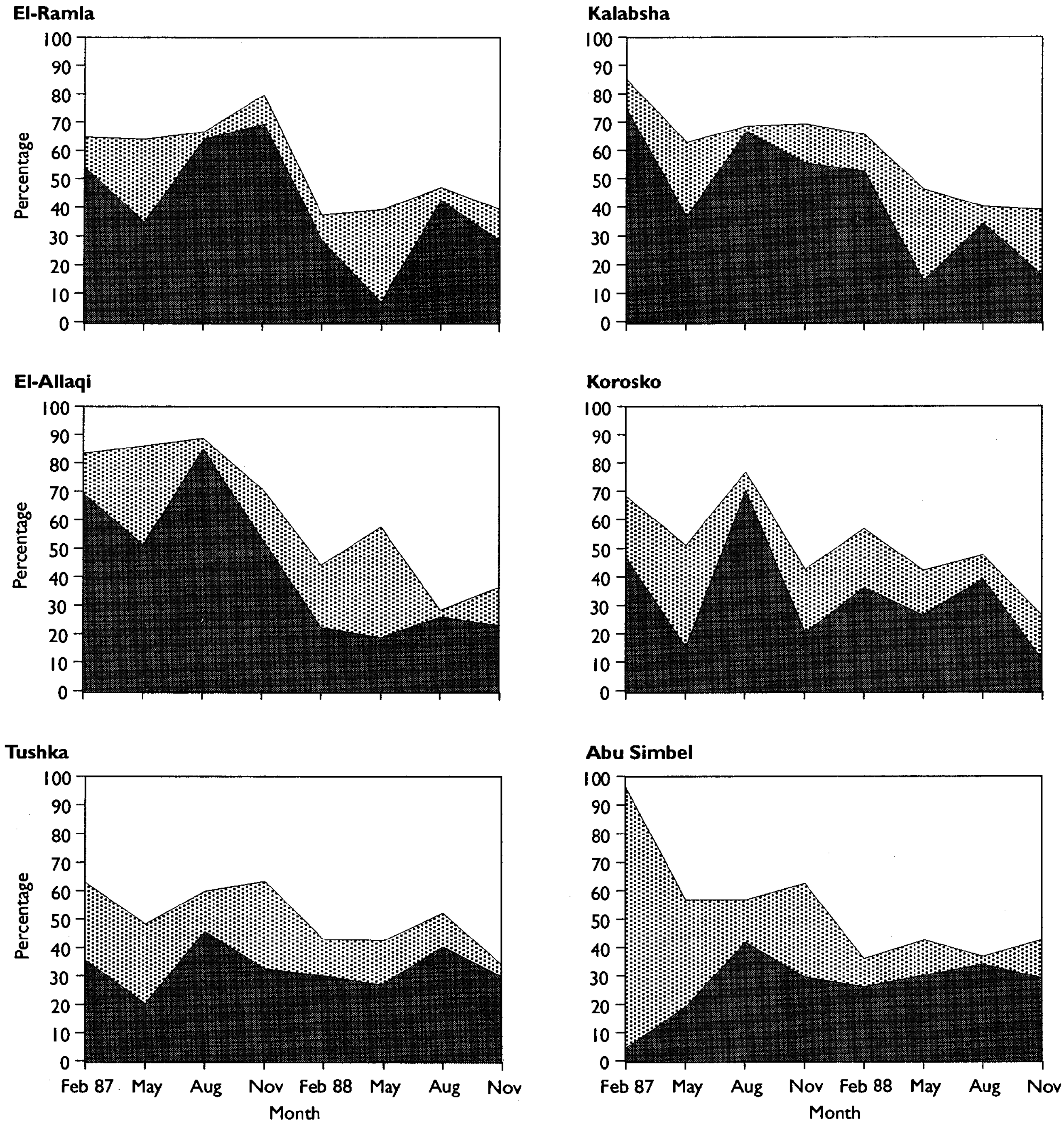

Fig. 3. Seasonal variation (August 1987-November 1988) in the percentage contribution of *Cyclops*, *Diaptomus* and nauplii in the copepod community at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel. *Cyclops* (■), *Diaptomus* (▨), Nauplii (□).

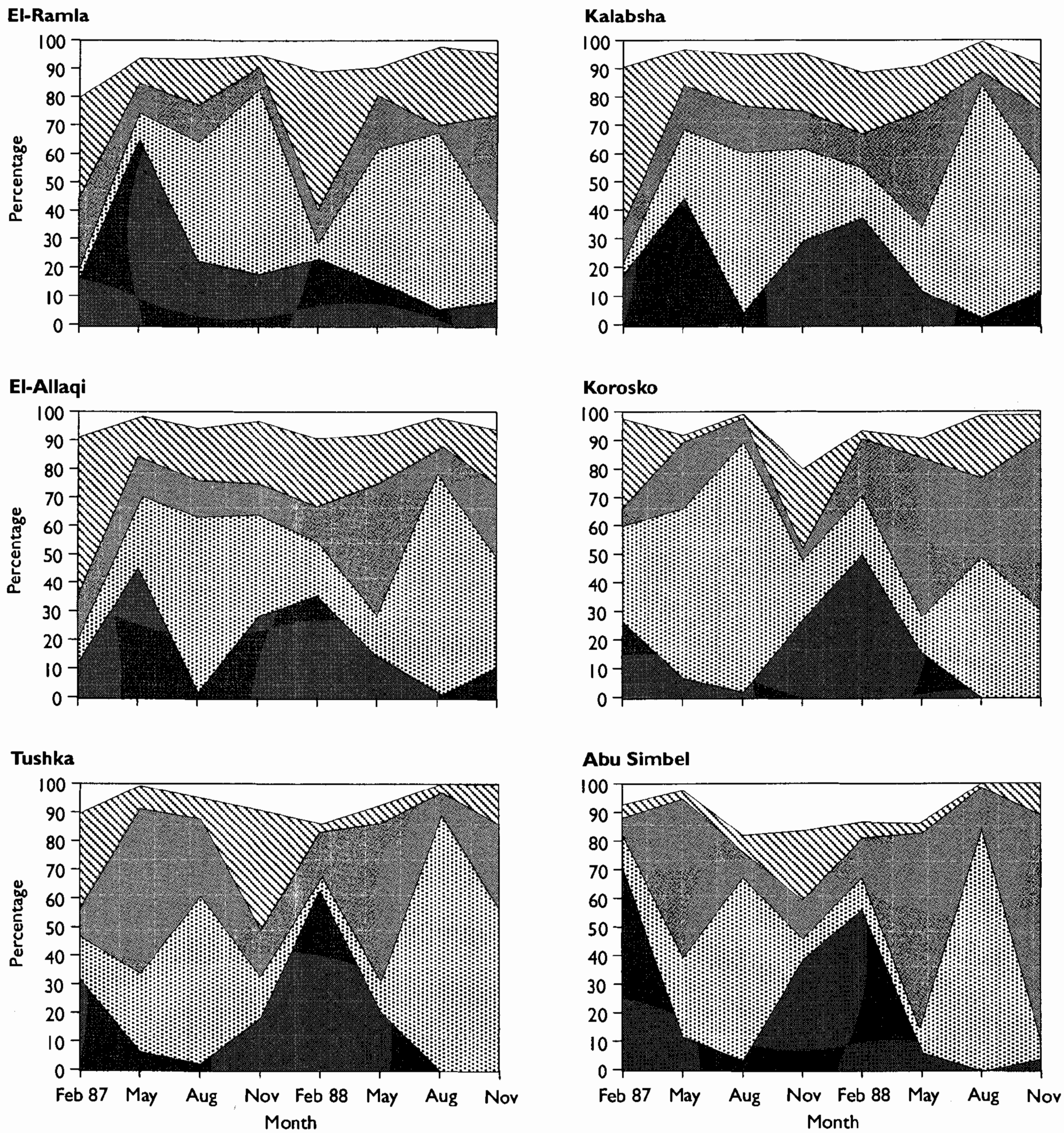

Fig. 4. Seasonal variation (August 1987-November 1988) in the percentage contribution of *Daphnia*, *Diaphanosoma*, *Ceriodaphnia*, *Bosmina* and others in the cladoceran community at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel. *Daphnia* (■), *Diaphanosoma* (⬚), *Ceriodaphnia* (▩), *Bosmina* (▧), others (□).

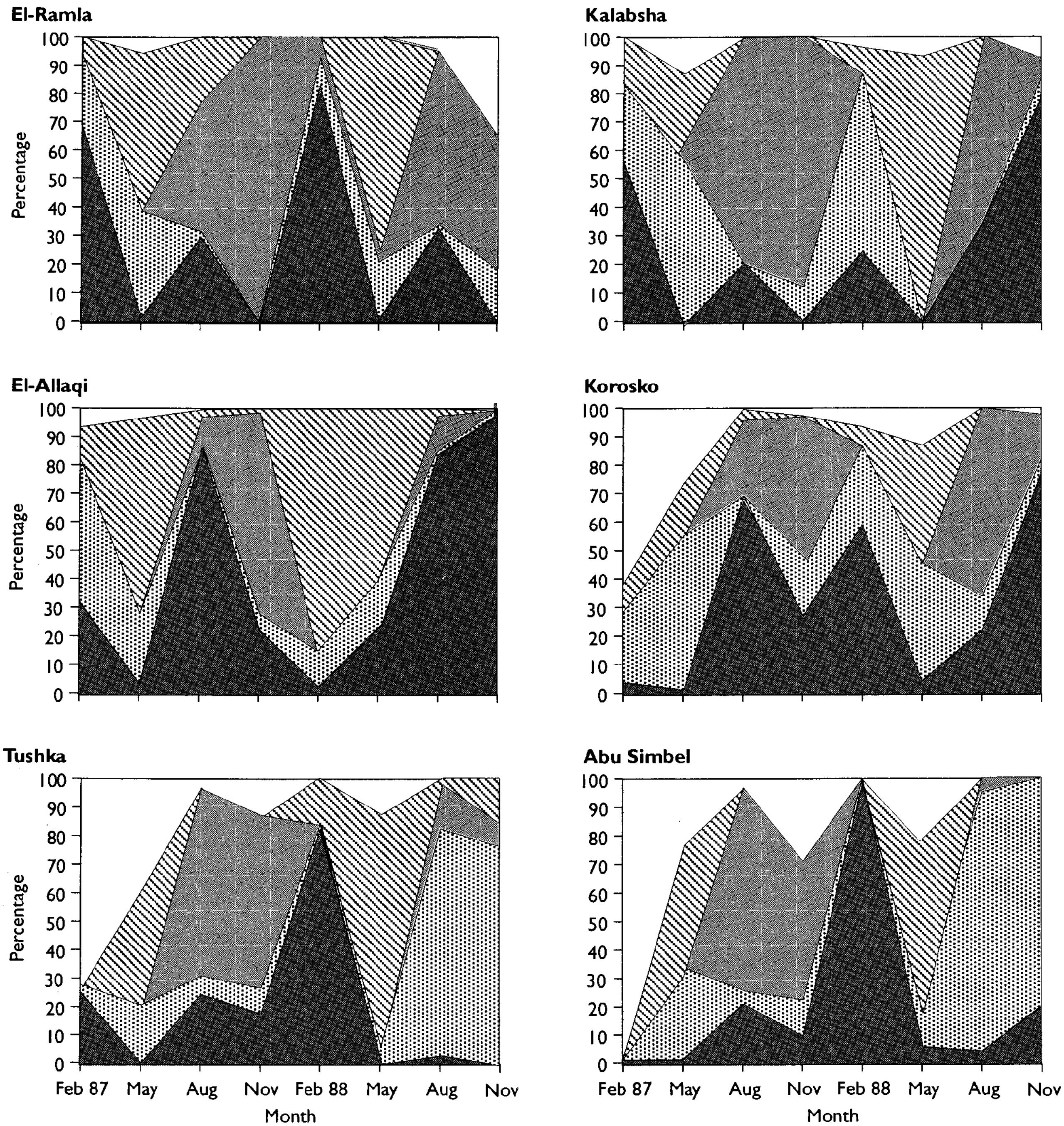

Fig. 5. Seasonal variation (August 1987-November 1988) in the percentage contribution of *Brachionus, Keratella, Playtias, Asplanchna* and others in the rotifer community at El-Ramla, Kalabsha, El-Allaqi, Korosko, Tushka and Abu Simbel. *Brachionus* (■), *Keratella* (▒), *Platias* (▩), *Asplancha* (▧), others (□).

commonest at all stations (Fig. 2). Cladocerans were the second most abundant group. Only on one occasion did cladocerans dominate the community (February 1987 at Station 6). Rotifers were the least important group showing two peaks in August 1987 and 1988.

In general, *Cyclops* dominated the copepod community in 1987 (Fig. 3). *Diaptomus* were at a maximum in May 1988 at stations 1-3. Station 4 recorded a peak of *Diaptomus* in May 1987 and station 5 in November 1987. In February 1987, *Diaptomus* dominated at Station 6. At Stations 1, 2, 4 and 5, the maximum number of nauplii was recorded in November 1988. At Stations 3 and 6, the maximum was recorded in February and August 1988.

Seasonal variations in the species composition of cladocerans at Stations 1-6 are shown in Fig. 4. One or two peaks of *Daphnia* abundance were observed in May 1987 at Stations 1-3 and in February 1987 at Stations 4-6 and in February 1988 for all stations. The community was dominated by *Diaphanosoma* in August 1987 and in August 1988. *Ceriodaphnia* showed moderate percentages during 1987 at stations 1-3. At Stations 4-6, *Ceriodaphnia* showed two peaks in May 1987 and in May 1988. *Bosmina* was more abundant at Stations 1-3 than Stations 4-6. It persisted throughout the study.

Seasonal variation in the species composition of rotifers at Stations 1-6 are shown in Fig. 5. Two to four peaks of *Brachionus* were noticed in February and August 1987 and 1988. *Keratella* showed a moderate percentage at Stations 1-4. At Stations 5 and 6, *Keratella* dominated the community in August and November 1988. *Playtias* dominated the community in August and November 1987 at Stations 1, 2, 5 and 6. At Station 3, it dominated the community in November 1987 only. In the case of Station 4, *Playtias* showed a moderate percentage in November 1987 but dominated the community in August 1988. *Asplanchna* showed one or two peaks in May 1987 and 1988 and predominated the community in May 1988. It was predominant in the community in May 1988 at Stations 1-3 and 5.

Conclusions

In 1988, the zooplankton numbers showed a noticeable decrease at Stations 5 and 6; remarkable to moderate increases at Stations 2-4 and a slight decrease at Station 1. Several factors could affect the decline of zooplankton numbers at Stations 5 and 6, one being transparency, which was very low (Secchi disc depth was 0.4-0.7m) especially during August and November due to the floodwater. The low transparency could also adversely affect the phytoplankton community. At Stations 2-4, the transparency was low because of phytoplankton abundance (high chlorophyll *a* concentration). It was noticed that the maximum numbers of rotifers coincided with the highest water temperature. The correlation coefficients between rotifers and water temperature and transparency were positive ($p<0.001$) and negative ($p<0.001$), respectively.

Monakov (1969) recorded the density of zooplankton in the floodplain of the White Nile (Aljab, Shambe, Jor, No and Atar) in 1964, which ranged from 180 organisms m^{-3} in Aljab to 59 000 organisms m^{-3} in Atar. Abu Gideiri (1969) found very few zooplankton in the Morgran areas (White Nile) during the flood season (July-September) but after the subsidence of the flood waters, a rapid increase in zooplankton occurred and a maximum was reached in November-February. He also recorded a small number of zooplankton in April-July at Shagara and Jebel Aulia (White Nile) and the increase began in August to reach a maximum in September to early October. Masundire (1989) recorded a wide range of values of total adult crustacean plankton abundance from as low as 4 individuals l^{-1} to more than 30 individuals l^{-1} in Lake Kariba, Zimbabwe. He found two peaks in abundance, one in March and the other in July-August. He attributed the March peak to a nutrient flux resulting from the local rainy season, and the second peak (July-August) coincided with the period following the lake's turnover and mixing. Abu Gideiri's (1969) results are more likely to resemble the Lake Nasser data with the minimum during the flood season and the maximum in August-October. Moreover, Entz (1976) stated that zooplankton was poorest usually in the first wave of the floodwaters. The richest zooplankton development could be noticed always just in front of the flood in areas not yet affected by the floodwater.

Zooplankton data in this investigation are similar to those of Entz (1976). The August peak was greatest at Stations 1-4 and smallest at Stations 5-6. The latter stations are affected by floodwater before the other stations. The maximum numbers of zooplankton were recorded mainly in the upper 10 m of the water column and correlated with chlorophyll *a* concentration. Habib et al.(1987) and Habib and Aruga (1988) stated that the upper layer of water column from the surface to 8-10 m generally contained high chlorophyll *a* concentrations from March or April to October or November.

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Macrobenthic Fauna

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Fishar, M.R.A. 2000. Macrobenthic fauna, p. 75-79. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

A quantitative estimation of the macrobenthos in Lake Nasser was carried out during the winter of 1997-1998. Nine stations along the main channel of the lake and five main khors were selected. The macrobenthic community of the lake consisted of five groups (oligochaetes, crustaceans, insects, gastropods and bivalves). The annelids were the most dominant benthic phylum in the main channel, constituting 90.2 and 88.4% of the total benthic number and mass, respectively, followed by molluscs and arthropods. The highest standing crop was recorded in the southern localities (Tushka and Abu Simbel), while the lowest was recorded in the northern part of the lake. The khors, El-Ramla and Tushka, had the most productive benthic fauna while Korosko had the poorest. The formation of macrozoobenthos communities in the lake can be divided into three phases: (1) filling phase which covered the early years of impoundment, from 1966 to 1978, and was characterized by mass development of chironomids and oligochaetes, which were able to utilize organic matter at great depth and live under anaerobic conditions; (2) post-filling phase, which covered the next 10 years and was characterized by an increasing number of individuals and diversity of species, owing to the establishment of favorable conditions for zoobenthos to flourish (a pronounced decrease in standing crop, attributed to the African drought, was noted at the end of this period); and (3) equilibrium phase from about 1990 until the present, which was characterized by a remarkable increase of diversity and fluctuation within a definite range of individuals.

Introduction

The composition and biomass of the benthic macroinvertebrate community have long been considered to be good indicators of water quality and lake productivity. The aim of the present work was to study the benthic community structure, distribution and changes in abundance from the formation of Lake Nasser until the present.

Materials and methods

Quantitative sampling of the bottom fauna was performed in the winter of 1997-1998 at nine stations along the main channel of Lake Nasser, namely, Aswan High Dam, El-Ramla, Kalabsha, El-Allaqi, El-Madiq, Korosko, Amada, Tushka and Abu Simbel. Sampling was also carried out in five khors, El-Ramla, Kalabsha, El-Allaqi, Korosko and Tushka (see El Shahat, this vol., p.4). An Ekman grab (opening area 400 cm^2) was used. The collected samples were washed in the field through a small hand-net of 500 µm mesh diameter. The samples were stored in plastic jars after adding 7% formalin solution. Sorting and identification of the species were carried out, if possible, in the laboratory. The different groups were counted and weighed after drying on filter papers for five minutes to remove excess water. Results are given as total numbers of bottom fauna per square meter as well as their biomass in grams fresh mass per square meter (G.F.W. m^{-2}).

Results

Community composition

The community composition of macrobenthos in Lake Nasser in the winter of 1997-1998 is represented by oligochaetes, insects, crustaceans, bivalves and gastropods. In the main channel, oligochaetes were the most dominant of the benthic groups, constituting 90.2% and 88.0% of the total benthic number and mass, respectively, followed by molluscs 5.0% and 8.6% and arthropods 4.8% and 2.9% (Fig. 1). In the khors, the percentage composition of different groups varied. Oligochaetes were the most abundant in El-Ramla, Kalabsha and Korosko but with lower percentage values than in the main channel. Arthropods were most abundant in El-Allaqi and Tushka. However, molluscs were fewer in their numerical abundance, but their biomass percentages were higher than other groups (Fig. 2). The dominance of oligochaetes in most sampling sites in the main channel and khors is possibly due to their ability to adapt to many kinds of habitat and their tolerance to low oxygen concentrations or anoxic conditions (Brinkhurst 1970).

Distribution

In the main channel, the distribution of bottom fauna varied widely from one region to another. The lowest population density and biomass were observed in northern localities (Aswan High Dam and Kalabsha), while the highest values were recorded in the southern ones (Tushka and Abu Simbel). The middle stations were relatively similar (Fig. 3). The decline in standing crop of benthos in the north was attributed to the increasing depth of the water and the reduction in dissolved oxygen (Fishar 1995).

Oligochaetes were most abundant at Tushka and Abu Simbel, while the lowest standing crop was recorded at Kalabsha. They were represented by four species, *Limnodrillus udekemianus*, *L. hoffmeisteri*, *Pristina* sp. and *Branchiora sowerbyi*. The first and second species were recorded at all stations, while *Pristina* sp. was found in the middle and northern parts of the lake. *B. sowerbyi* was recorded only in the northern part of the lake.

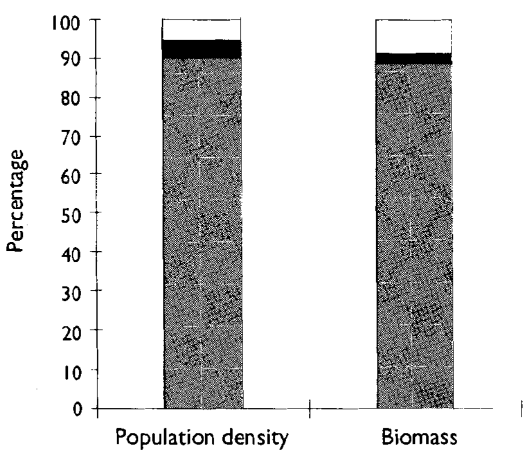

Fig. 1. Percentage number and mass of benthic groups in the main channel. Molluscs (□), arthropods (■), annelids (▩).

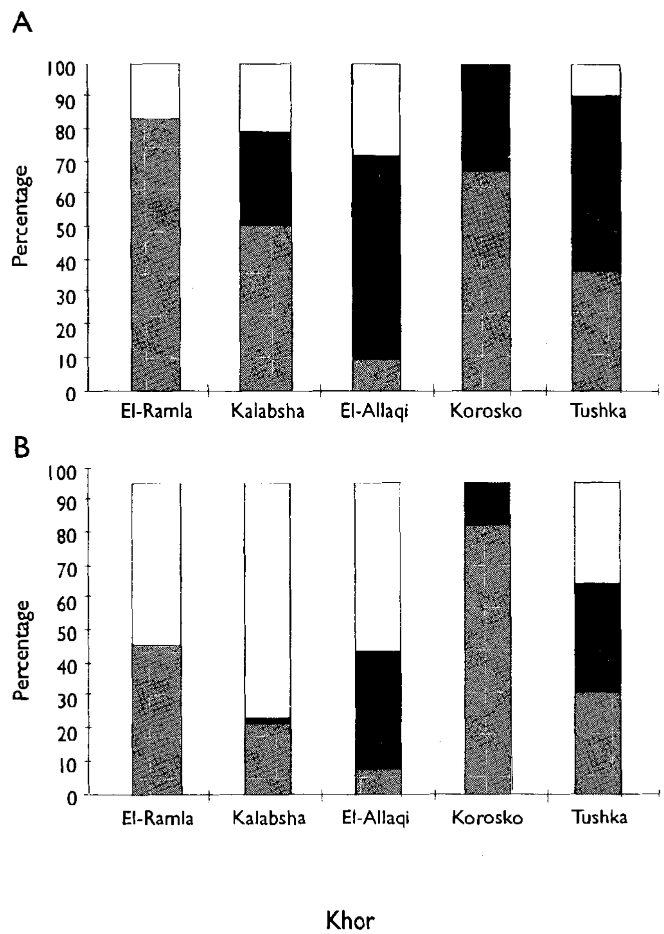

Fig. 2. Percentage composition (A) number and (B) mass of benthic groups in five khors. Molluscs (□), arthropods (■), annelids (▩).

Arthropods showed irregular distribution along the main channel of the lake. They were represented by three main groups, ostracods, chironomids and tricopterans. Chironomid larvae and pupae were recorded at most stations of the main channel, while the ostracod species were recorded in the southern stations (Amada and Abu Simbel). The tricopteran species appeared only at Kalabsha.

Only one species of mollusc was identified, *Valvata nilotica*, which was found in the middle stations (El-Madiq and Korosko).

The benthic community in the khors was more rich and diversified than in the main channel. This was mainly due to the shallower water, lack of current and the presence of macrophytes which offered a favourable habitat by providing protection from predators, food and a good substratum for these organisms. In the khors, as shown in Fig. 4, El-Ramla was the most productive followed by Tushka and

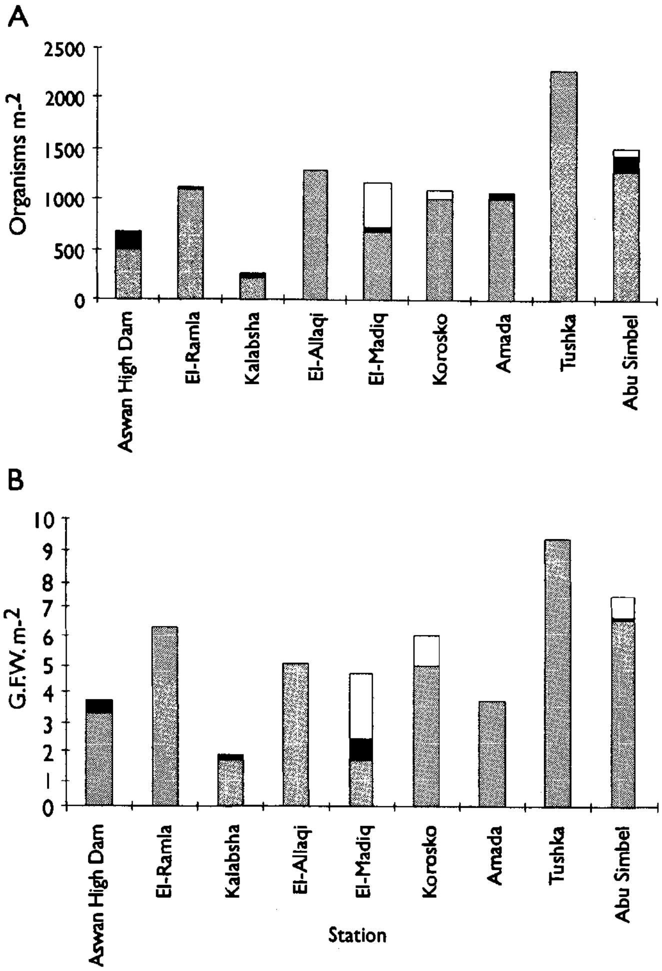

Fig. 3. (A) Population density (organisms m^{-2}) and(B) biomass (G.F.W. m^{-2}) in the main channel. Molluscs (□), arthropods (■), annelids (▩).

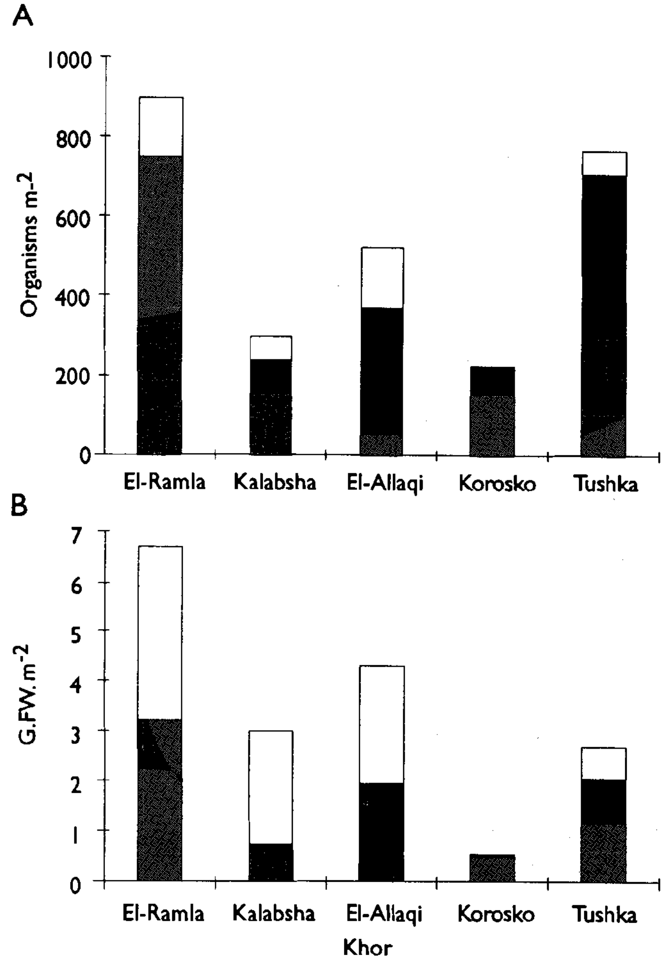

Fig. 4. (A) Population density (organisms m^{-2}) and (B) biomass (G.F.W. m^{-2}) in the major khors. Molluscs (□), arthropods (■), annelids (▩).

El-Allaqi. The lowest population density and biomass was observed at Korosko.

Oligochaetes counted in khors were highest at El-Ramla while the lowest number was recorded at Korosko. They were represented by the same four species as the main channel. *L. udekemianus* was found at all khors while *B. sowerbyi* was observed at Kalabsha and Tushka.

Arthropods were characterized by an increase in number of individuals and species in khors compared with the main channel. Tushka was the most productive followed by El-Allaqi. They were represented by ostracods and insects (larvae of *Chironomus* spp., *Caenis* sp. and *Micronecta* sp., and nymph of both *Enallagma* sp. and *Perithemis* sp.).

The distribution of molluscs showed that the highest standing crop was recorded in the northern khors (El-Ramla, Kalabsha and El-Allaqi). Molluscs were not found at Korosko. Six species were recorded in the khors, *V. nilotica*, *Bulinus truncatus*, *Physa acuta*, *Melanoides tuberculata*, *Gyralus ehrenbergi* and *Ferrissia clessiniana*.

Conclusions

The standing crop of the total macrobenthic invertebrates in Lake Nasser averaged 1 169 organisms m^{-2}, 5.488 G.F.W. m^{-2}. This average standing crop was lower than the corresponding values in some Egyptian saline lakes, Qarun and Bardawil (Aboul-Ezz 1988; Fishar 1992), and higher than that recorded in Wadi El-Rayan lakes (Fishar 1998).

The average total bottom fauna in the lake changed annually. As shown in Fig. 5, the lowest standing crop of benthos was recorded at the beginning of the impoundment of the lake (Latif et al. 1979), and increased gradually with the rise in water level. The standing crop dropped sharply to a

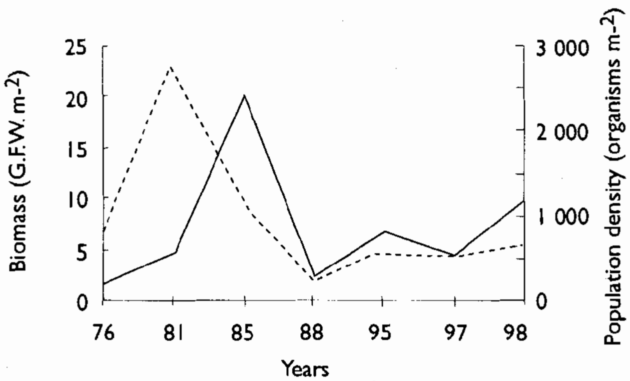

Fig. 5. Population density (organism^{-2}) and biomass (G.F.W. m^{-2}) of benthos in the main channel, 1976-1998.

minimum during 1988, and increased again during the following years. This was due to the drop in the lake level resulting from the major African drought (lasting until 1988) which caused a partial drought in some zones and major changes in ecological conditions.

According to the classification of MacLachlan (1974) for human-made lakes in Africa, three stages can be differentiated in the formation of zoobenthos in Lake Nasser (Table 1). The first stage (filling phase) covered the early years of impoundment (1966-1978) and was characterized by a mass development of chironomids and oligochaetes (*Tubifex* sp.) which were able to utilize organic matter at great depth and live under anoxic conditions. Some workers (Entz 1978; Latif 1984) found the freshwater crab, *Potamonatus niloticus*, prawn, *Caradina nilotica*, and some snails (including *B. truncatus*) in the littoral zone. It should be noted that these species were endemic riverine species and most of them died at the end of this stage. The second stage (post-filling phase) covered the next 10 years, 1979-1989, and was characterized by an increase in the standing crop as well as in species

Table 1. Benthic invertebrates recorded in Lake Nasser by different authors.

	First phase					Second phase		Third phase		
Species	Entz and Latif 1974	Entz 1976	Entz 1978	Entz 1980	Latif 1984	Elewa 1987	Iskaros 1988	Fishar 1995	Fishar 1997	Fishar 1998
Annelida										
Limnodrillus udekemianus						+	+	+	+	+
Limnodrillus hoffmeisteri						+	+	+	+	+
Tubifex sp.		+								
Branchiora sowerbyi						+	+	+	+	+
Pristina sp.								+	+	+
Helobdella conifera							+	+		
Alma sp.			+							
Arthropoda										
Ostracods								+		+
Caradina nilotica			+		+			+	+	+
Potamonatus niloticus					+					
Chironomus larvae	+	+	+	+	+	+	+	+	+	+
Nymph of Odonata							+	+	+	+
Nymph of Anisoptera								+	+	
Nymph of Ephemeroptera								+	+	
Nymph of Tricoptera						+		+		+
Nymph of Hemiptera				+	+			+	+	
Nymph of Coleoptera								+		
Mollusca										
Valvata nilotica						+	+	+	+	+
Melanoids tuberculata						+	+	+	+	+
Bulinus truncatus						+	+	+	+	+
Physa acuta						+	+	+	+	+
Cleopatra bulimoides						+	+	+	+	+
Gyralus ehrenbergi								+	+	
Pisidium pirothi								+	+	+
Spharium simile								+	+	
Ferrissia classiniana										+
Corbicula flaminalis	+				+	+	+			
Hydrozoa										
Hydra vulgaris								+		

diversity owing to an increase in organic matter, dissolved oxygen and surface area of the lake which provided a substratum of mud, trees and rocks. The standing stock of benthic animals was reduced at the end of this stage due to a decrease in water level resulting from the African drought (Elewa 1987; Iskaros 1988). The third stage (equilibrium phase) from about 1990 until the present has been characterized by an increasing diversity of species and fluctuations in the range of individuals. The indications are that the community of benthos in Lake Nasser is beginning to stabilize.

It can be concluded from the present study that Lake Nasser is a fertile lake. More detailed investigations, especially on meio- and microbenthos, are needed to follow up the changes in the benthic community which contribute to the development of the fisheries.

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DISCUSSION

Q. Do you have the information to calculate the biomass of the macrobenthos?

A. Yes, the information is available.

Fish-eating Birds

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Tharwat, M.E. 2000. Fish-eating birds, p. 81. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Open-water areas and large concentrations of fish are natural attractants to fish-eating birds. In addition to predation, the birds damage fish that escape, disturb brood stock and contribute to the spread of disease and parasites.

The number of bird species and subspecies that occur in Egypt are 123 and 392 respectively, of which 186 are resident, 12 are extinct and 17 are endemic (Tharwat 1997). The rest are migratory birds, which visit Egypt in summer from the south or in the winter from the north. Some visit Egypt twice a year, in the spring on their way south or in the autumn when travelling north to Europe and Asia. Forty-one species and subspecies are known to inhabit the Lake Nasser area. Twenty of these are fish-eating birds, namely: the great cormorant, *Phalacrocorax carbo sinensis* (Blumenbach); the African darter, *Anhinga rufa rufa* (Lacepede and Daudin); the white pelican, *Plecanus onocrotalus* L.; the pink-backed pelican, *P. rufescens* Gmelin; the bittern, *Botaurus stellaris stellaris* (L.); the little egret, *Ardea garzetta* L.; the Goliath heron, *A. goliath* Cretzschma; the purple heron, *A. purpurea* L.; the yellow-billed stork, *Mycteria ibis* (L.); the ruddy shelduck, *Tadorna ferruginea* (Pallas); the garganey, *Anas querquedula* (L.); the pochard, *Athya ferina* (L.); the black kite, *Milvus migrans migrans* (Boddaert); the African fish eagle, *Haliaetus vocifer* (Daudin); the moorhen, *Gallinula chloropus chloropus* (L.); the eagle owl, *Bubo bubo ascalaphus* Savigny; the common kingfisher, *Alcedo althis althis* (L.); the osprey, *Pandion haliaetus haliaetus* (L.); the common black-headed gull, *Larus ridibundus* L.; and the scissor-billed tern or African skimmer, *Rynchops flavirostris* Vieillot.

Open-water areas and concentrations of fish are natural attractants to fish-eating birds. As well as consuming fish, the birds damage fish that escape, disturb brood stock and contribute to the spread of disease and parasites. Large concentrations of shore birds can cause pollution problems. Those causing most damage are gulls, egrets, cormorants, pelicans, ospreys, terns, kingfishers, ducks and herons.

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DISCUSSION

Q. What is the daily consumption of fish by the birds in the lake?

A. I do not have these data. There are some estimates from a lake in Zimbabwe, which indicated that birds could consume up to 2% of the total commercial catch.

Age and Growth of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art.

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Adam, H.A. 2000. Age and growth of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art., p. 83-84. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Scales were used to age and estimate the growth of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art. The average standard lengths of *O. niloticus* for the successive age groups I to IV years were 241, 300, 354 and 392 mm, respectively. For *S. galilaeus*, the average standard length for the successive age groups I to III years were 224, 250 and 275 mm, respectively.

Introduction

Oreochromis niloticus L. and *Sarotherodon galilaeus* Art. are the most common species in Lake Nasser capture fishery. This study investigated the age and growth of the two species. Age and growth are parameters used in fisheries science and management.

The scales of *O. niloticus* and *S. galilaeus*, used to age the fishes, are typically cycloid and fan-shaped. Concentric ridges or circuli are arranged around the focus, which may be central or slightly off center towards the posterior. Radial grooves extend from the focus to the anterior edge of the scale. The size of the scales varies from one location to another on the fish (Azim 1974). Different terms have been applied to the spaced circuli. In the present study, following Arora (1951), the boundary between the winter and the succeeding summer band is considered as a year mark. The use of the scale method for age and growth studies of species of tilapia has been validated by others (Halden 1955; Jensen 1958; El Bolock and Koura 1960, 1961; Elester and Jensen 1960; El Zarka 1961; Azim 1974) but not in this study.

Materials and methods

Random samples of *O. niloticus* and *S. galilaeus* were collected monthly from January 1989 to December 1990. For each individual fish, the date and locality caught were recorded and the standard length was measured to the nearest millimeter using a measuring board. Scales from each fish were collected from the left side below the lateral line behind the pectoral fin, and stored in envelopes. The location from which the scales were taken was consistent throughout. This consistency was shown by Joris (1957) and El-Zarka (1959) to be a necessary precaution to avoid discrepancies that might arise during growth calculations. Before reading, the scales were cleaned with 10% ammonium hydroxide solution, washed with distilled water, and mounted dry between two glass slides bound with tape. They were examined with the help of a scale projector.

Results and conclusions

The average standard lengths of *O. niloticus* for successive age groups I to IV years were 241, 300, 354 and 392 mm, respectively. The growth increment in length was greatest in the first year and markedly decreased with age. For *S. galilaeus*, the average standard lengths for the successive age groups I to III years were 224, 250 and 275, mm respectively. As with *O. niloticus*, the growth increment was greatest in the first year and decreased with age.

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DISCUSSION

Q. Do you have total mortality rates (Z) for Nile tilapia?

A. I have them as well as fishing mortality rates.

Q. Do you have gonadosomatic values for the major species?

A. None.

A Note on the Relationship between Catch and Water Level

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Agaypi, M.Z. 2000. A note on the relationship between catch and water level, p. 85-86. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The main commercial fish of Lake Nasser is the Nile tilapia, *Oreochromis niloticus* L., accounting for more than 90% of the total catch. Water level changes affect both the biology of tilapia and the fisheries. During the spawning season, tilapia reproduction is influenced by the water level and as tilapia are caught in the shallow, littoral areas, the change of water level affects the size of the fishing area. The average annual water level (m above mean sea level [AMSL]) and ln (catch per unit effort [CPUE] two years later) were the best fit to the data, where CPUE is the total annual catch (t) divided by the number of boats operating in the year.

Introduction and analysis

Agaypi (1995) and Yamaguchi et al. (1996) discuss the relationship between catch and water level for Lake Nasser. Data on water levels have been recorded from 1966 to the present (1997 in this study) (see El Shahat, this vol.). The number of boats and total annual landings (mt) through the same period have also been collected. Agaypi (1993a,b) gave catch data by species and month from 1983 to 1992. Other data are available from the author.

An analysis was undertaken to find the best relationship between water level (maximum, average and minimum, m AMSL) and CPUE defined as the total annual catch divided by the number of boats operating in the year. The highest correlation ($r = 0.782$, $p<0.001$) was found between average water level (m AMSL) and ln (CPUE two years later) (Fig. 1).

Tilapia species, in particular *O. niloticus* L., are the most dominant fishes inhabiting shallow water areas <10 m. The greatest proportion (>90%) of the catch is composed of this species (see Khalifa, this vol.). When the water level rises, the shallow water areas increase. This provides more spawning area but greater fishing pressure. High water level in a given year appears to assist recruitment to the fishery two years later. More precise data such as catch and effort by gear type and area and the quantity of fish caught but not accounted for (poached) will be required for a more detailed analysis of the relationship between water level and recruitment.

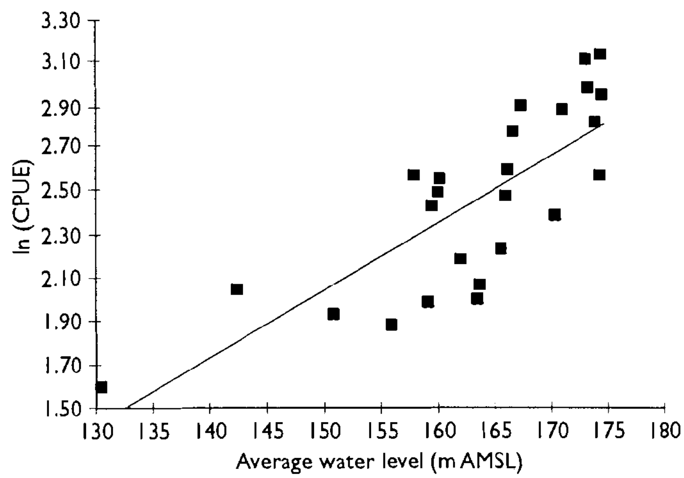

Fig. 1. Relationship between ln (CPUE two years later) and average water level (AWL, m AMSL) where ln (CPUE) = 0.0310 AWL-2.6157.

Acknowledgements

The author is grateful to J.F. Craig for the statistical analysis.

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DISCUSSION

Q. What is 'underground' fishing?

A. Poaching or illegal fishing.

Q. Can scientists check on the effects of poaching?

A. This is impossible.

Q. Has the fish catch been plotted against fishing area?

A. No.

Q. For how long has stocking of tilapia fry been carried out?

A. From 1990 to 1997.

Population Dynamics of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art.

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Khalifa, U.S.A., M.Z. Agaypi and H.A. Adam. 2000. Population dynamics of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art., p. 87-90. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

A sampling program for collecting the basic information needed for long-term management of sustainable catches in Lake Nasser was established in 1996-1997. The results indicated that tilapias composed about 90% of the total lake fisheries production. For the first time, the occurrence of both *Tilapia zillii* and *Oreochromis aureus* was recorded. The former contributed about 2% to the total catch. In terms of relative abundance, it was found that fishes were more abundant in the southern sectors than in the northern ones. Length composition data for *O. niloticus* L. and *Sarotherodon galilaeus* Art have been analyzed to make a preliminary and rapid assessment of their stocks under present conditions. Parameters of the von Bertalanffy growth function have been calculated as follows: L_∞ 54.73 and 37.80 (cm), K= 0.270 and 0.294, and t_0 = -0.745 and -1.187 for *O. niloticus* and *S. galilaeus*, respectively. Instantaneous mortality rates (fishing and natural) were determined. The results indicated that the stocks of both *O. niloticus* and *S. galilaeus* have been overexploited, where E (the exploitation rate) was about 0.8 for the two species. The long-term effects of reducing fishing mortality by 10% would increase the catch of *O. niloticus* by about 65% and that of *S. galilaeus* by 7%.

Introduction

About 5 000 fishers belonging to five cooperatives operate the Lake Nasser fishery. About 2 000 fishing boats are used. Only a few boats, those operating floating gill nets in the open water, have outboard engines. The fishers presently operate in village and family groups at about 970 bases located in at least 79 separate fishing areas. The area boundaries are more or less fixed, with respect to shoreline features. The effects of the fluctuating water level on the boundaries are the source of some conflict among fisher groups.

Three main kinds of fishing gear are used. These are the sinking gill net (kobak), the floating gill net (sakorata) and the trammel net (duk). Longlines (sharak) and cast nets (toraha) are used less frequently. Sinking gill nets and trammel nets are used along the shore at depths of up to 10-15 m. The former are usually operated overnight. When the weather and water conditions are favorable, sinking gill nets are used in the open waters of the khors and to some extent in the main channel. The predominant fish caught in gill nets are *Alestes* spp. and *Hydrocynus* spp.. The catch is usually gutted, salted and preserved in tins. Fish species caught in trammel nets are *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Lates niloticus*, *Bagrus bayad*, *B. docmac*, *Mormyrus* spp., *Synodontis* spp. and *Barbus* spp. Tilapias and Nile perch form the major bulk of the trammel net catch. The fish are stored on ice.

The catch is collected by carrier boat. There are about 100 carrier boats each collecting fish from an assigned area. All of the collected fish, fresh and salted, are landed at the Aswan Fishing Harbour. The landings are sorted. In the case of fresh fish, tilapias and Nile perch are recorded separately (as bolti and samoos, respectively) because they are not difficult to identify, large quantities are landed, and they have a relatively high market value. Minor species, of about the same market value, tend to be combined under one common name. Accordingly, the nominal catch statistics do not give an accurate figure of the composition of the landings.

It is desirable to distinguish between "catch" and "landings" because a sizeable quantity of fish caught is not landed or not reported as landings. The difference between the catch and the landings is due to consumption by the fishers, poaching and discards due to spoilage, or being under the minimum legal size. Thus, records at the harbor will only provide data on the quantity landed (about 50% of the catch).

Management information, needed for the long-term maintenance of sustainable catch, include:

- biological data (especially life history data, relating to fecundity and age of reproduction);
- changes in the population biomass; and
- major changes in abundance.

Biological information requires continuous extensive sampling and aging of the catch. Biomass and abundance (numbers) estimations depend on catch and effort data. In Lake Nasser, these data are unreliable and very poor.

A cooperative sampling program between the National Institute of Oceanography and Fisheries and the Fishery Management Center has been established to study the lake fishery and stock assessment. The program is intended to collect basic information required for the long-term maintenance of sustainable catch in the lake. The present work summarizes the important results obtained so far and introduces a preliminary and rapid assessment of *O. niloticus* and *S. galilaeus* stocks in the lake.

Materials and methods

Catch data and catch composition and effort in the major khors of Lake Nasser were collected from 1996 to 1997. The sampling was done from fishing boats, i.e., prior to delivery to the carrier boats.

The lake was divided into four sectors: (a) khors El-Ramla, Dahmit and Kalabsha; (b) khors Abesco, El-Allaqi and Garf Hussein; (c) khors Korosko, El-Seboa, Wadi El-Arab and Tomas; and (d) khors Aniba, Tushka and Forgondi (see El Shahat, this vol., p.4). At least one khor in each sector was sampled during the survey. An interview questionnaire was prepared to collect data that included the following: date, name of khor, name of the skipper, number of fishers in the boat, type of net, length of net, mesh size, number of hauls, fishing time and total catch by species. In addition, a form for recording fish length and total weight accompanied the questionnaire. From the collected data, catch per boat per day and catch per fisher per day were calculated as indices for relative abundance. Also, catch composition by species and group of species for the different sectors was estimated.

For studying the population dynamics of *O. niloticus* and *S. galilaeus*, the collected length frequency was used. Battacharya's (1967) length frequency method was adopted and length-weight relationships were obtained by the least squares method. Subsequently, parameters of the von Bertalanffy growth function (L_∞, K and t_0) were calculated.

The instantaneous total mortality coefficient (Z) was determined by the length converted catch curve method (Pauly 1983). Natural mortality (M) was obtained from Pauly's (1980) empirical relationship and Ursin's (1967) equation. Fishing mortality (F) was calculated by subtracting the geometric mean of the two values of M from Z.

To predict the maximum yield per recruit and the corresponding fishing mortality, the Beverton and Holt (1956) yield per recruit model was constructed for the two species. Length at first capture was estimated by graphical methods (Caddy 1981). Length-cohort analysis (Jones 1981) was used to estimate the average number attaining each length during the year, as well as the average numbers present in a length group at any particular time.

Results and conclusions

Analysis of the boat catches sampled indicated that there was no distinct difference in the catch composition between sectors. In general, *O. niloticus* made up the bulk of the catch (70%), *S. galilaeus* contributed about 20% and *L. niloticus* about 6%. For the first time, both *Tilapia zillii* and *O. aureus* are recorded in the lake. The former contributed about 2% to the total catch (Table 1).

Two measures of effort have been obtained from the collected data, number of fishers and number of boats. The catch per unit effort (CPUE) is used as an index of relative abundance. Accordingly, catch $boat^{-1}$ day^{-1} and catch $fisher^{-1}$ day^{-1} were used to compare the abundance of fish in the different sectors (Table 2). The results showed that the fishes are more abundant in the southern (3rd and 4th) sectors.

Table 1. Percentage composition by species in the different sectors of the lake.

	Sector				
Species	1	2	3	4	Overall
Oreochromis niloticus	68.2	78.6	58.8	68.7	68.8
Sarotherodon galilaeus	22.5	10.7	22.6	20.7	20.3
Tilapia zillii	1.9	0.6	2.8	1.1	1.6
Lates niloticus	5.9	7.6	3.9	5.2	5.8
Mormyrus spp.	0.3	0.8	3.6	0.1	0.7
Synodontis spp.	0.5	0.9	7.6	4.2	2.2
Others	0.7	0.9	0.6	0.2	0.6

Table 2. CPUE as an index of fish relative abundance in the different sectors of the lake.

Sector	Catch (kg) $boat^{-1}$ day^{-1}	Catch (kg) $fisher^{-1}$ day^{-1}
1	34.8	14.6
2	34.8	11.5
3	38.8	17.1
4	71.2	19.5

Growth in length (L) and weight (W) for *O. niloticus* could be described by:

$$L_t = 54.730\ (1-e^{-0.270\ (t+0.745)})$$
$$W_t = 6414.871\ (1-e^{-0.270\ (t-0.745)})^{2.842}$$

Growth in length (L) and weight (W) for *S. galilaeus* could be described by:

$$L_t = 37.800\ (1-e^{-0.294\ (t+1.187)})$$
$$W_t = 1849.626\ (1-e^{-0.294\ (t-1.187)})^{2.449}$$

The mortality rates for *O. niloticus* and *S. galilaeus* were Z=1.21 and 1.97, M=0.24 and 0.34, and F=0.97 and 1.63, respectively. The exploitation rates for the two species were 0.80 and 0.83 indicating that both *O. niloticus* and *S. galilaeus* were heavily exploited in the lake.

The length at first capture (l_c) for the two species was 19 and 17 cm for *O. niloticus* and *S. galilaeus*, respectively. Length at recruitment was chosen as the smallest length observed in the catch, 12.5 and 13.0 cm for the two species, respectively.

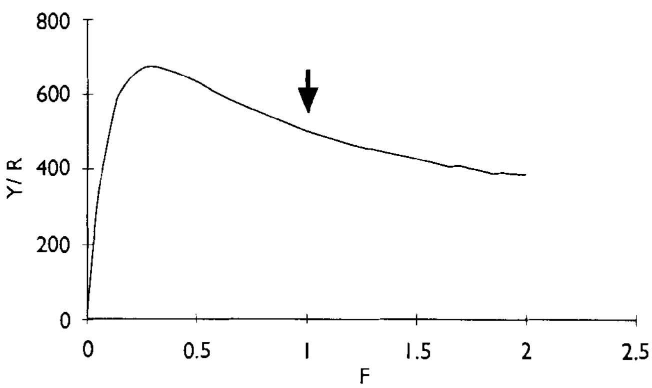

Fig. 1. Yield per recruit (Y/R) (g) of *O. niloticus* as a function of fishing mortality (F). Arrow indicates present annual fishing mortality at 0.97.

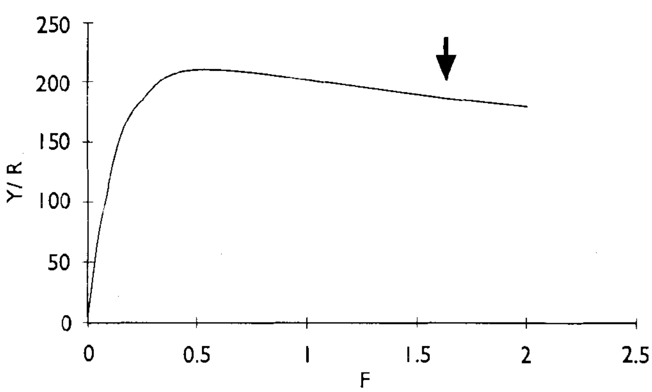

Fig. 2. Yield per recruit (Y/R) (g) of *S. galilaeus* as a function of fishing mortality (F). Arrow indicates present annual fishing mortality at 1.63.

Application of Beverton and Holt (1957) yield per recruit model (Figs. 1 and 2) showed that the maximum yield per recruit for *O. niloticus* was 681 g, at F=0.30. At the present level of fishing mortality (0.96), yield per recruit is 518 g. For *S. galilaeus*, maximum yield per recruit was to 214 g at F=0.55. At the present level of fishing mortality, the yield per recruit is 190 g.

In applying length cohort analysis, it is assumed that the length composition is in steady state, and that the numbers caught represent annual catches per length group. Fig. 3 shows that the total abundance of *O. niloticus* was about 39 million. The catch was about 11 million while the natural mortality about 9 million. For *S. galilaeus* (Fig. 4), the total abundance was about 18 million, the catch was 12 million and the natural mortality was about 6 million. Biomass of *O. niloticus* and *S. galilaeus* was about 27 901 and 4 598 t, respectively.

The long-term effect of reducing fishing mortality by 10% was studied by applying length-cohort analysis. It was found that the present catch of *O. niloticus*, 14 721 t, would increase to about 24 378 t (65%). For *S. galilaeus*, the reduction in fishing mortality would result in an increase in the total landing from 4 472 to 4 797 t (7%). The present data

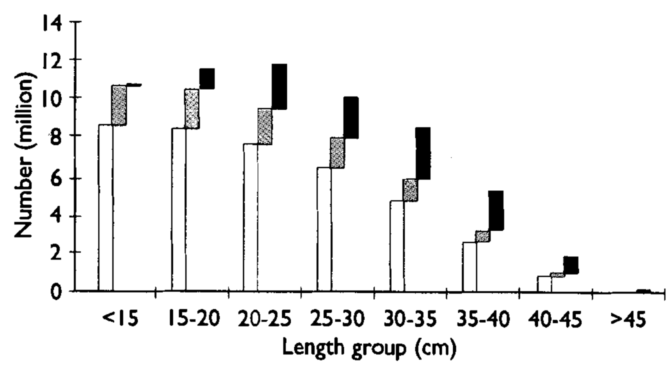

Fig. 3. Length-cohort analysis of *O. niloticus*. Standing crop (□), natural mortality (▒) and fish mortality (■).

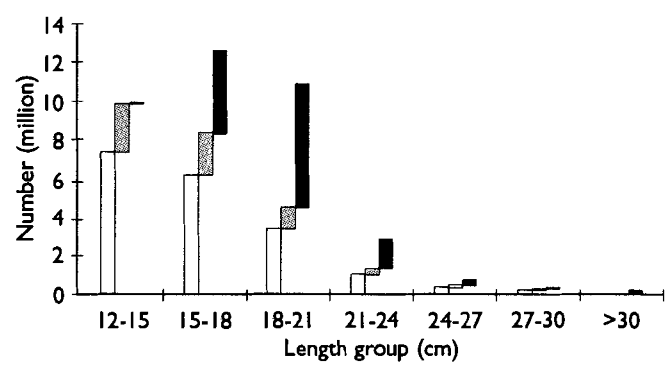

Fig. 4. Length-cohort analysis of *S. galilaeus*. Standing crop (□), natural mortality (▒) and fish mortality (■).

are only preliminary and the sampling program should be continued on a regular basis.

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DISCUSSION

Q. You mention yield per recruit (Beverton and Holt). Did you calculate biomass per recruit?

A. Yes. I also calculated relative biomass per recruit.

Q. Can you calculate the total fish biomass in the lake?

A. I have estimated this. However acoustic surveys would give more accurate results.

Net Cage Culture of Silver Carp, *Hypophthalmichthys molitrix* Valenciennes, Without Artificial Feeds

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Shenoda, B.Z. and M. Naguib. 2000. Net cage culture of silver carp, *Hypophthalmichthys molitrix* Valenciennes, without artificial feeds, p. 91. *In* J.F. Craig. Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Trials were carried out on using floating cages to culture silver carp (*Hypophthalmichthys molitrix* Valenciennes) from March 1990 to June 1991. The effect of stocking density on growth was studied. Three cages of 100 m^2 capacity were stocked with 400, 700 and 1 397 fingerlings (average weight 28 g). The final average individual masses were 1.62, 2.02 and 1.23 kg and the net production for each was 421, 761 and 1 082 kg, respectively.

Introduction

To utilize the abundant phytoplankton production of Lake Nasser, an experiment on the net cage culture of silver carp (*Hypophthalmichthys molitrix* Valenciennes), without artificial feeds, was performed to evaluate the feasibility of raising fish to marketable size. Floating cages were found to be suitable for use in the lake where the water level varies by about 18 m.

Materials and methods

The floating net cages were 5 × 5 × 5 m in size. The top of each cage was raised 1 m above the surface so that the volume for culture per cage was 100 m^3. Three net cages were tied together and anchored near the shore at Abu Simbel harbor. The net was made of multifilament nylon with mesh size initially of 17.8 mm. This was changed to 40.0 mm six months after stocking. To keep the net shape square, 64 1-kg sinkers were used, distributed along the bottom edges of the net. The cages were covered with netting to prevent fish jumping out. The experiment was carried out from March 1990 to June 1991. Silver carp fingerlings were 28 g average mass, and stocking density was 400 in cage 1, 700 in cage 2 and 1 397 in cage 3.

Results and conclusions

Net production was 421 in cage 1, 761 in cage 2 and 1 082 kg in cage 3. Total production was 2 263 kg, 7.8 kg m^{-3} (Table 1).

Table 1. Result of silver carp culture in net cages without artificial feed.

Cage no.	Fish stocked (no.)	Fish harvested (no.)	Survival rate (%)	Ave. mass at harvest (g)	Total mass per cage at harvest (kg)
1	400	266	67	1 620	432
2	700	385	56	2 020	781
3	1 397	907	65	1 230	1 121

Acknowledgement

The authors wish to thank Dr. K. Sakai (Tokyo University of Fisheries) for his helpful advice.

DISCUSSION

Q. Do fishers want silver carp and is there a market for it?
A. They want silver carp although we are nervous about introducing an alien fish. It is better to use native fish. There is a market for salted silver carp.
Q. Have you tried to culture tilapia in cages?
A. Yes, but production is low and artificial food has to be provided. Fishers are not good at looking after them.

Fisheries Management and Enhancement

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El Shahat, M.M. 2000. Fisheries management and enhancement, p. 93-94. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Lake Nasser is an important source of fish for Egyptians. The High Dam Lake Development Authority is responsible for the management and development of the lake fisheries. Its goal is to maximize fish production and utilize the high lake productivity through several procedures and regulations: (a) a closed fishing season; (b) restrictions on gear type and mesh size; (c) determination of size for marketing; (d) production and restocking of native fish species; (e) establishment of infrastructure and ice plants at fish landing centers in the north and south regions of the lake; and (f) social welfare of the fishers through policy concern, construction of shelters and provision of medical care.

The High Dam Lake Development Authority (HDLDA) is responsible for the utilization of the natural resources in the lake region including fisheries, agriculture, mining and services.

To manage the fisheries industry, HDLDA controls research, administration and production. Management is achieved by a variety of techniques:

- There is a closed fishing season during the peak of the *Oreochromis niloticus* L. (tilapia) spawning season.
- Closed areas have been established to maintain tilapia stocks.
- There are restrictions on gear type to prevent catching immature fish.
- Production (in hatcheries) and restocking of native and exotic fish species to enhance the lake's fish populations are being practiced.
- Fish-landing and harbor facilities have been constructed at Aswan and Abu Simbel (300 km from the High Dam) to improve fish handling conditions.
- Workshops and a floating dry dock have been constructed for carrier boat maintenance.
- Fishers' societies and companies have been established for fish production, processing and marketing. The Misr Aswan Company for fishing and processing is one of the biggest companies in the region.
- Carrier vessels have been designed and constructed to transport fish and to keep it fresh.
- Ice plants have been established in Aswan and Abu Simbel for the fishing carrier boats.
- Experiments on aquaculture techniques and fish farming, including fish propagation of native species, are being undertaken. Net cage culture has been used to test the potential for the introduction of new species in the lake. Fish farming in khors and enclosures has been carried out to increase fish production.
- Fish meal is produced from fish waste and used in animal feeds.
- A fish pellet factory has been constructed.
- Environmental, physical, chemical and biological studies are being undertaken. A tentative relationship between fish and primary production has been derived.
- Special procedures to prevent lake pollution are being undertaken by applying Egyptian environmental laws. Pollution is monitored and controlled. HDLDA has taken all precautions to prevent sewage water from entering the lake.
- Studies on fishing operations and nets are being undertaken to develop fishing gear technology.
- Fishers' living conditions have been improved by establishing shelters, providing medical care and supplying food.

DISCUSSION

Q. The Fishery Management Center is concentrating on the biological aspects of management. What about the economic aspect?

A. Yes, we must manage with regard to the economic factors. However, we are unable to make predictions about the sustainable yield.

Q. The lake is supposed to be intensively fished, but yield is only 20 000 t. Why is the yield below expectations?

A. No explanation given.

Q. Have you studied the fish in the area closed to fishing near the Aswan High Dam?

A. Yes, but this is only a very small area compared with the rest of the lake.

Harvesting, Transporting, Processing and Marketing of Fish

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Barrania, A. 2000. Harvesting, transporting, processing and marketing of fish, p. 95-97. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

The storage of water in Lake Nasser commenced in 1964. Fish landings increased progressively during the period 1966-1981. However, during 1982-1997, the landings tended to decrease. In 1997 landings were estimated at 20 000 t. This was due mainly to the low water level and overfishing. About 90% of the fish were tilapia species. The most common gears used were trammel nets (duk) and gill nets (kobak) operated from small boats, most of which were equipped with outboard engines. The 4 000 fishers were dispersed over about 500 fishing bases of variable location, which were used as fish collecting sites. Approximately 10-20% of the fish caught were salted. To transport the fish (both fresh and salted) to the receiving harbor, a number of boats of varying sizes were operated by fishers' cooperative societies. The collection of the catch was rather poorly organized. The marketing of iced fish was done mostly by the Egyptian Marketing Company (EMC). Processed fish were marketed jointly by the Misr Aswan Company (MAC) and EMC, while fishers' cooperative societies were responsible for the marketing of salted fish. Price regulations for fresh fish caught were enforced, which led to smuggling of considerable quantities. Proper fisheries management, improvement in the fish collection system and the establishment of appropriate pricing policies are strongly recommended to achieve the predicted potential yield.

Introduction

The purpose of this paper is to provide a brief description of the present status as well as development requirements of harvesting, transportation, processing and marketing of Lake Nasser fish. The sources of information and data used include previous studies and records of the High Dam Lake Development Authority and the fishers' cooperative societies as well as field trips, observations and interviews with many people.

Fishing operations

The lake is divided into five fishing zones, affiliated to five different organizations (see El Shahat, this vol., p. 4). Fishing operations are carried out by fishers (4 000 in 1996), who are based along the shore or on small islands. There were an estimated 500 fishing bases in 1996. However, this number varies as locations are not fixed. The bases are sited near suitable fishing grounds and where they can be reached directly by the carrier boats.

Two types of locally made wooden boat are used mainly in Lake Nasser. In the northern half of the lake, the fishers use flat-bottomed, canoe-type, Alexandrine boats. As most of the fishing is in the khors (inlets), these boats are adequate as rough water is rarely encountered. In the southern part of the lake, the traditional "Nile River" fishing boats, which are heavier and broader, are used. Both types of boats are reasonably cheap to build and are adequate for fishing and transportation. In 1996, the number of fishing boats was estimated at 2 834, most of which are equipped with outboard engines of 15 hp or more.

Gill and trammel nets are used for fishing. *Alestes* spp. and *Hydrocynus* spp. are mainly caught in floating gill nets (sakorata) and most are salted. Trammel nets (duk) are used to catch *Oreochromis niloticus*, *Lates niloticus* and *Bagrus* spp. which are processed fresh.

Fish landings

Recorded annual data are available from 1966 to 1997 and are given by El Shahat (this vol., p. 3). The fish are usually landed at the Aswan High Dam port either fresh or salted. The contribution of salted fish decreased gradually from >50% in the 1960s to about 10% in the 1990s. This may be due to overfishing of the fish species that are salted, as they are sold at free market prices, compared to species that are marketed fresh which have lower enforced market prices. The most important species in the 1996 landings were *O. niloticus* (84%) and *L. niloticus* (4%).

The highest landings were observed in March, September, November and December in 1996 (Table 1). A closed season has been imposed since 1991 for the period 15 April to 31 May, the main spawning period of tilapia in the lake.

Table 1. Monthly landings (t) of fresh and salted fish, 1996.

Month	Fresh fish	Salted fish	Total
January	1 329	177	1 506
February	1 125	130	1 255
March	2 844	140	2 984
April	1 210	175	1 385
May	216	79	296
June	1 414	117	1 531
July	1 164	230	1 394
August	1 488	269	1 757
September	1 892	265	2 157
October	1 628	272	1 899
November	1 913	191	2 104
December	1 937	336	2 274
Total	18 159	2 381	20 540

Source: High Dam Lake Development Authority (HDLDA)

Fish transportation

Fresh and tins of salted fish (see below) are transported from the different regions of the lake (fishing bases) to the fish-receiving port at Aswan High Dam by a number of carrying boats (approximately 102 of varying sizes and capacity) operated by the MAC and the fishers' cooperative societies. Some of the carrying boats have refrigeration units while others use ice in the holds to preserve the fish. The fishers depend on the carrying boats not only to collect the fish, but also to supply goods, including salt used for preservation of some species, and for personal transport. However, it is reported that the carrying boats are not fully utilized. After the construction of the Aswan to Abu Simbel road, fishers started to smuggle the catch from many of the sites. Further, the carrying boats are not always accessible to all the fishers.

Salted fish

In recent years, about 7-12% of the fish caught from Lake Nasser has been salted. The prominent fish salted are *Alestes* spp., *Labeo* spp., *Hydrocynus* spp. and *Eutropius niloticus*. The fish caught are sun-dried for about 24 hours. The larger fish are gutted before being salted while smaller ones are salted whole. The fish are rubbed with salt then packed in tins. They are transported to the salted fish marketing center and separated by species and packed in separate tins. At this stage, the quantity of salt is adjusted. The tins are then tightly sealed and stored. The fish are ready for consumption after three months. Salted fish from Lake Nasser are subject to spoilage and heavy losses. They are considered to be a low-grade product.

Fish marketing

The Egyptian Marketing Company (EMC) markets most of the iced fish. Both MAC and EMC market fish fillet products. Salted fish is sold through the Marketing Centre of Salted Fish in Aswan, where the product is auctioned to wholesalers under the control of representatives from the fishers' cooperative societies. Cairo is the main receiver of Lake Nasser fishes. Fewer are marketed in Aswan and the towns of Upper Egypt.

Price regulations for fresh fish are enforced. The prices are set by the Ministry of Supply and Trade, and are reviewed periodically. The final price to be paid to producers is decided after determining the degree of freshness. This system usually creates problems for all parties concerned and leads to smuggling of considerable quantities of the catch. The obligatory prices do not reflect the real economic ones. The black market has flourished and administering controlled prices has become difficult and expensive. The two available alternatives are either to determine the economic price of fish based on the cost of production and marketing or according to the interaction between the forces of supply and demand, reflected through auctions occurring in other parts of Egypt.

Conclusions

Development efforts should strive to improve the fisheries management of the lake. Accurate data, including information about the real catch and fishing effort, are required. The current division of the lake into closed geographical areas should be examined and revised if necessary. Fish handling, collection and processing are poor and need improvement. An appropriate pricing policy is needed.

Recommendations

To exploit the fisheries of Lake Nasser in a sustainable manner, the following recommendations are suggested:

- One body should administer the exploitation and management of the whole lake instead of the boat owners who, at present, control most fishing areas of the lake. The current distribution of fishers should be revised.
- The rules and regulations for fishing in the lake should be enforced.
- A thorough assessment of the stocks available and their distribution should be conducted so that the extent to which the lake can be safely fished at different water levels is known. The data provided from previous studies are mostly from fish landings at the Aswan High Dam port rather than the actual fish catches, and this has been a major constraint to analysis.
- The unexploited area in the pelagic region of the lake should be given attention.
- More efficient and economic alternatives for collection and transportation of fish from the fishing camps to the port should be investigated. This includes improving fish handling.
- Appropriate pricing policies are needed to encourage fishers to deal through legal channels.

DISCUSSION

Q. Why has the amount of salted fish declined? There is a free market and prices are high.

A. The species that are salted have been overfished.

Q. How is an estimate to be made of the quantity of fish poached? Cannot the government give better prices to stop this practice?

A. Poaching is a 'free enterprise' (outside the government). By poaching, the fishers are getting a better price for their fish. The Egyptian Government is working towards a free market.

Some Socioeconomic Aspects

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Mohieddin, M.M. 2000. Some socioeconomic aspects, p. 99-101. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

This paper attempts to raise a debate on the current state of sociological research on Egyptian lakes. It stresses the need for a solid database as an essential starting point. Furthermore, it shows that the existing problems can only be understood when viewed from a perspective that takes into account not only the biophysical aspects of lakes but also the socioeconomic ones. In planning for the sustainable development of Lake Nasser, a thorough understanding of organizational, behavioral, environmental and political processes is required. The paper provides a brief assessment of the state of sociological research on lakes in Egypt followed by a review of the development of Lake Nasser and the consequences of the Aswan High Dam construction. It discusses the development of fishing activities and their concomitant aspects, i.e., production, organization and marketing. The paper also stresses the fact that the lake is a contested terrain for several government agencies. This is a major problem that needs to be addressed if any meaningful policy on lake management is to be elaborated and effectively implemented.

Introduction

To say that the sociology of lakes in Egypt is an underdeveloped field of investigation is an understatement. The field is virtually nonexistent. A few academic studies and some related to applied projects are available (personal information), but the subject is far from a coherent body of knowledge. This is surprising, given the fact that about 41% of Egypt's fish production in 1996 came from the 10 lakes and coastal depressions (GADF 1997). Furthermore, a considerable number of villages, towns and fishers and their families are almost totally dependent for their livelihood on these areas.

Of the lakes in Egypt, Lake Nasser stands out as one of the most understudied from the sociological point of view. In the Working Reports of the Fishery Management Center, issued by the High Dam Lake Development Authority (HDLDA), between 1993 and 1996, there is not a single study devoted to the social aspects of the lake. Another report on the developmental profile of the governments of Aswan and Qena makes a very hasty statement in reference to the lake: "Lake Nasser offers a unique opportunity for freshwater fishing, however, data on production in the governorate are not available" (Nagi et al. 1994). Given the current state of knowledge on lakes in general and Lake Nasser in particular, this paper can only attempt to raise questions rather than provide answers.

Lake Nasser and its impact

The physical impacts of building the Aswan High Dam were to flood land in the reservoir area, create a new body of water, change the amount and timing of the flow of water downstream and generate electrical power at the dam site. These impacts were expected to change the regional and national economy, provoke shifts in human settlements, and later alter the water relations of the alluvial lands of the river valley and the delta (White 1988).

The connections between physical and social effects were perceived as relatively direct: flooding the reservoir area would cause population dislocation, creating the new reservoir would provide fishing grounds and improve navigation, generation of power at the dam would increase electricity supply and reduce energy prices, and the regulation of the stream flow would result in increased agricultural production, improved navigation, reduced sediment flow downstream, and an opportunity to change crop patterns and water scheduling (White 1988).

The clearest losers resulting from the dam construction have been the 100 000 or more Nubians, half-Egyptian and half-Sudanese, who had to be evacuated from their homes in the zone and transferred to government-built villages far from the river (Pearce 1994). They settled in eight villages on newly irrigated lands in the Kom Ombo area, 20 km to the north of Aswan. The history of this mass evacuation in Egypt has been recorded (Kennedy 1977, 1978; Fahim 1982). Much less is known about the Sudanese who were moved to the area of Khashm el Gibra.

Some 30 years after their relocation, a few observations were made about the Nubians in Egypt. Their health had improved through a reduction in the incidence of infectious diseases. Their agricultural production remained relatively modest. Prompted by the efforts of social workers in the new villages, the Nubians had increased their interest and effectiveness in handicrafts. However, they were unhappy in their desert edge locations without their palm trees and river banks, and they were reported to be anxious to return to the river or the lakeshore (White 1988). The development project at Tushka may provide an opportunity for some of them to go back. The impact of their return on the aquatic environment of the lake and hence its fisheries is not known.

Since the 1960s, employment in the fishing industry has grown considerably. According to the 1960 census, the Governorate of Aswan had 547 fishers (Maslahat 1962). By 1966, there were about 600 working on 200 boats in the lake alone. These figures increased by almost 10 fold to reach 5 000 fishers and 2 000 boats in 1981, accounting for 5.7% and 6.0% average annual rate of increase for fishers and boats, respectively (GADF 1997). By comparison, the overall average annual growth rate of the labor force for the entire Governorate of Aswan during the intercensus period of 1976-1986 was 1.6% (CAPMAS 1978, 1989). These numbers have not significantly changed since 1981, and thus the lake provides few employment opportunities. Fishers working on Lake Nasser are organized in several cooperatives that vary in size as measured by the number of boats under their control (see El Shahat, this vol., p. 6). According to GADF (1997) data, these cooperatives had in their possession a total of 2 851 boats working in the lake in 1997 (Table 1). The largest cooperative owned 1 431 boats, and the smallest had 61. It is not known if there are other boats fishing in the lake and if so what is their resistance or willingness to join the cooperatives.

For each of these cooperatives, a production target is set by GADF. In 1997, the production target was 34 164 t. Actual landings were at about 19 300 t, a difference of about 15 000 t (44%) between targeted and actual.

It is not clear how these production targets are set, or upon what assumption they were based. It is not clear if the fishers themselves are consulted about production targets. However, the general pattern is one of production shortage in all cooperatives, except for the Nubian cooperative, which comes very close to achieving its set target (99.7%) (Table 1).

These data clearly indicate that fishing performance is weak. This is so despite the fact that the Aswan Governorate is ranked third in the nation in terms of annual per capita production of fish, 39 kg. It has only been surpassed by the two Red Sea Governorates, Suez (95 kg) and the Red Sea (55 kg).

It is worth noting that the statistics on the lake's yield (see El Shahat, this vol., p. 6) are highly variable and subject to controversy. Data from HDLDA set production for 1996 at 20 540 t (about 4.8% of the total national production of fish). Data from GADF indicated production at about 45 401 t in the same year (about 10.5% of the total Egyptian production). Although there has been a systemic decline in production in the past two decades, severe discrepancies in data sources make any kind of analysis highly susceptible. An accurate database is clearly needed for any meaningful analysis of the current status and for future lake planning.

With declining production and increasing numbers of fishers and boats on the lake, one would expect much more fierce competition for fishing and diminishing returns. This provides a perfect prescription for illegal fishing practices, which in turn impacts on fishing sustainability. The declining productivity from the lake has been attributed to low water levels in the lake during the 1980s (see El Shahat and Agaypi, this vol.) resulting from successive years of drought in Africa, overfishing and the centralized pricing system, which in turn leads to the spread of fish poaching. Recently, there have been some allegations that Nile crocodiles are threatening life in Lake Nasser. It is estimated that the lake has about 260 crocodiles (>3 m) in addition to an unspecified number of small ones (Al-Ahram 1998). They are seen as a threat to fishers and their livelihood. Striking a balance between biodiversity and sustainability of fishing and the livelihood of fishers is complex and cannot be dealt with in such an oversimplistic way.

Apart from production, markets and marketing (distribution) must be considered. Until now, pricing of fish produced from Lake Nasser is subject to control by the state. This is probably because freshwater fish are considered to be more in demand by the majority of the population compared to saltwater fish. However, this remains an assumption as no one knows who consumes what, how fish markets are structured and if there has been a change in the taste of the urban population that has led to declining demand for freshwater fish. Furthermore, it is not known how fishers respond to

Table 1. Targeted, actual and shortages of fish yields (t) and number of boats working in the lake in 1997 by co-operative societies.

Cooperative societies	No. of boats	Actual production (t)	Targeted production (t)	Shortage (t)	Ave. production per boat
Mother	1 431	8 741	17 148	8 407	6.1
Aswan Fishermen's	605	2 230	7 260	5 030	3.7
Misr Aswan	228	1 648	2 724	1 076	7.5
Nubian	526	6 262	6 288	26	12.0
Al-Takamol	61	419	744	325	6.8
Total	2 851	19 300	34 164	14 864	6.8

changing policies: poaching is only one option. If their entire household economy is considered, what alternative subsistence strategies do they adopt in order to resist government intervention? All these sociological questions require investigation not only with regard to Lake Nasser but also to all other lakes in Egypt.

Finally, there is the issue of the administration of the lake. Like other lakes in Egypt, Lake Nasser is a contested terrain, where several authorities have vested interests including GADF, HDLDA, the Ministry of Agriculture, the Ministry of Public Works and Water Resources, the Ministry of Tourism and the Governorate of Aswan. Each of these has its own plans for the lake. These plans are not necessarily compatible with one another and sometimes they conflict. The history of ministries' and authorities' joint committees has been one of "agreeing not to agree". An agreement has to be reached and a clear long-term policy has to be devised if sustainability of the lake's ecosystem is to be achieved.

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DISCUSSION

Q. Poor relations among lake users are one of the main constraints in lake development. These divisions are social and have to be addressed. Are there conflicts between fishers and boat owners?

A. There is no information on this.

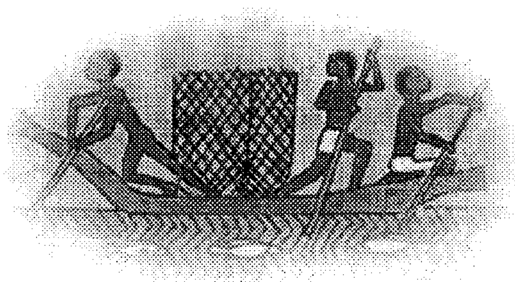
Q. There is a difference between scientists and sociologists. The former make predictions, the latter don't. Can you make a prediction if prices were not fixed?

A. It is not my job to make predictions. There is an increasing concentration of wealth among the boat owners. The fishers are isolated although there has been a slight change in their standard of living.

Q. How can we transfer scientific knowledge to the fishers?

A. We need to bridge this gap and provide information to the fishers. This will give them confidence and make them partners in the system.

III



Constraints and techniques

Constraints and Issues

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ABSTRACT

Some of the major biological, economic and social constraints on the fishery are outlined. A summary of a workshop discussion provides a consensus on the major issues. The participants recommended that the next stage in the project development was to compile a database on existing knowledge, identify information gaps and train those involved in the fishery.

Introduction

The factors which influence the fishery of Lake Nasser are many and varied. To understand these factors will take an in-depth analysis of present knowledge about the lake and further field and desk studies. Likewise, the constraints that do not allow the fishery to reach its full potential are varied and complex, and cannot be understood without detailed examination and discussions with concerned parties.

Some of the possible constraints on the fishery are presented in Fig. 1. These can be biological, economical and sociological. The total mass of fish available to the consumer may be below maximum because (a) insufficient fish are landed (a decline in the catch); (b) the fish landed are unsuitable (for example, carps are not acceptable to most Egyptians although sardines, if they were introduced into the lake, probably would be); (c) fish are captured illegally (poaching); and/or (d) the fish landed are spoiled. Some causes for these constraints are given in the figure. The relative importance of each will become apparent as the state of knowledge about the system is elucidated.

Workshop discussion

- The lake appears to be highly productive so nutrients do not appear to be limiting.
- The lake does not seem to be overfished. There have been no complaints from fishers. This does not mean that measurements of potential yield from population dynamic studies should be ignored.
- It is important to look at the fishers' reaction to change.
- There is a lack of reliable and available data on the ecosystem.
- All previously obtained data should be published in refereed scientific journals, to ensure their quality and to make them available to interested parties.
- Should we adapt the "no hypothesis role" and assume that conditions will not deteriorate, and the fishery will continue without any recommendations for better management? No. Although the lake is considered to be highly productive, it should not be left without plans for effective management. The lake will be overfished. Interaction with other lake users should be considered in developing a strategic management plan.

Compilation of group reports on overcoming constraints

The following are the workshop participants' majority views on the main issues, which need to be considered in the planning process:

- Has the potential production of the lake been estimated accurately? No.
- Is there potential for fish other than tilapias? Yes.
- Could the tilapia catch be increased? Possibly.

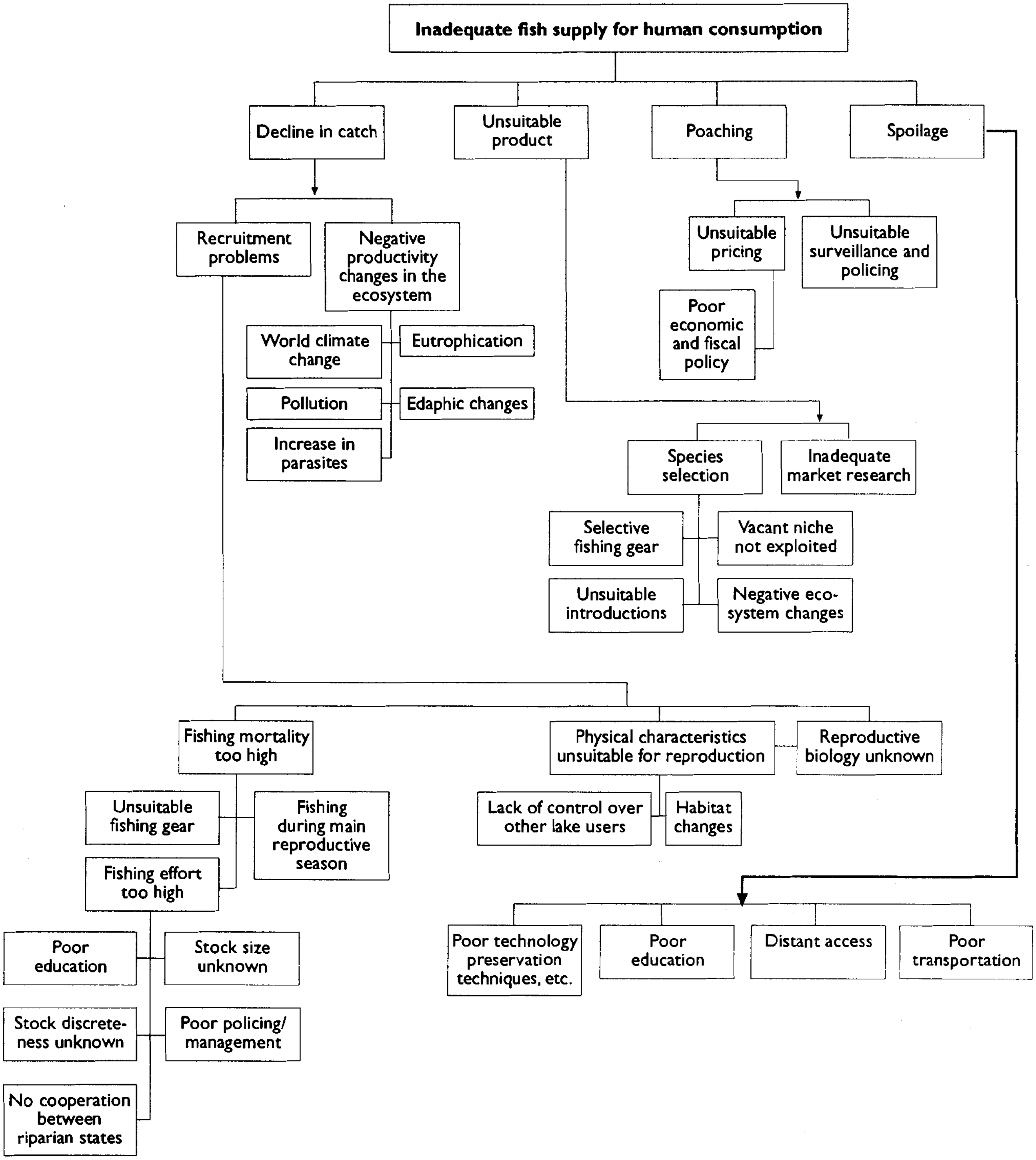

Fig. 1. Constraints on the Lake Nasser fishery.

- Do nutrients limit productivity? No.
- Do fluctuations in water level affect productivity? Yes.
- Are economic and social factors significant constraints? Yes.
- Is there an empty pelagic niche? Yes, there is potential for landings of at least 70 000 t of sardines or other suitable introductions.
- Should we support the introduction of new fish to increase productivity? Yes, but with some disagreement.
- Can illegal fishing be controlled? No.
- Can recreational fishing increase wealth among the fishing communities? Possibly.
- Could remote sensing be a useful tool in research? Yes.

- Does stock enhancement improve the fishing in the lake? Most participants felt that there was no evidence for this. Stocking with hatchery-reared tilapia should be evaluated.
- Could aquaculture be increased around the lake, and would you support the development of cage culture in the lake? Yes, but with reservations in view of its possible impact on water quality.
- Is water quality a prime concern for the management of the lake? Yes.
- Could artificial reefs significantly increase fish productivity? Uncertain.
- Are there too many bodies administering the lake? Yes.
- Is the present management system satisfactory? No.
- Are there any endangered fish species, and is their conservation important? Uncertain.
- Is there a potential danger from water hyacinth? Possibly.
- Would potential benefits from the lake be increased by improving the postharvest treatment of fish? Yes, upgrading would provide fish suitable for export.
- Are parasites a problem? Unknown.
- Are fish kills a problem? No.

Top priorities for the next stage in project development:

1. Compilation of existing knowledge

Raw data to be assembled onto CD-ROM, making them available to users

The existing data require analysis, and information gaps need to be identified (see below). The workshop was unable to ascertain what data were accessible, although in some cases it was obvious that available data had not been analyzed correctly.

Preparation of a manuscript based on existing data

The contents of the manuscript may be limited by lack of suitable information and will almost certainly not be suitable for a modern management plan. For example, ecosystem modelling requires current information on biomass and production at each trophic level. The document will act as background work for identifying the most important areas for future research required to fulfill the objectives of the project. The contents would be:

Section 1. Descriptive
- Physical and chemical limnology
- Primaiy production
- Secondary production
- Benthos
- Fish biology
- Fish-eating reptiles and birds

Section 2. The fishery
- Fishery assessment and management
- Economics
- Social aspects
- Ecosystem modelling

Section 3. Critical issues
- Stock enhancement
- Overfishing
- Water quality
- Introductions
- Artificial reefs
- Protected areas
- Endangered species
- Other lake users

2. Training needs

- Scientists and technicians
- Fishers
- Processing

Possible information gaps identified by the workshop

The participants, with the limited amount of information at their disposal, considered the following to be lacking (the list will be modified after compilation and analysis of existing data; see top priorities above):

1. Data from Lake Nubia (Sudan)
2. Data from remote sensing
3. Wind forcing and currents
4. Temperature profiles
5. Surface area and habitat distribution
6. Light regime
7. Oxic/anoxic boundary
8. Total nitrogen, phosphorus and silicon distribution
9. Chlorophyll *a* (planktonic and benthic)
10. Algal taxa
11. Biomass and production rates (planktonic and benthic)
12. Stock discreteness
13. Conservation of endangered species
14. Stock potential and assessment by catch statistics, acoustics and experimental fishing
15. Rehabilitation, including artificial reefs and sanctuaries
16. The effect of parasites and the role of birds and other species as intermediate hosts

17. The threat from the introduction of floating macrophytes
18. Human population, organization, system structure, origin of the fishers and income distribution
19. Legal and illegal marketing structure (can illegal fishing be controlled?)
20. Processing technology (postharvest treatment)
21. National plan(s) for development
22. Review of policy of interested government agencies and respective plans for the lake
23. Cost of production and marketing
24. Pricing policy
25. Cost/benefit analysis of management policies such as enhancement
26. Environmental and social impact assessment
27. Infrastructure development plans such as roads and landing sites that will have impacts on the industry

RAPFISH: A Rapid Appraisal Technique to Evaluate the Sustainability Status of Fisheries

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ABSTRACT

RAPFISH is a new rapid appraisal technique for evaluating the sustainability of fisheries. Fisheries may be defined flexibly, from a broad scope such as all the fisheries in a lake, down to a single jurisdiction, target species, gear type or vessel. A set of fisheries may be compared, or the time trajectories of individual fisheries may be plotted. Ordinations of sets of attributes are performed using multidimensional scaling followed by rotation. Ordinations are bounded by reference points that simulate the best and worst possible fisheries using extremes of the attribute scores, while random fisheries define the center of the plot. Separate RAPFISH ordinations are performed using sets of predefined attributes in ecological, economic, technological and social disciplines; more disciplines may be added as required. Attributes are chosen to reflect sustainability within each discipline, and although intended to remain fixed for all analyses, may be refined or substituted, as improved information becomes available. A combined ordination may also be performed, providing an unweighted conflation of the disciplines. Some validations of the method are presented, using simulated fishery data. Published work using RAPFISH is reviewed briefly along with prospects for further improvements of the technique, and an example for three major herring fisheries is described.

Introduction

In conventional stock assessment, much effort goes into determining stock status relative to biological reference points, such as levels of fishing mortality, spawning biomass or age structure (Smith 1993), where the objective is to obtain diagnostics that may give early warning of serious depletion or collapse. Increasingly, stock assessment relies upon the estimation of many stock parameters and requires extensive current and historical data measured from the fishery and from independent biomass surveys. There is a mismatch between the complexity of these stock assessment models and the high degree of irreducible uncertainty inherent in fisheries research (Walters 1998). At the same time, extensive data requirements preclude the application of these models to many of the world's fisheries. Moreover, conventional stock assessment relates to the ecological, or occasionally, the economic sphere, and yet fisheries are in reality a multidisciplinary human endeavor that has social, technological and ethical implications. Ideally, an evaluation of sustainability of a fishery in all of these spheres should be required for objective decision making.

This paper describes a recently developed novel technique, RAPFISH, that employs simple, easily scored attributes and aims to provide a rapid, cost-effective and multidisciplinary appraisal of the status of a fishery, in terms of sustainability (Pitcher et al. 1998; Pitcher, in press; Pitcher and Preikshot, in press). The technique is still under development and only the most recent version is described here. Multivariate ordinations of scored attributes evaluate fishery status separately within ecological, technological, economic and social areas; further areas such as ethics may easily be included. A combined, unweighted interdisciplinary evaluation can be added. We show how the method may be used to diagnose emerging problems in fisheries, in other words to evaluate the "health" of fisheries by making comparisons.

The RAPFISH technique

While fisheries management is increasingly seen to be as much about managing human behavior as about fish ecology (e.g., Jentoft 1998), apart from economics, most analyses of the human aspects of fisheries have been nonquantitative with little predictive or diagnostic power. Nevertheless, this human dimension is so intertwined with the gear, vessels, markets; biological and economic sustainability, management, allocation and the rebuilding of depleted and collapsed stocks, that the study of fisheries can be regarded as truly multidisciplinary. RAPFISH is a rapid appraisal technique designed to allow an objective multidisciplinary evaluation, but it is not intended to replace conventional stock assessment for setting quotas, etc.

Definition of fisheries to be evaluated

The RAPFISH method is very flexible about the scope of fisheries included in the analysis. For example, the ordination can be of a set of fisheries or the trajectory in time of a single fishery, or both. Snapshots of a fishery in time may be taken at regular intervals such as every year or every five years or at points when major shifts are known to have occurred. Points, which plot very closely together, or even fall at identical locations on the ordination, will not disrupt the analysis.

Additionally, the actual scope of what is considered a fishery turns out not to affect the results, provided that roughly the same scope is chosen for items to be compared. For example, at one extreme, all of the fisheries in a country or lake may be combined and compared en masse with those in other lakes or countries (e.g., for African lakes, Preikshot et al. 1998). At the other extreme, the method can accommodate a fishery for two different species using the same gear type on the same vessel, or for the same species in the same location using two different gear types. An example of the former is fishery for sardines and anchovies on "volante" pair trawls in the northern Adriatic. An example of the latter is the "volante" and "lampara" fisheries for anchovies in the Adriatic (for both see Pitcher et al. 1999). Fisheries from individual fishing communities may also be compared.

Attributes and data required for disciplines covered

Work using the RAPFISH technique so far has ordinated fisheries in four disciplinary areas that are critical to long-term viability of a fishery:

- Ecological (including fish population parameters and environment)
- Technological (including gear and fishing characteristics)
- Economic (including both micro- and macroeconomic factors)
- Social (including social and anthropological factors)

Within each ordination, a set of nine to 10 attributes is defined. Attribute numbers are designed to maximize discriminating power in the ordination technique, where a rule of thumb is to have three times as many fisheries as attributes used to ordinate them (Stalans 1995). Criteria for choosing attributes are that they are easily and objectively scored, and that extreme values are easily ascribed to "good" and "bad" in relation to sustainability, and that scores are available for all the fisheries and time periods in the analysis. Table 1 lists the attributes for the four disciplines above that have been used in most analyses to date. Separate analyses will be comparable if the attributes are fixed.

Fixed reference points

To provide the ordination with fixed reference points, status is assessed relative to the best and worst possible fisheries that may be constructed from the set of attributes for each discipline. Two hypothetical fisheries, "good" or "bad", are simulated by choosing extreme scores for each attribute. Note that "good" and "bad" are evaluated in terms of sustainability of the fishery within the discipline. If these scores cannot easily be assigned to an attribute, then the attribute itself may not be useful for the RAPFISH analysis. The "good" and "bad" values are shown in the list of attributes in Table 1. The "good" and "bad" fisheries are generally plotted on the final ordination, and their positions are used to rotate the plot and to calculate percentage changes in status.

Random reference points

In addition, 20 random sets of attribute scores ("random" fisheries) are simulated for each discipline. Values are chosen at random from the score ranges for each attribute and entered as "fisheries" in the ordination. The objective here is to show if status evaluations are meaningful, since any fishery locations that lie inside the "random" area could have arisen by chance. More than 20 random points might be chosen to improve statistical rigor, but there are limits because most ordination methods allow only about 100 data points to be included.

After pilot work, in which the random fisheries ordination positions were shown to be normally distributed about zero (Pitcher et al. 1999), individual random fisheries have been replaced by the mean and 95% C.L. These are usually represented as crossed lines on the final ordination plot. Furthermore, by convention, the ordination plot is recentered to the zero of the random points.

Combined interdisciplinary ordination

Two ordination scores from each analysis, making eight scores in all when there are four disciplinary analyses, may

Table 1. List and definitions of attributes used in the analysis, divided into the four disciplinary areas, and showing the "good" and "bad" scores.

Attribute		Scoring	Good	Bad	Notes
Ecological					
1	Catch/fisher	t	Low	High	t/fisher/year
2	Exploitation status	0; 1; 2; 3	0	3	FAO-like scale; under, fully, heavily; overexploited to collapse
3	Recruitment variability	0; 1; 2	0	2	Low recruitment COV <40%; medium COV 40-100%; high COV >100%
4	Trophic level	Number	High	Low	Average trophic level of species in catch
5	Migratory range	0; 1; 2	0	2	1-2, 3-4, >4 jurisdictions encountered during migration
6	Catch < maturity	0; 1; 2	0	2	None; some (>30%); lots (>60%) caught before maturity
7	Discarded bycatch	0; 1; 2	0	2	Low 0-10%; medium 10-40%; high >40% of target catch
8	Species caught	0; 1; 2	0	2	Low 1-10; medium 10-100; high >100 species
9	Primary production	0; 1; 2; 3	3	0	g/m^{2}C/year; low=0-50; medium=50-90; high=90-160; very high=160+
Economic					
1	Price	US$/t	High	Low	US$/t of landed product for time of data point
2	Fisheries in GNP	0; 1; 2	2	0	Importance of fisheries sector in country: low; medium; high
3	GNP/person	US$/capita	High	Low	In country of fishery
4	Limited entry	0; 1; 2	2	0	Almost none; some; most (includes informal limitation)
5	Marketable right	0; 1; 2	2	0	Marketable right/quota/share right: none, some: full ITQ
6	Other income	0; 1; 2	0	2	Fishing mainly casual work; part-time; full-time
7	Sector employment	0; 1; 2	0	2	<10%, 10-20%; >20% employment in formal fishery sector
8	Ownership	0; 1; 2	0	2	Profit from fishery mainly to locals; mixed; foreigners
9	Market	0; 1; 2	0	2	Principally local/national; national/regional; global/international
Sociological					
1	Socialization of fishing	0; 1; 2	2	0	Fishers work as individuals, families or community groups
2	Fishing community growth	0; 1; 2	0	2	Growth over 10 years pre-data point: <10%, 10%-20%, >20%
3	Fisher sector	0; 1; 2	0	2	Households in fishing in the community: <1/3; 1/3-2/3; >2/3
4	Education level	0; 1; 2	2	0	Below; same; above-population average
5	Conflict status	0; 1; 2	0	2	Level of conflict with other sectors
6	Information sharing	0; 1; 2	2	0	None; some; lots
7	Fisher influence	0; 1; 2	2	0	Strength of fisher direct influence on actual fishery regulations
8	Fishing income	0; 1; 2	2	0	Fishing income % of total family income: <50%; 50-80%; >80%
9	Kin participation	0; 1	1	0	Do kin sell family catch and/or process fish: no (0) or yes (1)
Technological					
1	Trip length	Days	Low	High	Average days at sea per fishing trip
2	Landing sites	0; 1; 2	0	2	Landing sites dispersed; some centralization; heavily centralized
3	Pre-sale processing	0; 1; 2	2	0	None; some; lots (e.g., gutting, filleting) before sale
4	Use of ice	0; 1; 2	2	0	None; some ice; sophisticated (flash freeze, champagne ice)
5	Gear	0; 1	0	1	Passive gear = 0; active gear = 1
6	Selective gear	0; 1; 2	2	0	Device(s) in gear to increase selectivity: few; some; lots
7	Power gear	0; 1	0	1	No power assistance to gear = 0; power-assisted gear = 1
8	FADS	0; 1	0	1	Fish aggregation devices (= FADs) : not used = 0; used = 1
9	Sonar	0; 1	0	1	Sonar (acoustics) used to aid catch; no = 0; yes = 1;
10	Vessel size	0; 1; 2	0	2	Average length of vessels <8m (0); 8–17m (1); >17m (2)

Low - minimum from data, **High** - maximum from data.

be used as input data for a combined interdisciplinary ordination. This effectively provides an unweighted evaluation of sustainability status across all the disciplines. Whether this evaluation is useful for decision making depends on the view of the user. For example, fisheries that score well in the ecological area, may score poorly in economic terms. The combined ordination will tend to average out these differences.

Ordination method

After pilot work using Principle Components Analysis produced arched, biased plots, we employed nonparametric multidimensional scaling (MDS) (Kruskal and Wish 1978; Schiffman et al. 1981; Stalans 1995), an ordination technique that can produce unbiased distance "maps" of relative location (Clarke 1993). These maps may be rotated and shifted linearly with minimal disruption (Clarke and Warwick 1997).

A squared Euclidean distance matrix with attribute scores normalized using Z-values is employed because pilot work showed this produced the least disruption to monotonicity. MDS for ratio data in two dimensions is carried out for all the fishery points including the "good", "bad" and 20 "random" fisheries. We have used the SPSS statistical package (SPSS 1996) and the PRIMER package (Carr 1997). Goodness-of-fit is evaluated using stress values (values below 0.25 are considered acceptable by Clarke and Warwick 1997).

Rotation and display of results

Conventionally, we often expect to see a fall in quality or status to be represented graphically as a line falling from top left to bottom right. Accordingly, after ordination, we adopt a convention to rotate plots (to a least squares criterion) so that "good" appears at top left (azimuth 315°, relative to straight up as zero) and "bad" at the lower right (azimuth 135°). The MDS ordination technique allows this rotation because it does not bias the relative map position of the points.

In pilot work, in all cases the "good" and "bad" points fell very close to a straight line through the plot origin, and so, given the monotonicity described as a validation below, we are justified in interpreting this as an axis of sustainability. Hence by rotating the plot using least squares until "good" and "bad" lie at 90° and 270°, respectively, we can show status position along this axis. Changes in status of a fishery with time, or comparisons of status among fisheries, can then be represented as the percentage of the extent of the axis from "good" to "bad". At the same time, changes normal to axis (and normal to the top left/bottom right axis of the original plot) represent changes in fishery status that are not reflected in sustainability.

Estimating loadings of attributes on ordination axes

To examine which attributes most influence an ordination, the plots are rotated using least squares until "good" and "bad" lie at 90° and 270°, respectively, as described above. The X-axis is then taken as the dependent variable in multiple regression with the normalized attributes as the independent variables. Regression coefficients that are significant show relationships of the original attributes to the sustainability axis. Because of the nonparametric nature of the MDS technique, these relationships hold only for an individual ordination and do not transfer to other analyses.

An alternative method is to use canonical correlation (e.g., the canonical correlation package of Statistica, Statsoft 1996). Such an analysis allows the interpretation of the meaning of derived axes from the attributes most highly correlated with them (Stalans 1995). High positive correlation implies that when a particular attribute score was high for any fishery, it was likely to score high on an ordination axis. High negative correlation implied that low attribute scores were associated with high values on an ordination axis.

Clustering the ordination

Cluster analysis of the ordinated points can be used to group the ordinated fisheries in a mathematically objective fashion. A useful technique here is to promote "clumpiness" using the complete Euclidean distance rule possible (e.g., using the CA package of the Statistica package, Statsoft 1996), which creates groups by identifying each member's furthest neighbors. The first four or five readily identifiable groups may be chosen as convenient, since there are no clearly accepted rules for defining what constitutes a mathematical "group" in such investigations (Cooper and Weekes 1983). Tools such as the amalgamation schedules (in the CA package of the Statistica package, Statsoft 1996) may be used to judge the amount of variation explained by creating more groups. If such a plot shows little new variation, being explained by adding extra groups, then the linkage distance is essentially the same (Statsoft 1995).

Validation of the RAPFISH technique

To check that the method would ordinate fisheries monotonically, we simulated some fisheries whose status moved in single steps from "bad" to "good", scored on 10 ordinal attributes from 0 to 4. Fig. 1 shows the results from a RAPFISH ordination of one such simulated fishery (small open points). The trajectory is encouragingly monotonic. Fig. 1 also shows an ordination of a fishery exhibiting periodic large steps in status (three steps-large solid points), which are reasonably linearly preserved relative to the reference fishery, although movement at the edges occupies more space than at the center, probably on account of the Z transformation of the data.

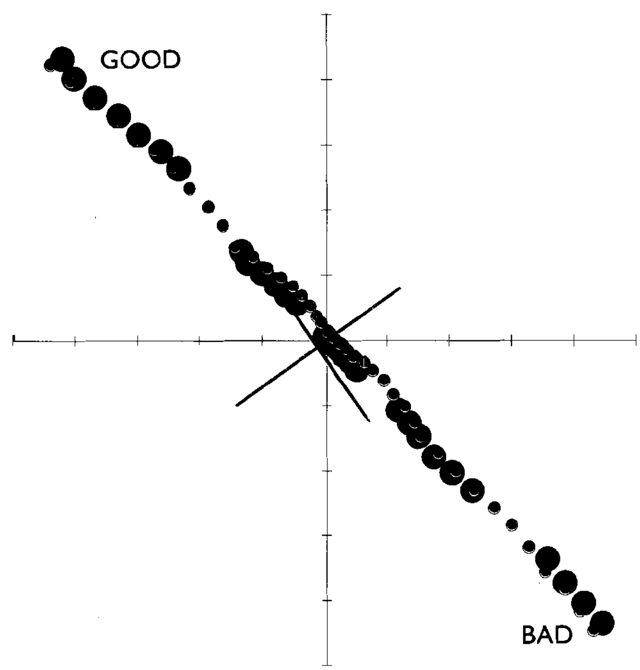

Fig. 1. An ordination showing that the trajectory of a simulated fishery is monotonic using the RAPFISH method. Small open points (●) show a simulated fishery exhibiting sequential steps in status from "bad" to "good", scored on 10 ordinal attributes from 0 to 4. Large solid points (●) show a second simulated fishery that occasionally jumps three steps in status.

As mentioned above, in both cases the "random" fisheries (cross) lie close to center of the plot, and this justifies our re-centering the fishery plots to the zero from the "random" fisheries.

Fig. 2 illustrates a RAPFISH ordination of three more simulated fisheries, together with the usual "good" and "bad" and "random" fisheries. Fishery A was simulated with large changes in the scores of individual attributes, but very little overall change in status: scores effectively were mirror images across the attributes. The resulting RAPFISH ordination reflects these large changes normal to the sustainability axis. They are accompanied by almost no change along the sustainability axis. Simulated fisheries B and C each follow U-shaped curves on the plot. Fishery B decreases in status, remains at about the same level with some neutral changes in attribute scores, and then improves along a different trajectory towards the starting point. Fishery C was simulated as the reverse of this trajectory. In each case, the RAPFISH ordination in Fig. 2 follows the intended path quite well.

Fig. 3 shows the results of rotating the RAPFISH ordinations for fisheries B and C until the sustainability axis is horizontal. Locations on this axis have been plotted as a percentage of the distance from "bad" to "good". The changes in the two fisheries mirror each other, as designed in the simulation, and they achieve the same sustainability status halfway across the plot.

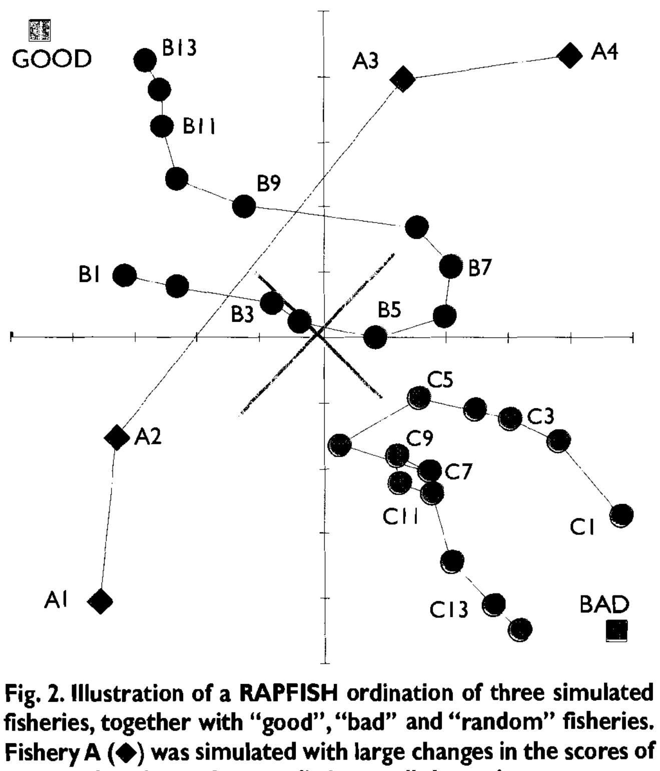

Fig. 2. Illustration of a RAPFISH ordination of three simulated fisheries, together with "good", "bad" and "random" fisheries. Fishery A (◆) was simulated with large changes in the scores of individual attributes, but very little overall change in status: scores effectively were mirror images across the attributes. Simulated fishery B (●) decreases in status, remains at about the same level with some neutral changes in attribute scores, and then improves along a different trajectory towards the starting point. Fishery C (●) was simulated as the reverse of this trajectory.

Interpretation of RAPFISH results

This paper shows that RAPFISH can track changes in sustainability status, with the caveat that sustainability is as defined by the original choice of attributes. Differences normal to the "good" to "bad" axis represent changes in fishery status that are not reflected in sustainability. Note that an excess of points to one side or the other of the ordination zero does not represent analytical bias, but a greater or lesser number of fisheries above or below the median status score that lies in the middle of our fixed scale from "good" to "bad".

The RAPFISH method has promise in that it is robust in several senses. First, users can learn not only from refinement of historical analyses, but also from more formal stock assessment science, about what are "good" and "bad" attributes that may be scored. Second, they can choose which discipline to concentrate on; the biological, social or economic analyses can be used alone or in combination with the technological area if required. It also provides a quantitative way of conflating interdisciplinary evaluations, a process considered essential in the management of many fisheries (Lane and Stephenson 1997). The present method avoids arbitrary weighting of disciplines in that the final ordination will reflect statistically the original choice of attribute values running from "bad" to "good" as the two fixed extremes. Third, the new method is robust in the sense that a response to criticisms of attributes from within each of the disciplines serves to improve the power of the ordinations within each field, rather than invalidate the method.

To date, RAPFISH analyses have been published for 26 world fisheries, from the commercial, subsistence, artisanal and industrial sectors (Pitcher et al. 1998); 24 small-scale

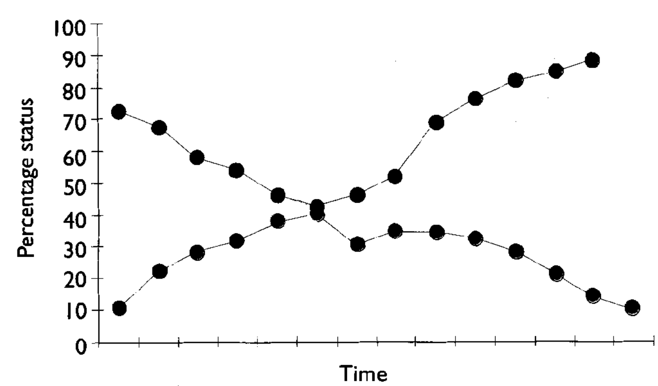

Fig. 3. Results of rotating the RAPFISH ordinations for fisheries B (●) and C (●) until the sustainability axis is horizontal. Locations on this axis have been plotted as a percentage of the distance from "bad" to "good".

artisanal fisheries from the tropics (Preikshot and Pauly 1999); 32 African lake fisheries (Preikshot et al. 1998) and 29 fisheries for sardine, Atlantic herring, Pacific herring and anchovy, including time series for three major herring fisheries (Pitcher et al. 1999). Additional work had included a comparison of the status of distant water USSR fleets in Mauritania and Senegal (see Pitcher and Preikshot 1998). By way of example, Fig. 4 illustrates results obtained for three time series from herring fisheries: the Norwegian spring spawning herring, North Sea herring (both Atlantic herring) and British Columbia (BC) (Pacific) herring. RAPFISH analyses are shown for ecological, social, economic and combined ordinations. This material is taken from Pitcher et al. (1999), where full details of data sources, the history of these fisheries and more detailed interpretations are given.

In the ecological ordination, the BC herring has a U-shaped trajectory, a reduction in status being associated with a narrowly avoided collapse of the meal fishery, followed by improvement after closure and re-opening as a carefully regulated roe fishery. This is like fishery B in the validation, while the two Atlantic herring fisheries exhibit inverted U-shaped trajectories like fishery C in the validation. Both Atlantic fisheries end up in as poor a position as their starting points in the 1950s, as collapse and closure is followed again by

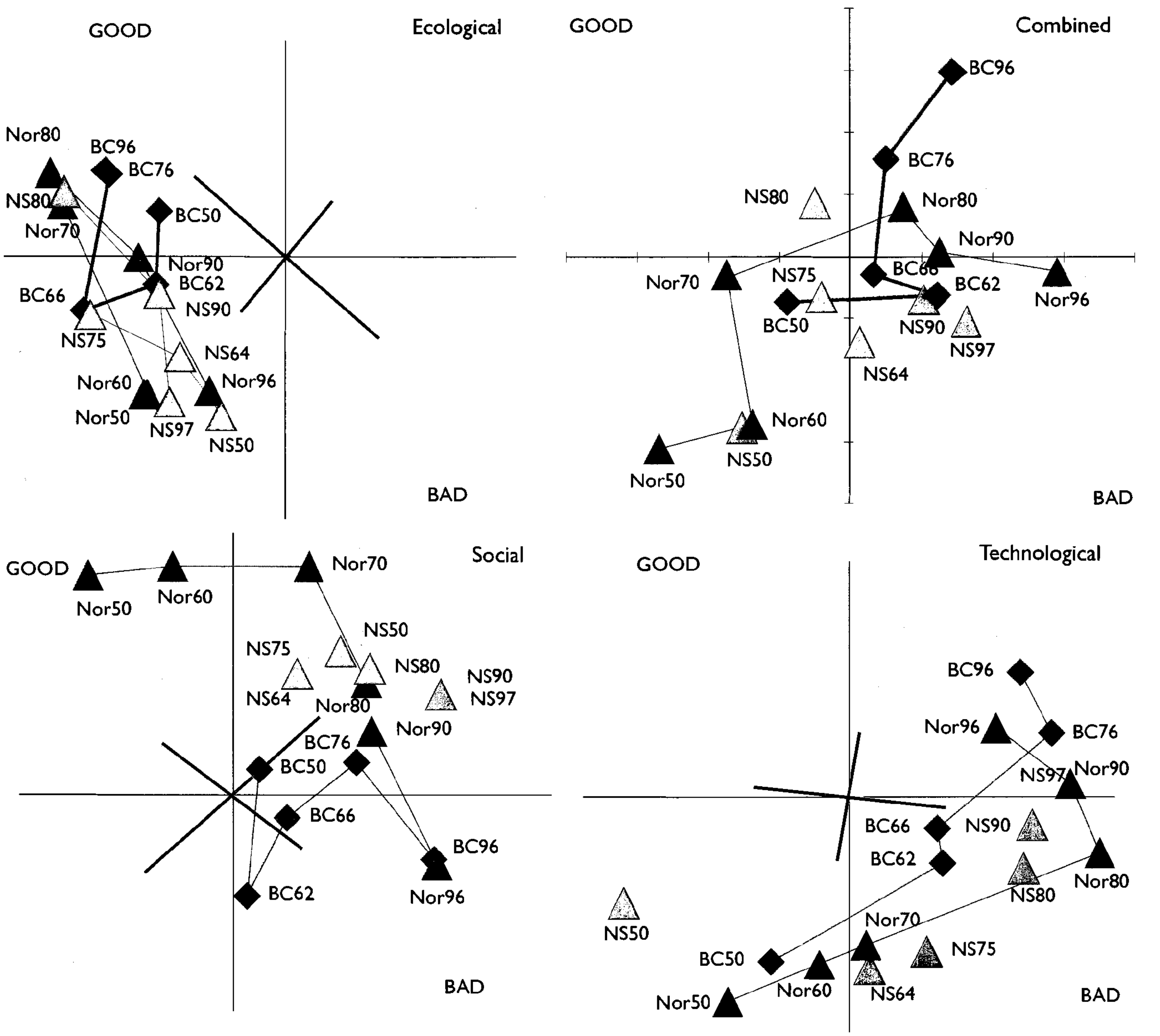

Fig. 4. RAPFISH results for three time series from herring fisheries: the Norwegian spring spawning herring, North Sea herring (Atlantic herring) and British Columbia (Pacific) herring. RAPFISH analyses are shown for ecological, social, economic and combined ordinations. From Pitcher et al. 1999, where full details of the data sources, the history of these fisheries and more detailed interpretations are given.

overfishing and depletion. In the social ordination, the principal feature is the high status of the Norwegian fishery in the 1950s, when small vessels were crewed by close kin from small-integrated coastal communities. This status decreases to end up in almost the same position as the BC fishery in the most recent year. In the technological ordination, the BC and Norwegian fisheries swing across the plot as drift nets give way to purse seines and trawls, both of these fisheries improving their status towards the end on account of the use of by-catch reduction devices. (A fourth ordination, in economics, is not shown here).

This example shows that the RAPFISH ordinations for the three herring fisheries mirror in general what we know of the ecology, economics and sociology associated with their histories of collapse and rebuilding, and their relative status and characteristics. Here, the RAPFISH technique appears to be giving the right signals about shifts in sustainability status, which might be loosely defined as fisheries "health". Note that the combined ordination averages the positions on the disciplinary ordinations.

Prospects for the RAPFISH technique

In addition to providing a rapid assessment of status, the RAPFISH method might be useful in a "triage" of fisheries (Pauly, in press), to determine where limited management resources might be focused to greatest effect. It may also be used to track changes in a single fishery in an attempt to foresee problems before some combination of biological, economic or social effects leads to disaster. An important question is whether this technique can be used to diagnose key problems (such as environmental change, overcapitalization or recruitment overfishing) early enough to give warning of impending trouble. Attributes that more clearly define the period immediately preceding a documented collapse would increase the power of this method.

A more formal analysis of the leverage of individual attributes would also be valuable. Errors, or differences in opinion in the scoring of the attributes, can be taken into account by including the extreme scores as separate "fisheries". Forecasts of fishery status in the coming year can be compared under different policy options.

RAPFISH analyses that employ additional disciplines, such as ethics, are in preparation. Additional fields that capture special features of a fishing gear that evolves with time, such as the cod traps used in Newfoundland since the 1750s, might be valuable for special analyses. And an important aspect of fisheries that has long been ignored, the impact of fishing on ecosystem structure (Pitcher and Pauly 1998), may also be an important field to add.

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DISCUSSION

Q. Who are your respondents?

A. People who know about their fisheries.

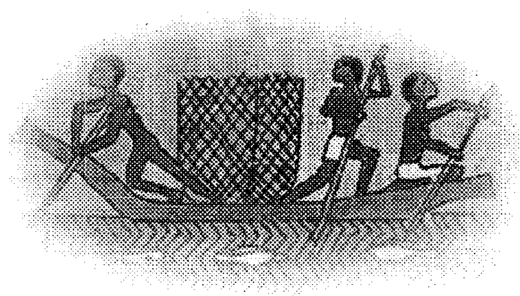
Q. Did you send this information to more than one person?

A. No, only to one person per fishery.

Q. Why did you not ask fishers themselves to do the evaluation?

A. I am going to do this in the near future in Newfoundland.

IV



Overviews

Ecosystem Studies and the Modelling of the Fishery in Lake Nasser/Nubia

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Patterson, G. 2000. Ecosystem studies and the modelling of the fishery in Lake Nasser/Nubia, p. 119-127. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT
This paper reviews basic limnological studies on Lake Nasser and recommends that further work concentrates on an understanding of seasonal structure, principal habitats of the lake and primary production rates in these habitats. This will provide accurate estimates of the carbon flux of the lower trophic levels that can be used in fish production modelling for the lake (ECOPATH). Appropriate methods to be adopted are also discussed and constraints identified.

Introduction

This paper attempts to draw together the discussions which took place during the Workshop. In particular, it considers basic ecological studies that provide relevant information for the management of the fishery in the lake. These include climate, hydrology, physico-chemical properties of the water column, and measurements of phytoplankton and zooplankton. The prime objective is to provide information for quantitative modelling (e.g., ECOPATH, Pitcher, this vol.) of the ecosystem. Studies of the "production basis" of the lake would also allow for short-term predictions of potential yield, which could be used in the management of the fishery on, for example, a seasonal basis. Ecological studies are also of value to allow an understanding of human-induced factors which may be having an impact on the lake (pollution), allowing management priorities to be set.

Current knowledge of the ecology of Lake Nasser is summarized in detail by Latif (1984). Papers presented at the Workshop and published as background papers in these proceedings provide additional and updated information.

This paper summarizes the author's view (derived from discussions generated during the Workshop) on how to direct hydrological and ecological studies (particularly at lower trophic levels) to better understand the basis for fish production in Lake Nasser. This will include an understanding of (a) hydrological cycles, (b) light regimes, (c) nutrient regimes (including oxygen) and (d) habitat types. Further, the collection of suitable data on (e) "biomass and taxa" and (f) carbon flux rates at lower trophic levels (primary and secondary production) will provide essential inputs into a larger ecosystem model (ECOPATH), giving insights into the basis of yield and variability in the fishery (see Pitcher, this vol.). The paper is broken into these headings (although there are many cross-cutting issues) and considers the various methods which could be adopted to perform the proposed work. Constraints to carrying out this program are also discussed. The Appendix specifically examines the value of remote sensing to the proposed study.

Hydrological cycles

Lake Nasser is a warm monomictic lake (using the definitions of Wetzel 1983) with a period of thermal stratification during the summer months, and complete mixing of the water column during the winter. Most published data on the thermal structure of Lake Nasser are from the central channel of the lake, and it may be that the mixing regime is more complex in some of the shallower bays (khors). It is also noteworthy that the hypolimnion rapidly becomes deoxygenated during the summer, and this is discussed in the section on "Nutrients and oxygen". Seasonal and interannual variation in overall volume of Lake Nasser is discussed in the section on "Habitat types".

The thermal structure of the lake is principally controlled by meteorological conditions (mainly air temperature and wind), and these factors are obviously not consistent year by year. Lake Nasser is further subject to interannual variation due to the variable volumes of water carried into the lake dependent on rainfall in the catchment. It is emphasized here, therefore, that all the studies suggested below have to be part of a long-term monitoring program designed to examine this inter-annual variation. A direct understanding of stratification is fundamental, and a program designed to understand the three-dimensional structure of the lake is recommended.

Studies on thermal structure generally require the use of a conductivity/temperature/depth probe (CTD) which allows for rapid plotting of water density/depth relationships. As stated above, there may be a complex stratification/mixing regime within the lake, and therefore the number of profiles recorded should be maximized. Profiles should be collected from shallower areas as well as from the main channel. Transects from shallow areas into the main channel during different periods of the annual cycle would usefully illustrate the whole three-dimensional structure of the lake. Since stratification is fundamentally linked to deoxygenation in the lake (see below), oxygen should be measured; incorporating an electronic oxygen meter with the CTD may appropriately do this.

Due to its reliance on ship deployment, the temporal intensity of measurements using a CTD is often limited. One solution is the installation of thermistor chains anchored to the bottom of the lake, to continuously record temperature at selected depths. These devices are expensive and, unless there are multiple deployments, site selection and therefore degree of spatial coverage, are problematic. It may be that a system of this kind close to the water outlet of the hydroelectric turbines could play a dual role in Lake Nasser, and the cost (and data) could be shared between researchers and the power-generating authorities. Additionally it is suggested that monitoring of night-time lake surface temperature using satellite imagery (with concurrent measurements of temperature profiles and surface temperatures to assist with calibration) may offer a synoptic view of lake structure (see Appendix).

As previously mentioned, the stratification/mixing regime is fundamentally driven by climatic factors. It is therefore important that meteorological data from the lake are collected so they can be related to the stratification/mixing regime by using various hydrological calculations on energy balance and stability of stratification.

Light

One of the characteristic features of the annual flood of the Nile in the lower Egypt Valley was the large amount of suspended sediments carried down by the river. Since the building of the Aswan High Dam, these sediments have tended to accumulate in Lake Nasser although they are carried a certain distance along the lake from their input point in the south. An important consequence of this turbid water is that it rapidly attenuates surface-arriving irradiance through the water column. This may be an important factor limiting primary production in the lake, and may be a more important factor than nutrient limitation (see below).

Light extinction is measured by calculating the slope of light intensity: depth curve using a submersible electronic probe sensitive to Photosynthetically Active Radiation (PAR). These devices can be incorporated with CTDs. The less expensive Secchi disc, though, is a useful indicator of light availability for photosynthesizing organisms, and it is suggested that Secchi depth be incorporated in all possible sample locations. This method is sufficiently simple that, combined with a Global Positioning System (GPS) reading, it can be carried out by nonspecialists (such as fishers). As many readings as possible in all parts of the lake and all seasons are recommended.

It would be advisable to relate Secchi depth with direct measurements of suspended materials, which involves filtering water, drying and weighing the filtrate to measure suspended load directly. The correlation will never be perfect due to variation in the nature of the suspended material (including plankton), but would probably suffice so that Secchi depth can be used as a semi-quantitative measure of suspended load, as well as to estimate the depth of the euphotic zone.

The possibility that remote sensing may be able to provide a more synoptic view of suspended load (and therefore light penetration) is discussed in the Appendix. Direct measurements using light meters and/or Secchi depth would then play an important role in improving the quantitative estimate of sediment load from remote sensing.

Nutrients and oxygen

Lake Nasser is clearly rich in nutrients, as large amounts are carried into the lake during annual floods from the catchments of the Blue and White Nile. Figures for dissolved nutrients in the lake quoted by Goma (this vol.) and by Latif (1984) indicate high levels of orthophosphate (>0.3 mgl^{-1} P) and nitrate (>0.5 mgl^{-1} N) in the open water of the lake. Values in the enclosed khors are likely to be higher. An approximation of the published N:P ratios suggests that N probably becomes deficient before P (i.e., the lake is potentially N limited); and the high numbers of heterocystous N-fixing cyanophytes in the lake (principally *Anabaena* spp.) also indicate relative N deficiency. However, the fact that there are easily detectable concentrations of available N and P in the water column suggests that nutrient deficiency is not a factor in the lake and that, possibly, the only limitation to production is light (see above) and the annual deoxygenation of a large proportion of lake water.

From this point of view, it is surprising that Lake Nasser has not suffered (as is common with similar nutrient-rich waterbodies in the tropics) a major bloom of aquatic macrophytes. Because many of these problematic exotic weeds exist in the catchment of the lake, it seems unlikely (though not impossible) that this is due to a lack of inoculum. At present, a bloom of aquatic macrophytes must be considered as a potential problem and should be monitored diligently, as it could have a catastrophic effect on the fishery and an even worse impact on the operation of the hydroelectric output of Aswan High Dam.

Limnological studies often include measurement of available nutrients. There are, however, a great number of problems in interpreting these data. Point measurements of nutrients take little account of their flux rates. For example, a number of highly productive waterbodies show levels of dissolved nutrients consistently below detection limits (approximately 3 $\mu g l^{-1}$, i.e., values < 1% of those found in Lake Nasser). This perceived anomaly between low nutrients and high production is due to the rapid recycling of dissolved nutrients in nutrient-limited systems. Nutrient status can be somewhat better interpreted by measuring "total" values of N and P by digesting unfiltered water samples. This still leads to problems of interpretation since it is likely that values for "total" N may overestimate the N value available as a nutrient for the phytoplankton; "total" P is a better measure of available P. Studies on nutrients in Lake Nasser should be directed towards understanding the nutrient budget of the lake, and it is suggested that knowledge of major nutrient pathways would be of value. This would include water inputs at source, atmospheric inputs, internal recycling of nutrients, as well as N-fixation by cyanophytes and denitrification by bacteria. It would require, however, a major study and it is suggested that some limited program of measuring total nutrient values (N, P and Si), as well as an understanding of the major sources and sinks of nutrients, would suffice where a greater level of detail regarding primary production rates (in different habitats) is part of the same program (see below).

Increases in human population in the Lake Nasser region (particularly the major program to settle large numbers of people close to the lake as part of the Tushka Project) are likely to result in increased nutrient input to the lake. Whether this will have an impact on the already nutrient-rich water is doubtful. More likely is the increase of other pollutants (hydrocarbons, pesticides and heavy metals) which may prove a problem. Environmental impact assessment (EIA) of resettlement programs in the region of Lake Nasser is recommended.

The summer deoxygenation of the hypolimnion is an important feature of Lake Nasser. The depth of the oxic-anoxic boundary varies in the main channel of the lake from 10 to 30 m according to Latif (1984) and Abd Ellah et al. (this vol.). The depth of the oxic-anoxic boundary in shallower parts of thc lake is not reported, but the extent of deoxygenation may be an important factor in limiting fish production. Fish cannot survive in deoxygenated water and therefore parts of the lake they can occupy during summer are reduced. Truly pelagic fish (of which there are few in Lake Nasser due to thc original riverine fauna) will simply be compressed into the upper parts of the water column. Large areas of benthos, however, will be inhabitable for the stratified periods, and this limitation of feeding areas may be a notable constraint on fish production. This may be exaggerated due to the fact that populations of less-mobile benthic invertebrates will be fewer in areas subject to repeated deoxygenation. Fishar (this vol.) showed there was very limited benthic fauna in deeper waters). It is recommended that greater attention be paid to plotting the oxic-anoxic boundary in all parts of the lake in order to understand the variation in habitat conditions (see section below on habitat types).

Conditions of deoxygenation at the sediment/water interface of large portions of the lake will also allow trapped nutrients to be released from the sediment as they become more soluble at lower redox potentials. This factor may be important in maintaining the high nutrient status of the lake.

Habitat types

Similar to most tropical lakes subject to wet and dry seasons in the catchment, there is a seasonal variation in lake level. As large quantities of water are drawn off to maintain power generation and acceptable volume of flow in the lower Nile, this is even more exaggerated in Lake Nasser. There is a seasonal difference in water level of 10-20 m, with lowest values around August and highest values around December. In addition, the mean annual level of the lake has varied since the closure of Aswan High Dam, with a period of filling from 1964 until the early 1980s, followed by a decline due to a period of exceptionally low rainfall in the catchment. Since the late 1980s, the volume of the lake has risen close to its highest acceptable level, which equates to a water volume of 168 km^3.

These water level variations have enormous consequences on lake habitats with, for example, productive benthic areas drying out during periods of low water level, or becoming too deep to support active photosynthesizing organisms (i.e., below the euphotic depth) during periods of high water level. Similarly, inundation of benthic areas with deoxygenated hypolimnetic water may also have a dramatic effect on primary and secondary production (see section on nutrients and oxygen above). Benthic production may be a major, if not the dominant, input of carbon into the food web of the lake. This may be exaggerated in Lake Nasser where the fish fauna is of predominantly benthic feeding fish and lacks true pelagic species.

The bathymetry of Lake Nasser is well known, being basically that of the well-mapped topography of Nile Valley prior to closure by the Aswan High Dam. It would seem appropriate that a simple geographical information system (GIS) could be developed which considered depth (at various filling levels), oxic-anoxic boundary depth and light regime (with knowledge of water turbidity), to define those areas dominated by benthic and pelagic production for any given time. Values obtained for biomass (both primary and secondary producers) and production rates could be applied to this habitat mosaic to give overall lakewide production estimates. This would inevitably be a fairly crude estimate of lakewide production (though improving with greater knowledge of limnological processes and primary production rates - see below), though far preferable to previous estimates. It would generate more realistic figures of benthic and pelagic production for entering into the ECOPATH model. A GIS of this kind would also allow greater understanding of interannual variation in fish catch, as it would provide a lakewide estimate of carbon input.

It may be useful to calculate the variation of lake surface area from satellite imagery (see Appendix) for comparison with that calculated from knowledge of lake bathymetry.

Biomass and taxa

The simplest way to estimate biomass of primary producers is to measure chlorophyll *a* concentration; and methods for assessing both planktonic, floating macrophyte and benthic chlorophyll *a* are straightforward. Converting chlorophyll *a* concentrations to total dry mass (needed for the ECOPATH model) leads to inaccuracy in the estimation of dry weight, despite the fact that published conversion rates exist. This is, however, likely to prove more straightforward than other direct or indirect measurements of plant biomass. Dry mass of macrophytes is relatively simple to measure directly, but for microscopic algae it is particularly difficult. Biomass for planktonic algae often estimated from biovolume, which depends on a calculation of size and shape of all planktonic taxa and a reasonable quantitative method of estimating the populations of these taxa—this is done by counting (usually with an inverted microscope). To count samples to the level of accuracy required for biomass estimates requires skill and is time-consuming. It is probably not necessary to count to this level of accuracy if chlorophyll *a* measurements are also being made.

Examination of identified taxa present in both planktonic and benthic populations should, however, be carried out at least to a semi-quantitative level, as seasonal or spatial variations in dominant taxa provide important clues for lake processes. Particularly, the relative proportion of the main algal divisions should be recorded where, for example, a high proportion of cyanophytes may indicate the possibility of fish poisoning, N-fixation (where heterocysts are present); and also are generally regarded as poorer food items for fish compared to other groups (such as diatoms).

The only accurate way to measure zooplankton biomass is by counting the organisms (usually sampled using a variety of nets) and working out a relationship between size of individuals and their biomass (simply counting individuals will not suffice as an input to the ECOPATH model). Since the zooplankton community tends to be dominated by a few species only, it is possible to make reasonable estimates of zooplankton biomass in this way

Similarly for benthic invertebrates, methods for biomass estimation involve counting and size estimation. This is a more difficult exercise than for plankton since the benthos is much more heterogeneous than the pelagic environment and the range of organisms found is greater. For Lake Nasser relating distribution of benthic populations to the depths of light penetration and the extent of deoxygenated sediment boundary water, will reveal a great deal about the principal secondary producers. As stated above, it is felt that benthic production may dominate over pelagic production, and therefore is worthy of increased study. Since the distribution of benthic organisms is highly depth dependent, an appropriate sampling strategy would be to assess benthic populations on a transect from the lakeshore to deeper water. It would be appropriate to carry this out at low and high levels of water to investigate the ability of these organisms to recolonize substrate exposed during periods of low water level, as well as their ability to recolonize deoxygenated zones after reoxygenation during the autumn turnover. Fishar (this vol.) has made good preliminary studies of the benthic fauna.

It is likely that efforts to estimate bacterial biomass would prove of little value unless major resources are dedicated to them. This is not likely to be required for the satisfactory production of the ECOPATH model of the lake, though the amount of carbon recycled via detrital breakdown of bacteria could be high.

Carbon flux rates

Obviously a critical value required by the ECOPATH model, and one of the well-accepted limiting factors on fish production, is the rate of primary production in Lake Nasser. There are some published rates for primary production of plankton

(Habib, this vol.), though no published rates for the benthos primary production (to this author's knowledge). As stated earlier, benthic production may be a larger proportion of total lake primary production than previously envisaged.

The choice of methods for measuring primary production is principally between radioactive ^{14}C (measures carbon uptake) or oxygen light/dark methods (measures oxygen evolution by photosynthesis). The ^{14}C method has advantages where photosynthetic rates are low and greater sensitivity is needed; the oxygen method is less sensitive but requires lower technology and is a better measure of both gross and net photosynthesis than the former (which measures some value between gross and net photosynthesis). At lower rates of photosynthesis, the oxygen method suffers in comparison where longer incubation periods may be required to show an oxygen difference between the light and dark incubation vessels. Since production rates for Lake Nasser are generally high, this is probably not a problem, and therefore it is recommended that the oxygen method be used exclusively.

The oxygen method for measuring planktonic photosynthesis is already well established in Lake Nasser. Techniques for measuring benthic production are a little more complex, and require light/dark incubation chambers which can be placed over areas of rock or sand and water samples drawn off to measure oxygen concentration. It is easier to deal with these chambers by sending down divers to sample the water prior to their being disturbed by the removal of benthos for measurement of biomass (as chlorophyll *a*). The use of divers is probably inappropriate due to the presence of crocodiles. The alternative to *in situ* incubations may be to develop a shipboard method on benthic core samples.

Though aquatic macrophytes would be included in benthic samples, it would be useful to measure production rates on portions of macrophytes by labelling individual plants to examine growth.

Though techniques to estimate biomass of secondary producers are straightforward (though time-consuming), estimating production rates of both zooplankton and benthic fauna is difficult. It may be that this value could be satisfactorily entered as "unknown" in the ECOPATH model. The cohort method, often used for measuring secondary production of zooplankton, is unlikely to be of value in Lake Nasser since invertebrate populations will probably not be easily separable into distinct cohorts. Life-cycle studies on common zooplankters would answer this. A similar but more highly developed method than cohort analysis is the "growth increment summation method" (for discussion, see Rigler and Downing 1984) which takes into account the development rates of each distinct life stage. This may be appropriate for estimating zooplankton production rates for the few dominant species in the lake. Measurement of production rates for benthic fauna is also notoriously difficult and probably beyond the scope of the program proposed for Lake Nasser.

As stated above, bacterial production may form an important link in the carbon pathways of Lake Nasser — particularly in deoxygenated benthic environments. The dominant processes are likely to be methanogenesis and sulphur reduction (hydrogen metabolism); measurement of methane and hydrogen sulphide concentrations in deoxygenated hypolimnetic water may give an approximate value of the rate of these processes during the stratified season.

There is a recently developed method using stable isotope ratio analysis to indicate both the sources of energy (carbon) of biological tissue. This can assist with an understanding of the relative contribution of benthic production versus pelagic production in fish tissue since the different carbon sources are likely to have different isotopic signatures (^{12}C:^{13}C). Additionally, the ratios of nitrogen isotopes (^{14}N:^{15}N) in fish tissue are a good indicator of their trophic position. Nitrogen ratios could be used to test the ECOPATH model and the relative trophic level at which various species and ages of fish could be assigned. Further information on this method is available in Lajtha and Michener (1994). It is felt that initially tissues should be sampled and stored for possible analysis of stable isotope ratios, and a study of this kind be costed.

Constraints

A list of constraints were identified at the Workshop (see also Craig, this vol.) which outlined the difficulties of performing the studies described above. It is in these areas that efforts should be made towards initiating improvements and to which resources should be directed. Establishing the balance of effort in dealing with these different constraint areas is one of the major challenges in upgrading the ecological research capacity on Lake Nasser. Constraints identified were as follows:

- Scientists responsible for sampling and processing data may not be sufficiently trained
- Lack of scientific equipment (both major items and consumables)
- Lack of computing facilities
- Lack of literature
- Lack of communication and technical support from scientists outside the region (isolation)
- Lack of well-trained technicians (particularly in equipment maintenance)
- Lack of ship time to carry out sampling programs
- Lack of time (this alludes to those scientists charged with insufficient data collection and being too busy with other duties).

All these constraints need to be addressed by future projects. They can be summed up as "adequately training and resourcing staff of the national institutions responsible for carrying out these studies". Improving communications is a vital part of this process.

There also appears to be a lack of clarity of institutional responsibility and need for a coordinated approach to this work. The workshop discussions reported in these proceedings can be regarded as an important first step in developing an integrated approach. Data from a wide range of national institutions should be collated, for example, the High Dam Lake (Nasser) Development Authority collects hydrological and meteorological data, which should be archived and made available to all scientists in the region. A number of other similar examples exist. These data may already be available, and it is possible that scientists are simply not aware of them. In particular, a greater level of cooperation is encouraged between the two principal aquatic research organizations, the Fishery Management Centre and the National Institute of Oceanography and Fisheries. They should demarcate their areas of responsibility in order to avoid duplication or, worse, gaps in data collection.

Although there is no evidence of research and monitoring taking place in the Sudanese part of Lake Nasser/Nubia, it is clearly desirable that Egyptian and Sudanese scientists cooperate in the monitoring of this shared resource. Knowledge on the quality and volume of input waters from the Nile can be provided only from Sudan, and it is likely that at least these basic values are collected in Khartoum below the confluence of the White and Blue Nile.

Conclusions

Future efforts to understand the productive basis of Lake Nasser should concentrate on estimates of primary producer biomass (as chlorophyll *a*) and production, and their spatial and temporal variation. This will require knowledge of variation in the principal factors that dictate distribution of primary producers, such as stratification (inducing oxygen depletion), light penetration and habitat types. Nutrient studies should be carefully planned to ensure that results can be related to biological functions and therefore be interpreted. Measurement of populations of secondary producers (principally the invertebrates) should also be carried out with the objective of understanding the biomass of each major group on a lakewide basis. Values derived from these studies will then be used in modelling to determine whole-lake processes, particularly the production of important commercial fish species.

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DISCUSSION

Q. How important is wind in nutrient cycling in Lake Nasser, in view of its importance in other lakes? Is there a database of meteorological measurements, including wind speed?

A. Wind is very important in determining stratification patterns, perhaps more important than temperature. Data on wind speed are available but there are still some uncertainties about how to analyze them. The importance of wind on the lake is well known, and fishers have reported that fish kills occur after windy periods, when anoxic water is brought to the surface. Methods to incorporate wind data into density estimations are available.

Q. A large quantity of data is now available from remote sensing. How much of this could be applied to Lake Nasser?

A. Satellite data can provide information, such as surface temperature, which cannot be collected by conventional means in a large lake such as Lake Nasser.

Q. You emphasized the importance of benthic productivity. FMC have some data on this. It ranges between 60-420 t $year^{-1}$ at a lake level of 160 m. How could the estimate be improved?

A. If basic morphometric data are available, and the pattern of stratification is known, it should be possible to determine the area available to benthic algae, and therefore to estimate benthic productivity. Even if this were a general estimate, it would be possible to determine the relative importance of benthic and pelagic production.

Q. Lower trophic levels in the system are the basis for fish production but are of little interest to fishery managers. Can you determine which limnological factors are of critical importance to the fishery?

A. This is a difficult question to answer, as it is not always easy to link limnological factors to the actual practice of fisheries management.

Q. Primary production is very important in generating material through carbon fixation, and therefore needs to be understood. However, increasing primary productivity may drive material into a microbial loop. What needs to be known to understand the consequences of increased primary production in Lake Nasser?

A. This phenomenon is most common in disturbed systems and may be a consequence of overfishing. Estimating biomass in ecological models may help to determine if material is going into microbial loops, but we need to understand the carbon pathways.

Q. Water management of Lake Nasser indicates major losses of water, the quantity of which depends on changes in lake level. When the lake is high, this might be 2-3 m $year^{-1}$, but when it is low, it might be as much as 8 m $year^{-1}$. Can we recover what is lost, and what are the effects of density patterns on fish?

A. Limnology cannot determine the extent of water losses, but an understanding of limnology enables the consequences to be predicted. The pattern of density in the water primarily affects deoxygenation, which can lead to nutrient limitation, restrict benthic productivity, and cause fish kills. One fish kill was reported in 1997; but fish kills are not generally a problem since fish are able to avoid deoxygenated water.

Q. Would you comment on the cycling of nutrients like orthophosphate or nitrate.

A. High levels of nutrients like orthophosphate or nitrate, as in Lake Nasser, indicate surplus nutrients. In Lake Malawi, for example, these nutrients were never detectable; this indicates that nutrients do not limit production in Lake Nasser. Nutrients in deep water are recycled, but those lost in the outflow will be replaced by those brought by the inflow, so the system is probably in equilibrium. Temperate waters tend to be P-limited, while tropical waters are often N-limited. However is there any evidence of this in Lake Nasser? A quick way of assessing the extent of N-limitation is to examine the prevalence of heterocysts in blue-green algae.

Q. The Nubian villages that were drowned had extensive cultivated areas around them. Could the decay of plant material in these areas be contributing to the deoxygenation and high nutrient level in Lake Nasser?

A. This is always the case in tropical reservoirs shortly after they fill, but the short retention time of Lake Nasser means that nutrients from this source will have been lost by now. Nutrient losses should by this time be balanced by the inflows. It is relatively simple to estimate a nutrient budget, especially in Lake Nasser, which has only one in-flowing river.

Q. In many parts of the world, attempts have been made to increase fish productivity by adding nutrients or creating artificial upwelling. Is there a scope for this in Lake Nasser?

A. Not really. The scale of Lake Nasser is too great for engineering solutions like this. Anoxic water may create problems in the turbines or downstream, and could also increase sedimentation.

Q. What is the effect of water level fluctuations on the pelagic fishery of Lake Nasser?

A. Probably very little. It is the benthic system that is most likely to be affected by the fluctuations.

APPENDIX

Use of the National Oceanic and Atmospheric Administration (NOAA) satellite imagery to interpret suspended loads and thermal structure of Lake Nasser

Lakes and reservoirs are dynamic systems, and significant changes can occur over a period of a few days. Satellites can be used to survey whole waterbodies over this time span. NOAA satellites can measure lake surface temperature, distinguish between water and land, and measure concentrations of suspended matter in the water column[1]. The orbit of the NOAA satellite passes each point on the earth's surface twice a day at approximately the same time each day (giving one day and one night images). Daytime images are used for measuring suspended matter in water; night-time images are used for measuring lake surface temperature and water extent. The resolution of NOAA satellites is approximately 1 km^2, and therefore for Lake Nasser there will be approximately 6 000 pixels (data points) making up the image.

Most archived raw NOAA imagery is downloadable from the World Wide Web at no cost. The NOAA data archive site on the Web for the Lake Nasser region shows that from August 1997 to August 1998, there were 64 images available,

[1] Assuming cloud-free conditions—not likely to be a major problem in the region of Lake Nasser.

spaced approximately evenly throughout the year (approximately five images per month). Almost all are day images, however, which can be used for sediment measurements but not for thermal studies and water extent. For the period August 1996 to August 1997, there was a greater number of images (total 236), and these are a mix of day and night.

The NOAA website is being added to all the time. It will certainly be operational in the foreseeable future (funded under NASA's Mission to Planet Earth—a 15-year program). There are also other alternative sources of NOAA data for the area. This may be required since it appears that the number of images archived for the area can change from year to year. One possibility is to specifically request from NOAA that the 1 km resolution data be captured routinely over the area and archived on the web (this may be a free service). Since the area of our interest (Lake Nasser) is relatively small, it may be that some users requesting data from the same orbit (for example US Government sources) would have priority. Occasionally, therefore, the Lake Nasser data would not be archived. A further alternative to web-derived data is to have a local NOAA receiver with processing software. This guarantees regular "real-time" data, but is costly (approximately US$50 000). It may be an option if the system can be proven to be of value. Ground-truthing of NOAA imagery for Lake Nasser is seen as an important next step before the purchase of a receiver is considered. An important advantage of a local receiver is that imagery arrives in real-time, and therefore allows immediate response with respect to management actions or directing sampling programs.

The NOAA images of Lake Nasser shown here are of surface temperature (Fig. 1) and suspended matter (Fig. 2). The algorithms used to derive these values are not tested for Lake Nasser and are therefore not completely reliable. Fig. 1 shows temperature variation of the surface water, and these values seem close to the expected (Latif 1984). The image was captured in April when the thermocline was beginning to form. Warmer water in the south compared to the north suggests that the thermocline develops earlier in the south of the lake. The narrower parts of the channel also show higher surface temperatures, suggesting earlier formation of the thermocline in these relatively sheltered parts of the lake.

In Fig. 2 the estimate of suspended matter is semi-quantitative and could only be further improved by comparing satellite-derived data directly with *in situ* measurements of suspended matter (or some proxy value of suspended matter such as Secchi depth). Fig. 2 does, however, clearly show the change in concentration of suspended matter between the source of sediment input in the south of the lake to the Aswan High Dam in the north where water clarity is much higher.

A project to assess the value of NOAA imagery would be an ideal research topic for an Egyptian postgraduate student spending approximately 50% of his/her time in a center of excellence for remote sensing, and 50% in the field working with a regional institution, collecting *in situ* data. This would be a suitable M.S. or a Ph.D. For further information on remote sensing of inland waters see: Patterson, G., M. Wooster and C. Sear. 1995. Real-time monitoring of African lakes, reservoirs and wetlands using remote sensing with special reference to Lake Malawi/Niassa. NRI Special Publications (copies obtainable from the author).

Aquaculture

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ABSTRACT

Construction of the Fishery Management Center (FMC), Aswan, was completed under Japanese aid in 1981. Cooperative studies between the Japanese and Egyptian Governments on seed production and aquaculture continued until 1993. Techniques for artificial seed production of tilapia (*Oreochromis niloticus*) were developed at FMC, and a large-scale hatchery was completed in 1998. Experiments on breeding and stocking the lake with silver carp (*Hypophthalmichthys molitrix*) fry were carried out. Fry production technology for benni (*Barbus bynni*) and Nile perch (*Lates niloticus*) have been investigated. Relevant legislative and management measures must be implemented for successful fish propagation. Investigations to determine the cause of species decline must be made before selecting suitable species for enhancement. The possibility of introducing new fish species into the openwater pelagic area is being considered.

Introduction

In May 1978, the author came to Aswan for the first time to formulate an integrated regional development plan for the Lake Nasser area in southern Egypt. From the results of this research, the Egyptian Government judged that fisheries showed the most promise. Fishing was already practiced in the lake and there was a high potential for production. The FMC, constructed under Japanese grant aid, was completed in December 1981. Cooperation between the Center and Japan continued for 12 years until December 1993. Expert help was supplied by the Tokyo University Fisheries Department.

Main results obtained in seed production and aquaculture

Mass production technology for tilapia *(Oreochromis niloticus)*

The techniques of artificial seed production, which consist of egg taking and fertilization from cultured and/or captured wild fish, hatching out and rearing of fry up to release size, were developed at FMC. It has been possible to produce about 500 000-600 000 fry (average body mass 2-7 g) per 300 female broodfish which were kept in 400 m^2 ponds. A new large-scale hatchery was completed in 1998. Judging from the tentative production performance undertaken by FMC, it is considered that 5-6 million fry can be produced in the new hatchery per annum.

Culture of silver carp, *Hypophthalmichthys molitrix*

Since 1984, FMC has conducted induced spawning of silver carp by hormone (pituitary) injection. FMC can produce one million eggs and 100 000 fry each year. Experiments were carried out on the potential of stocking the lake with silver carp fry. FMC installed three net cages in separate areas of the lake, and fry of 28 g were stocked. In one area, fish grew to about 2 kg in 15 months and production was 7.8 kg m^{-2}. In the other two areas, they hardly grew and survival was low (See Shenoda and Naguib, this vol.).

Artificial propagation technology for fish conservation

Several fish species in Lake Nasser and the River Nile have declined. Fry production technology has been investigated for benni (*Barbus bynni*) and Nile perch (*Lates niloticus*). Induced spawning of Nile perch was attempted by hormone (HCG) injection. The female released some eggs, but these eggs did not fertilize. Benni were caught by bottom gill nets from January to December 1987 in Lake Nasser. Two periods of maturity (based on gonad development, "GSI") were noted in March-June and September-October. Eggs from these fish were stripped and artificially fertilized and reared from July to December. They grew to 52 cm and 80% survived. Growth decreased at 23.0°C and stopped at 16.0°C. At the end of December, all fish died when the temperature dropped to 15.0°C.

Techniques and measures for the successful propagation of fish resources

When fisheries resources are decreasing in natural waters, efforts should be made for recovery by using techniques such as propagation. Three areas of study are involved:

- Legislation: restriction and prohibition on catching specified species; establishment of closed seasons and areas; restriction on the use of specified fishing gears; and methods and size limits.
- Management of the natural environment: the increase and improvement of spawning grounds; establishment of conservation areas; and removal of predators.
- Stocking: release of large quantities of eggs and fry into natural waters.

Selection of fish species for propagation

Fish species that are suitable for propagation and that tend to decrease in the lake must be chosen. According to fishery statistics of 1966-1992, catches of *Labeo* spp. and *Bagrus* spp. have decreased remarkably. Tilapia also decreased at certain fishing sites. In the choice of fish species for propagation, it is necessary to determine whether the decrease is due to overfishing, change in environmental conditions, or interrelationships among fish species. The following information are required:

- Environmental information: water temperature, pH, transparency, dissolved oxygen, TDS, chlorophyll *a*, phyto- and zooplankton (species and number), and total nitrogen and phosphorus.
- Biological information: habitat and food preferences during ontogenetic development, interrelationships among species, age and size at maturation, preferred spawning grounds and spawning seasons.
- Fishery information: monthly catch statistics classified by the fishing grounds and by species, fishing gears employed, fishing effort and landed fish surveys (distribution of fish length and age, GSI, etc.)

A number of important factors have to be considered before releasing large numbers of artificial seed. In particular, following the Rio de Janeiro Convention (1992), care must be taken with the introduction of exotic species which may have a detrimental effect on the ecosystem. Stocked fish should normally be endemic.

Benni is one of the important species of Lake Nasser and common in the southern part. Techniques for the artificial seed production of this species should be improved, and large numbers of fry stocked in the lake.

Labeo and *Bagrus* species may have decreased due to low oxygen in the bottom layers of the lake in summer and/or overfishing by bottom gill nets in the southern part of the lake. These factors need to be investigated.

The Egyptian Government hopes to introduce new fish species into the openwater area of Lake Nasser, which makes up as much as 80% of the total lake area but only 6% of the total catch.

Conclusions

The fundamental task of FMC is to conduct research that will be useful in maintaining the natural living resources of Lake Nasser. Aquaculture should continue to release a large quantity of tilapia fry, and study the effect of release by tagging methods. Experiments on seed production of useful native species should continue. The selection and introduction of fish species, which can utilize the openwater area in Lake Nasser, should be undertaken to increase total yield of the lake.

DISCUSSION

Q. What is the contribution of cage culture for fish such as silver carp? How do you control escapes from these cages?

A. The cages can be placed in inshore rocky areas or in deep parts of the lake where there is no fishing. The culture of these fish can increase the income of fishers. Fish do escape from the cages, but they do not appear to reproduce in Lake Nasser. The fishers have caught a few escaped fish from the experiment in 1990.

Q. What aquaculture systems should be used to avoid water quality problems?

A. Silver carp cultured in cages are not given artificial food and therefore there are no problems. In the net cage culture trials, no pollution was found in the surrounding area.

Q. Why not use tilapia for cage culture instead of silver carp since the former is preferred by Egyptians?

A. This may be done on a small scale, relying on the fish to feed on natural foods. However, on a large scale, artificial feeding would be required and this could lead to water quality problems.

Stock Enhancement

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ABSTRACT

Enhancement of fish stocks through repeated stocking with material raised within aquaculture installations is one of the most widespread measures for management of inland fisheries today. Stocking programs have often been implemented without properly examining the causes for the decline in the fishery or the reasons for suboptimal production. This has resulted in failures of stocking programs in the past because factors, such as overfishing, poor fisheries management and degradation of the aquatic environment were not simultaneously addressed. Few stocking programs have been evaluated in terms of their returns, cost-benefits and associated environmental impacts.

Introduction

Enhancement of fish stocks through repeated stocking with material raised within aquaculture installations is one of the most widespread measures for management of inland fisheries today (Welcomme and Bartley 1998). Stocking of open waterbodies refers to a repeated release over a prolonged period to supplement or sustain a population of a species that generally already exists or that was introduced before (Cowx 1998). In contrast, introductions are usually carried out in a limited time frame with the aim to establish self-reproducing populations. The aims of stocking programs are to supplement or sustain the recruitment of one or more aquatic organisms and thus to raise the total production or the production of selected elements of a fishery beyond a level which is sustainable by natural processes (FAO 1997a). The definition of the term "stocking", and whether the outputs of stocking programs should belong to aquaculture or capture fisheries production statistics, is still a topic of debate. Because stock enhancement is often not included as a separate item in production records, future prospects of stocking as a tool to increase food security are difficult to predict. Inconsistent reporting makes global assessment of stock enhancement complicated, so formulation of a clear definition of stocking and guidelines for its reporting need to be developed both globally and nationally.

In the literature, stocking or stock enhancement is also referred to as hatchery enhancement, culture-based fisheries, artificial stocking and extensive aquaculture. For the purpose of this paper the term "stocking" is used.

Stocking should be considered if the natural reproduction rate of the target species is not sufficient to sustain a certain level of production or biomass in a population. However, stocking programs have often been implemented without properly addressing the causes for the decline in the fishery or the reasons for suboptimal production. This has resulted in failures of stocking programs in the past because factors, such as overfishing, poor fisheries management and degradation of the aquatic environment, were not simultaneously addressed. It is of utmost importance that stocking programs are undertaken concurrently with appropriate monitoring and management measures, e.g., restriction of fishing effort, closed seasons, closed areas and protection of vital habitat, to make them sustainable and more effective.

Stocking is practiced for various reasons of which the most important ones are (Cowx 1994; Welcomme and Bartley 1998):

- Compensation: to mitigate a disturbance to the environment caused by human activities. The quality of the altered or alternate habitat should be sufficient to ensure survival of the stocked fish. Native species should be stocked and care should be taken to stock similar numbers of a genetic structure resembling the 'old' situation.

- Enhancement: to maintain the fisheries productivity of a waterbody at the highest possible level or to re-establish fish populations in seasonal waterbodies. Avoidance of negative impacts of the stocked species on the wild stocks must be ensured. The habitat must be able to sustain the extra production.
- Maintenance: to compensate for recruitment overfishing. It is critical to avoid changing the gene pool, which may reduce the fitness of the native stock.
- Conservation: to retain stocks of a species threatened with extinction. It must be ensured that the quality of the environment is sufficient to ensure reasonable survival rates. The genetic diversity of the stocked fish should be as variable as possible because the population size is likely to be small.
- Restoration: to restore fish stocks after a limiting factor has been removed or reduced (e.g., water quality improvement, habitat restoration).

Generally, stocking programs in developing countries focus on maximizing fisheries production for human consumption (Welcomme and Bartley 1998). An extensive literature search in FAO's Aquatic Sciences and Fisheries Abstracts (ASFA) database on stocking literature in the Asian, African and Latin-American regions showed that 72% of the references, those that included a reason for the stocking operation, were for production of food and income (Table 1). Stocking for enhancement is often the first apparent reason in developing countries, but other reasons can be important such as the release of masheers, *Tor* spp., in India for conservation (Ogale 1994). However, stocking for compensation, conservation and restoration is generally more important in developed countries because it is related to improving the quality of life.

Two different management approaches can be distinguished in stocking programs. First is the intention to support a fishery without benefiting an exclusive user group. This kind of stocking program is generally organized by governments and often has a political basis to subsidize fishers' communities and convince them that governments are looking after them. The need for critical evaluation of cost-benefit ratios of such programs is generally not pressing and this is the main reason for the scant attention that has been paid to properly evaluate this type of stocking exercise. The second approach relates to release of organisms, which are subsequently harvested by the releasing agency. Because costs of stocking are generally high, the responsible agency or management group will aim to maximize the benefits and to increase the efficiency of the operation. Stocking operations are generally more effective and sustainable when the resource users assume the responsibilities and costs of management (FAO 1997b). Unfortunately, it is often very difficult, usually impossible, to assign an exclusive user group to the resource because the majority of inland fisheries in the world have open-access. The establishment of restricted access fisheries may disadvantage people, often the poor, who rely most on the common property resources. It is therefore important to identify the beneficiaries or target groups before deciding whether a stocking program is the best solution to enhance the fishery. There may be better options, for example, modifications to the environment, such as the creation of dry season reserves and sluice gate management, which have been used to enhance fish populations in flood control schemes in Bangladesh (Hoggarth and Halls 1997). It is therefore important to explore not only stocking but also a whole range of possibilities to enhance a fishery.

Table 1. Purposes of stocking in Asia, Africa and Latin America.

Stocking purpose	No. of references	%
Food and income	77	73
Recreation	14	13
Plant and animal control	7	7
Conservation	5	5
Compensation	2	2
Restoration	1	0
Total	106	100

Global information on stocking

In an extensive literature search of FAO's ASFA database for relevant information on various kinds of inland fishery enhancements in Africa, Asia (including Middle East), Oceania and Latin America (South and Central America, excluding North America), 215 relevant articles on stocking were extracted, which is a modest amount of literature. The global distribution of this information is shown in Fig. 1. Most of the information comes from the Asia-Pacific region: China, India, Sri Lanka, Bangladesh, Australia, Papua New Guinea, Japan, Thailand and Indonesia. Latin America and Africa contributed 33% of the information base. Stocking is widely applied in China. Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) normally account for 60-80% of the fish used. The reservoir yield increased from 180 (1957) to 650 $kg{\cdot}ha^{-1}$ (1996). The contribution of stocking to this increased production is however difficult to estimate because it is not separated from other statistics. Yields in some reservoirs in India increased x10 as a result of extensive stocking (Sugunan 1995). In Sri Lanka, the introduction of *Oreochromis mossambicus* was successful in terms of the establishment of self-reproducing populations. However, the repeated stocking of carps in perennial reservoirs did not have a positive

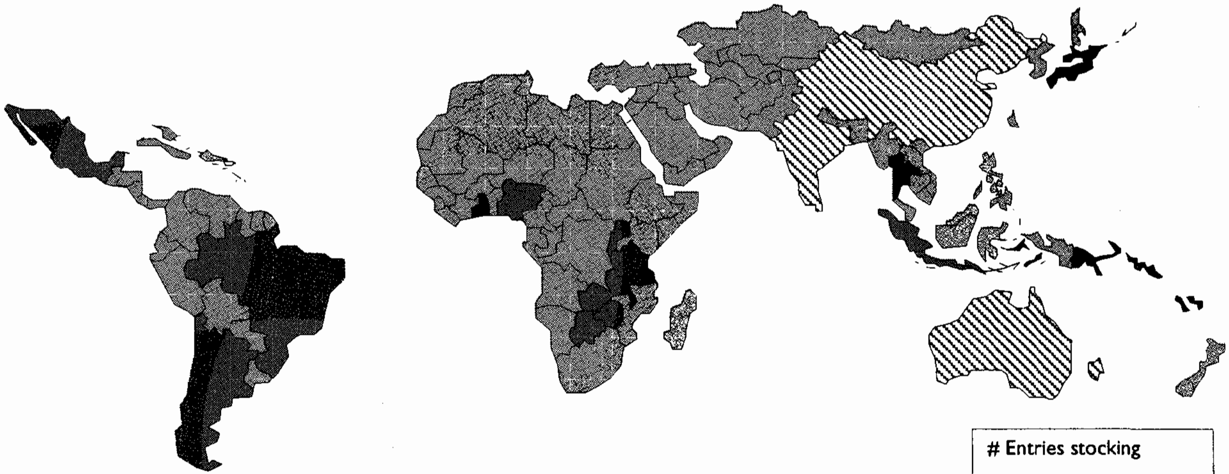

Fig. 1. Distribution of stocking information in Asia, Latin America and Africa.

impact on fish production in these reservoirs (De Silva 1988). The stocking of smaller seasonal reservoirs did produce some good results (Amarasinghe 1998). In Thailand, stocking programs have been carried out since 1950. Regular stocking of 5.6 million ha of waterbodies between 1978 and 1987 was performed. In large reservoirs, the recovery rate of carps has been estimated to be <1% (Pawaputanon 1991). In 1990 the need to stock with indigenous species was emphasized (Verapat 1995). The effects of these programs remain unclear.

In Japan, *Oncorhynchus tschawytscha* was released in rivers for compensation stocking and *Ctenopharyngodon idella* was experimentally stocked for control of aquatic weeds. In Latin America, Argentina, Brazil, Chile, Cuba and Mexico have carried out stocking. Though many waterbodies in this region have been stocked for years, a proper assessment of stocking effectiveness has never been conducted (Quirós 1998). In Cuba, introductions and supplemental stocking of large and medium-sized reservoirs (>100 ha) with Chinese carps and with *Oreochromis aureus* has been practised since 1970 with considerable success. However, natural reproduction of the introduced species explains part of the success. In Brazil, where stocking is a statutory requirement for the mitigation of dams, less success has been registered (Welcomme and Bartley 1998). In Mexico, stocking of *O. aureus* and carps in reservoirs has led to a significant increase in production (Juarez-Palacios and Olmos-Tomassini 1991). In Africa, the countries appearing in the ASFA database are Ghana, Botswana, Zimbabwe, Zambia, Tanzania, Uganda, Nigeria and Egypt. However, actual stocking effort and experience in this region are relatively limited and most references refer to planning. Restocking of small waterbodies in Zimbabwe in response to a severe drought was successful, though this was only one occasion (no repeated stocking) (van der Mheen 1994). In Burkina Faso, annual stocking of some small seasonal waterbodies (<50 ha) with *Oreochromis niloticus* and additional feed supply increased the yield considerably (Baijot et al. 1994).

FAO is assembling world hatchery production data on a regular basis. Fig. 2 shows the main countries reporting hatchery production for release into the wild between 1984 and 1995. The term "release into the wild" also includes hatchery-supported introductions, e.g., tilapias. It can however be concluded that most countries practice hatchery production for stocking and introductions.

Table 2 lists freshwater fishes reported to be stocked in Asia, Oceania, Africa and Latin America, as found from the ASFA searches. The main groups are carps (Chinese, Indian, common carp), tilapias and salmonids. Local species include *Labeo dussumieri* native to Sri Lanka and artificially stocked into seasonal tanks (De Silva 1988), and *Maccullochella* spp. native to Australia (Petr 1998). Artificial reproduction techniques have been developed for many other Australian native species.

The main 25 freshwater species and species groups reported to FAO for release into the wild in Asia, Oceania, Africa and Latin America, are presented in Table 3. This list only includes the hatchery production reported to FAO and may therefore not give a complete overview of the real global production.

Stocking success

Yield is related to stocking rate

It has been shown for several waterbodies that stocking increases yield. Linear relationships were found for the Nansahe Reservoir in China ($R^2 = 0.70$) for Chinese carps (Li

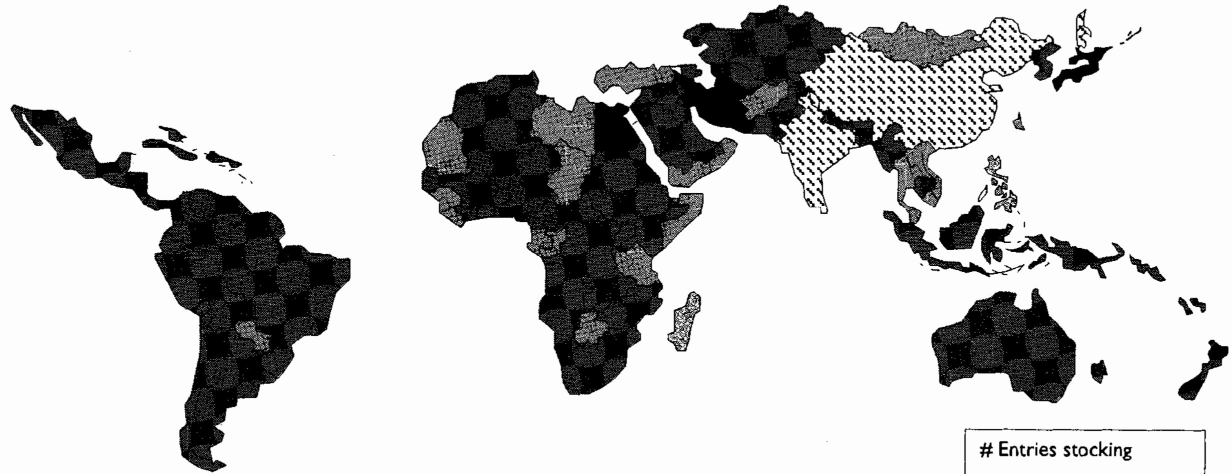

Fig. 2. Distribution of hatchery production for release into the wild in Asia, Latin America and Africa.

Table 2. Stocked species in Asia, Oceania, Africa and Latin America.

Genus	Species	Main countries
Hypophthalmichthys	*molitrix*	China, Brazil, India, Israel
Aristichthys	*nobilis*	China, Sri Lanka
Labeo	*rohita*	Sri Lanka, India
Oreochromis	spp.	Brazil, Cuba, Mexico, Tanzania
Oncorhynchus	*mykiss*	Australia, Papua New Guinea, Argentina
Oreochromis	*aureus*	Israel
Cyprinus	*carpio*	India, Brazil
Ctenopharyngodon	*idella*	India, Japan, Thailand
Oreochromis	*niloticus*	Thailand
Salmo	*trutta*	Australia
Oncorhynchus	*masou masou*	Japan
Tor	*putitora*	India
Mugil	*cephalus*	Israel
Catla	*catla*	India
Cirrhinus	*mrigala*	Sri Lanka, India
Sarotherodon	*galilaeus*	Israel
Eriocheir	*sinensis*	China
Cherax	*tenuimanus*	Chile
Macrobrachium	*rosenbergii*	Brunei Darussalam
Gambusia	*affinis*	Australia
Colossoma	*macropomum*	Brazil
Bidyanus	*bidyanus*	Australia
Labeo	*dussumieri*	Sri Lanka
Trichogaster	*pectoralis*	Papua New Guinea
Tor	spp.	India
Tor	*khudree*	India
Tilapias		Israel
Tilapia	*rendalli*	Papua New Guinea
Maccullochella	*peelii peelii*	Australia
Labeo	*fimbriatus*	Sri Lanka
Pangasius	*sutchi*	Thailand
Osphronemus	*goramy*	Papua New Guinea
Oncorhynchus	spp.	Argentina
Macquaria	*ambigua*	Australia
Maccullochella	*macquariensis*	Australia
Maccullochella	*ikei*	Australia
Liza	*ramada*	Israel
Perca	*fluviatilis*	Argentina

and Wu 1995), for a series of lakes in Sri Lanka (R^2 = 0.70) and Mexico (R^2 = 0.66) and for 172 waterbodies in tropical Latin America (R^2 = 0.61) (Quirós 1998) which were stocked with tilapia but have self-reproducing populations. The precise role of self-reproducing populations of introduced species in the above relationships for Sri Lanka and Latin America however is not fully understood. Curvilinear relationships between stocking densities and yields are described by Amarasinghe (1998) for Sri Lankan reservoirs stocked with carps.

Yield per unit area is inversely related to the area of the stocked system

The larger the waterbody, the more difficult it is to increase yield per unit of area through stocking (Li and Wu 1995; Amarasinghe 1998; Quirós 1998). Larger waterbodies are more difficult to manage and less easy to fish. They are generally deeper and the littoral zone is relatively small. Competition and predation are difficult to control in larger waterbodies.

Planning

Important factors to consider in the planning of a stocking operation are presented in Fig. 3. The formulation of a stocking program should be based on well-defined objectives, a step often neglected or misinterpreted by managers and evaluators (Bartley 1996). In this context, it is also important to define who is going to benefit and who will bear the costs. The objectives will be partly based on the knowledge of the system, the status of the stock and waterbody, and on how conservation, biodiversity and food security are perceived. If the actual fisheries yield is lower than the predicted poten-

Table 3. Main species produced in hatcheries for release into the wild in Asia, Oceania, Africa and Latin America.

Species name	Summed production 1984-1995 (No. x 10^8)	Main countries
Cyprinus carpio	2 161	Cuba, Iran, Malaysia, Egypt, Brazil (+50)
Oreochromis aureus	951	Cuba, Nicaragua, Cote d'Ivoire, Dominican Republic
Mugil cephalus/Liza ramada	498	Egypt
Oreochromis spp. (mainly hybrids)	447	Taiwan ROC
Tilapia spp.	403	Egypt, Syria, Malaysia, Ghana
Hypophthalmichthys molitrix	373	Iran, Cuba, Egypt, Israel
Ctenopharyngodon idella	358	Egypt, Iran, Taiwan ROC, Cuba
Rutilus frisii kutum	315	Iran
O. mykiss/O. masou/O. rhodorus/ O. kisutch/Salvelinus pluvius	296	Japan
Lates calcarifer	282	Singapore, Australia, Malaysia, French Polynesia
Oreochromis niloticus	280	Saudi Arabia, Indonesia, Brazil, Colombia (+35)
Oncorhynchus mykiss	243	Colombia, Australia, Republic of Korea, Argentina
Macrobrachium rosenbergii	207	French Polynesia, Fiji, Mauritiuis, Martinique (+22)
Labeo rohita	187	Myanmar, Pakistan, Malaysia, Sri lanka, (India, Bangladesh)
Aristichthys nobilis	138	Cuba, Iran, Malaysia, Egypt
Oreochromis niloticus x *Oreochromis aurea* (hybrids)	138	Israel
Oncorhynchus keta	122	Republic of Korea, Chile
Oreochromis spp.	113	Mexico, Israel, Bahamas, Guatemala
Cyprinus carpio/C. specularis	111	Republic of Korea
H. molitrix/Aristichthys nobilis/ Ctenopharyngolon idella	98	Nepal
H. molitrix/C. idella/A. nobilis/L. rohita/ C. catla/C. mrigala	90	Nepal
Oreochromis mossambicus	77	Japan, Malaysia, Dominican Republic, Indonesia
Labeo rohita/Catla catla/C. mrigala	64	Nepal
Puntius javanicus	60	Indonesia
Puntius gonionotus	59	Malaysia, Fiji

tial yield, the reasons need to be investigated. Based on the outcome, efforts should be made to remove the constraints, which may be related to fisheries management and/or the environment. In conjunction with these measures, a stocking strategy can be developed which may require additional adjustments in fisheries regulations and/or habitat modifications. (Bartley 1996).

Development of a stocking strategy

Stocking density

Various models are in use to calculate initial stocking densities. They are all based on assumptions about the potential production or carrying capacity of a waterbody. This potential can, for example, be estimated through relations between yield and the size of waterbodies, the morphoedaphic index, MEI (Ryder 1965; Ryder and Henderson 1975), biomass of food organisms and primary productivity (Li and Wu 1995) and empirical relations between water quality parameters and yield (Amarasinghe 1998). After having obtained an estimate of the potential yield, stocking densities can be calculated in several ways.

Based on the inverted standard mortality formula derived by Welcomme (1976):

$$S = (qp/W) \exp(-z(t_c - t_0))$$

where: S is the number to be stocked, p the natural annual potential yield of the water body (MEI or alternative estimator), q the proportion of the yield derived from the species in question, W the mean mass at capture, z the total mortality, t_c = age at capture, t_0 = age at stocking.

The above formula was modified by Amarasinghe (1998) for perennial reservoirs in Sri Lanka:

$$S = (1000\ p/0.5\ MW) \exp(M(t_c - t_0))$$

where: S is the number to be stocked (no. ha^{-1}), p the potential yield increase of stocked species (kg ha^{-1}), W the mean mass at capture (g), M the natural mortality, t_c = age at capture, t_0 = age at stocking.

Li and Wu (1995) used the following formula for Chinese reservoirs:

$$d = F / WS$$

where: d is the number to be stocked (no. ha^{-1} $year^{-1}$), F = annual fish yield (kg ha^{-1}) estimated from biomass of food organisms, W the mean mass at capture (kg), S = return rate (%).

Lorenzen (1995) used mathematical modelling to evaluate a culture-based fishery for carps. The dynamics of stocking were related to stocking density, stocking size, fishing effort, competition, predation and the carrying capacity of the system. Information is also required on growth, natural mortality, density-dependent factors, fishing mortality, effort and gear selectivity. This is often difficult to obtain.

After calculation of the initial stocking rate, the density can be adjusted according to growth rates and size at harvest. This kind of adjustment is practiced in China. Basically, fast growth of a stocked species indicates an abundance of food and the stocking density can thus be increased. Depending on the desired size at harvest, an optimal stocking rate is derived after several years of experience. It has been shown in the Dongfeng Reservoir, China, that these empirical stocking rates indeed maximized the yield after evaluation of the stocking densities with a modified cohort analysis technique (Lorenzen et al. 1997).

Size of the stocked fish

The size at stocking is determined by the survival rate (the larger the fingerling, the lower the mortality rate) and the production costs (the larger the fingerling, the higher the costs). The optimal stocking size is often determined empirically. *A priori* knowledge on the biology of the native fish fauna may help to determine a minimum stocking size. In Chinese reservoirs, 90% of the bighead and silver carp fingerlings <13 cm were preyed on by an endemic piscivorous fish, whereas those exceeding 13 cm were rarely attacked by predators (Li and Wu 1995).

Time of release

According to Cowx (1994), fish should be stocked when flow rates and water temperatures are generally low to minimize displacement and stress. Fish should be released when food is available (Cowx 1994; Sugunan 1995) but not during the spawning season, as the stocked species may interfere with natural reproduction processes (Cowx 1994). Such "out of phase" releases may offer an excellent opportunity to distinguish cohorts of released and naturally produced offspring thereby improving the evaluation of stocking (Davenport and Ekaratne 1997).

Site and mechanism of release

Fish can be released: (a) at one site (spot planting); (b) at several sites (scatter planting); or (c) into the same region over a period of time (trickle planting) (Cowx 1994). Spot planting can lead to competition among stocked fish or with indigenous fish. Though this way of stocking is probably less effective than scatter or trickle planting, it is generally easier and less expensive. Trickle planting in particular requires extra labor and costs, and fish have to be available for a longer period.

Environmental assessment

Several international organizations stress the importance of a precautionary approach to resource management to avoid irreversible or slowly reversible changes (within two to three decades), and that priority should be given to conserve the productive capacity of the resource in cases where the likely impact of resource use is uncertain (FAO 1996). These aspects should be addressed during the formulation of any stocking program. More specifically these include: assessment of risks to the environment, native fish stocks, genetic composition of the resident and stocked fish; and assessments related to transfer of diseases. An overview of possible impacts and the associated measures for prevention, mitigation and rehabilitation is presented in Table 4.

Collection of information on the biology and ecology of the concerned species is an important first step. Because fish for stocking are mainly produced through induced spawning in aquaculture operations (Welcomme and Bartley 1998), the genetic characteristics of the hatchery fish are important for the assessment of the risks involved. The genetic characteristics can have an indirect effect on the indigenous species through predation, competition and new diseases. Directly, they can initiate changes in gene flow (hybridization and introgression) (Carvalho and Cross 1998). A first step should assess the genetic resources. Protein and isozyme analysis provides a quick and relativly inexpensive means to examine genetic variability. DNA analysis is also becoming available (Bartley 1996). The use of a large base of healthy, nonrelated, brood stock to maximize genetic variability and prevent the stock from inbreeding is especially important if a repeated release over a prolonged period is practiced. Alternatively, seed could be raised from natural resources in the hatchery, though this may be detrimental to natural populations and therefore not sustainable (Bartley 1996).

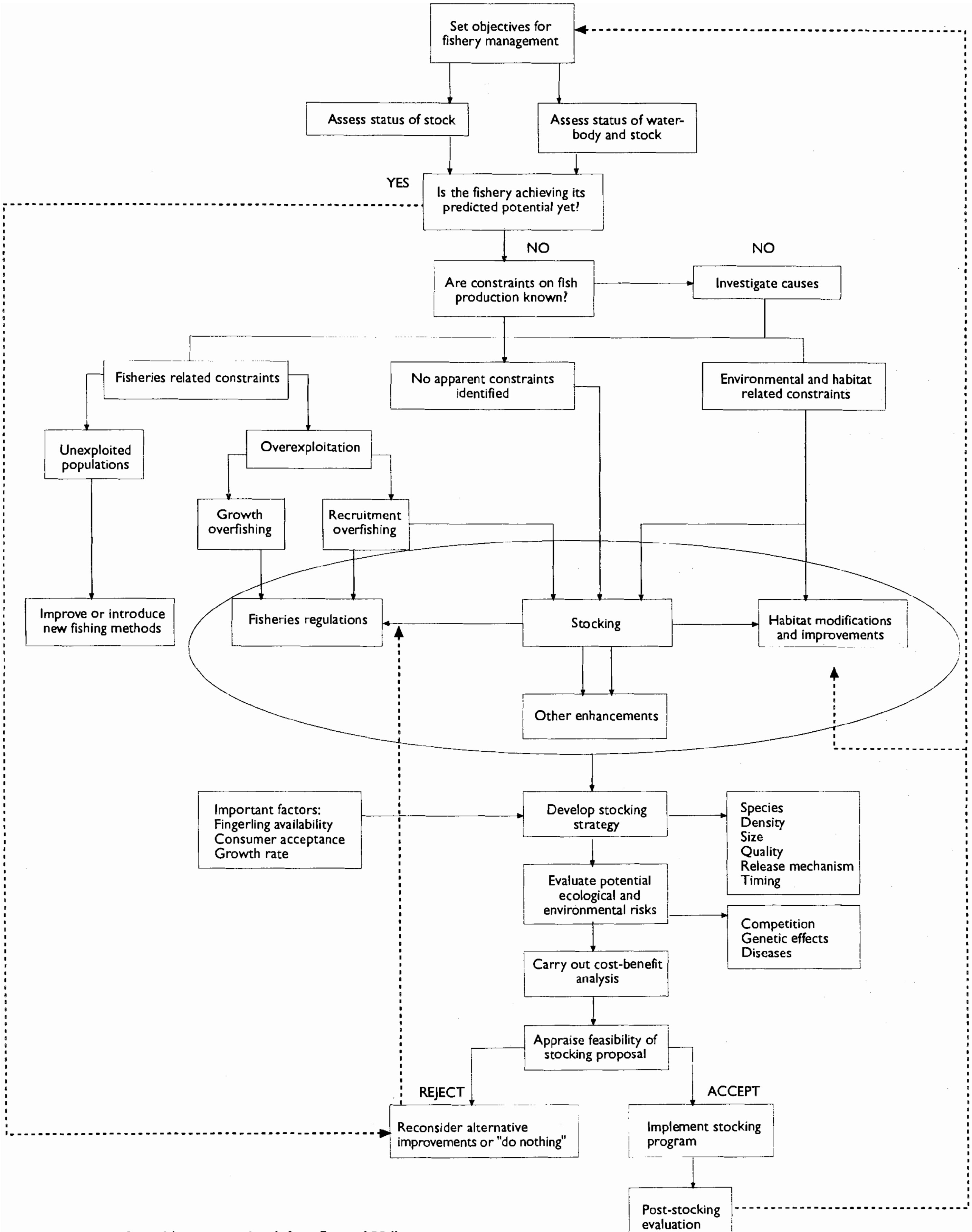

Fig. 3. Planning of stocking strategies (after Cowx 1994).

Table 4. Effects of stocking: environmental impacts, prevention, mitigation and rehabilitation measures.

Environmental impacts	Prevention (P)/mitigation (M)/rehabilitation (R) measures
Genetic changes • Direct effects through hybridization and introgression: disruption of adaptive gene complexes of native species; reduction in fitness; reduction of the genetic variability • Indirect effects through altered selection regimes and reductions in population size; reduction of the genetic adaptability; reduced fitness	• Limit possible effects of selection within the hatchery (adaptation to domestication) by avoiding stocked fish reared in captivity for more than one generation (P) • Minimize genetic impact on wild stocks by stocking fish from breeding programs that deliberately generate genetic diversity (P) • Use of sterile or nonbreeding organisms to reduce the chance of interbreeding with natural fish stocks (P) • Develop stocks specifically adapted to the local environment (P) • Use of stock from a waterbody with a similar environment (P) • Use sufficient fish for brood stock to avoid reducing the genetic variability (P) • Obtain stock from a number of sources to maximize the range of genetic material (P) • Build-up of stock by hatchery production based entirely on local stock (if available) and return brood stock to home system (P) • Redistribution of adults from elsewhere in the catchment (R)
Overstocking • Reduced growth rate • Increased mortality rates • Inhibition of natural production	• Population control of stocked species (R) • Provide extra resources (M) • Avoid stocking during natural spawning period (P)
Predation • Direct impact: direct consumption of adults, fry or eggs of other species • Indirect impact: changes in distributional patterns and behavioral effects	• Provide shelter for prey (P)
Competition Competition for food or space which may lead to: • oppression or extinction of populations • niche shifts	• Release by scatter or trickle planting instead of spot planting (P)
Diseases • Transmission with the transfer of stocks	• Health certification from exporter (P) • Use of hatcheries and quarantine stations (P) • Disease diagnostics (P)
Reduction in natural population of source: • through extracting large numbers of young fish from lakes, rivers and marine coastal areas for stocking	• Regular monitoring of densities; develop quota when necessary (P)
Environmental impacts associated with aquaculture production: • when using seed from aquaculture for stocking	• Environmentally sound management of aquaculture production system (P)

Cost-benefit analysis

The main costs involved in stocking programs are for the stocking material (40-70% of total costs) and for harvesting. The costs of seed production include capital for the hatchery and equipment, feed, brood stock (capture or housing and maintenance), transportation and labor. Harvesting costs involve salaries and fishing gears. The benefits can be various. The price of the fish determines the total output value and this is the most apparent benefit. However, other benefits, such as keeping fishers employed, and supporting indigenous communities and tourism may be strong incentives for governments. It is difficult to put a value on these social benefits, but ideally they should be included in the cost-benefit analysis.

Monitoring and evaluation

One of the main problems of a stocking program evaluation is the difficulty in distinguishing the hatchery fish from the wild population. Tagging of hatchery fish is one of the options available, but it is often expensive and involves handling of large numbers of fish with its associated problems. Mass marking techniques are available. Allozyme and DNA markers provide a means for evaluation including the possibility to assess hybridization and introgression (Bartley 1996).

In culture-based fisheries that are completely based on the stocking of artificially produced fingerlings, the evaluation is mainly based on recaptures (numbers or mass) at harvest. Recaptured numbers of carps in 15 small seasonal reservoirs (2-9 ha) in Sri Lanka varied between 12 and 64% (Amarasinghe 1998). Recovery of stocked *Labeo rohita* in two medium-sized reservoirs in Sri Lanka (690 and 3 362 ha) was around 23% (De Silva 1988). Recovery rates of 20% and above can be considered as excellent, although lower recovery rates can still be profitable.

Stock enhancement in Lake Nasser

Stocking of Nile tilapia (*O. niloticus*) has been carried out on a regular basis by the Fishery Management Center (FMC) at Aswan since 1988. Tilapia fry are artificially reproduced in a hatchery and reared in earthen ponds, close to the Aswan High Dam. Fingerlings with a body mass of 2.5-7.4 g (Agaypi 1995) were released in two khors of the lake, El-Ramla and Kalabsha (see El Shahat, this vol., p. 4). (Agaypi 1996). Details of this stocking effort and total catch of the area are given in Table 5.

After the start of the stocking program, catches in Kalabsha increased gradually to a maximum in 1991. However, catches declined in the following years, reflected in both catch estimates. A comparable trend was observed in El-Ramla. Despite the higher numbers released in Kalabsha in 1993 and 1994, the total catch did not show any response to the stocking effort and declined in this period, although catch per unit effort (CPUE) data suggest an increase between 1988 and 1990 (Table 6). The CPUE data were collected in August and December and may therefore not be representative for the whole year. Increased spawning success of the wild tilapia population due to increasing water levels in the lake is a possible explanation for this initial increase as suggested by Agaypi (1995). The declining catches after 1991 could be a result of various factors, such as reduction of fishing effort, overfishing, the use of small mesh sizes, no care for fry released, and substantial unofficial (unreported) fish landings (Agaypi 1996). In El-Ramla, catches increased in the absence of any stocking effort and later even declined after tilapias had been released. This suggests that factors other than stocking were responsible for the fish population dynamics. On the basis of these figures it is doubtful whether the stocking program had any positive effect on the catches.

A more precise evaluation of the stocking program should be carried out. It is important to start monitoring fishing effort and CPUE, assess the portion of the catch that is not officially reported (poached), and determine the contribution of the stocking program relative to natural recruitment for the tilapia population. This should be done by tagging experiments. The experiments should indicate whether the tilapia migrate outside their release area.

As mentioned in the general overview, stocking programs have often been implemented without properly addressing the causes for the decline in the fishery. Evaluation of the stocking program in Lake Nasser would therefore not only open the way for improvement of current practices there, but the results would be useful for other parts of the world.

Table 5. Stocking effort and catch of Nile tilapia in Lake Nasser (after Agaypi 1995, 1996).

Year	El-Ramla		Kalabsha		
	Numbers stocked	Annual catch (t)	Numbers stocked	Size (g)	Annual catch (t)
1988		895	522 000	7.4	663
1989		1 189	425 000	4.4	652
1990		1 825	557 000	2.0	949
1991	164 000	2 016	417 000	5.4	2 741
1992	928 000	1 429	556 000	2.5	1 963
1993	1 035 000	1 197	977 000	3.2	1 078
1994	1 175 000	1 871	1 070 000	?	?

Table 6. Annual average CPUE in the Kalabsha area based on data for fishing grounds No. 11-18 in August and December, 1988-1990. From Mohamed (1993).

Fishing ground	CPUE 1988		CPUE 1989		CPUE 1990	
	Aug	Dec	Aug	Dec	Aug	Dec
11	0.83	0.75	1.06	1.50	1.60	2.28
12	0.91	0.92	1.20	1.16	0.90	0.70
13	0.82	0.59	0.92	1.14	1.13	1.41
14	0.76	0.77	0.86	1.10	2.09	1.64
15	0.65	0.54	1.07	0.72	1.15	0.57
16	0.51	0.51	0.96	0.86	0.96	0.21
17	0.72	0.83	0.98	1.31	0.86	0.25
18	0.81	0.77	0.90	0.96	1.15	1.03
Average		0.73		1.04		1.12
Standard deviation		0.13		0.19		0.58

Attention should be paid to possible environmental impacts. Reduction of genetic variability and loss of adaptive gene complexes in the natural *O. niloticus* population may result from mixing with the released hatchery fish. Studies to characterize the genetic features of the natural and stocked populations are relatively sophisticated and expensive. However, preventive measures could be taken to minimize any possible impacts on the wild populations such as the use of a large base of healthy, nonrelated, brood stock in the hatchery to maximize genetic variability and prevent the stock from inbreeding. Other ecological impacts such as competition may also be important in Lake Nasser, especially during times of low water levels.

Besides regular stocking of *O. niloticus*, studies were conducted on the induced breeding and rearing of fry of *Barbus bynni*, *Labeo niloticus* and *L. coubie*, native to the Nile ecosystem and Lake Nasser (El Shaheed 1993; 1996) and for silver carp (Shenoda and Naguib 1993). The artificial reproduction of *B. bynni* and *Labeo* spp. is interesting from the viewpoint of restoration of these populations that have declined in the past decade. Silver carp has been used in cage culture trials but has not been released to the open water. There is concern that introduced silver carp may establish itself in Lake Nasser. In fact there is some indication that silver carp may be able to breed in the wild in southern Africa (Impacto 1997).

Conclusions

Stocking is one of the most widespread practices in inland fisheries management, but unfortunately it has often been practised without adequate planning, monitoring or evaluation. Because of concerns about the negative effects that stocking can have on the environment and the native fish populations, careful planning of these programs is very important. The impact of regular stocking of Nile tilapia into Lake Nasser on the catches of this species and on the lake's environment and ecosystem is not well understood. The available data do not permit any decisive conclusions in this respect, and it is therefore suggested that the stocking program be evaluated. The results of such an evaluation may be instrumental in improving the efficiency and effectiveness of the program.

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DISCUSSION

Q. What is meant by "natural stocking"?

A. In Lake Nasser, it is not known which part of the catch originates from the hatchery and which from the lake. Released fish can add to the recruitment but these fish should be bred from brood stock taken from the lake. The population in the hatchery should be as large as possible to prevent inbreeding. Tilapias have evolved to reduce recruitment variation. Large numbers of hatchery produced fry will overwhelm the genetic variance of the natural population. There is no evidence anywhere of lack of recruitment in tilapias under normal conditions. In other lakes, tilapias have adapted to the conditions of the lake. This genetic change should be allowed to take place. There are several potential genetic disadvantages of stocking which should be assessed. There is more potential danger from inbreeding in hatcheries than from the hybridization.

Q. Does stocking in Lake Nasser really affect yield? The natural tilapia population will produce approximately 25 000 million eggs. Will the five million fry from the hatchery have any added effect on this? We need to determine if the current program has any practical value. This would involve a cost-benefit analysis. There does not appear to be an apparent recruitment problem from observing the catches landed at the port.

A. There is a small possibility that stocking can be negative or positive, and a much greater chance that it has no effect at all. There should be increased monitoring of the fish that are stocked into the lake. Released fry should be tagged or have a genetic marker. Hatchery stocks can be fed with an isotope. This is incorporated in the ovaries and can be detected using a test costing about US$5 per fish. Another technique is to use micro-tags, which can be detected easily at the processing plant. In an experiment carried out by FMC, 7-9% of fry were tagged. None have been recovered. Fishers do not want to return tagged fish. An education program is needed to improve results. A higher price for tagged fish may be one way to recover the tagged fish.

It was agreed that an experiment should be developed early in the project to test the actual effects of stocking.

Q. What evidence is there that the changing water levels in the lake actually reduce fry production in the lake?

A. The marked tilapias from the hatchery should be released during the time of maximum spawning. Water level changes have a pronounced effect on aquatic weeds and thus influence the production area.

Q. If there was overfishing, could stocking be an answer?

A. Stock enhancement is not always able to mitigate overfishing. It is actually a subsidy to fishers.

Q. What other measures can be taken to help natural propagation?

A. FMC has applied closed seasons and closed areas to help natural reproduction. There are problems with enforcement of these. Mesh size is designated but it is not enforced. When Karipsa Bay became overfished, it was restocked for seven years. Production increased but the impact of stocking was not clear because of other factors.

Alien Fish Introductions: The African Experience and Its Relevance to Lake Nasser

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ABSTRACT

The introduction of alien fish species is an important tool in fishery management that has increased fish yields in many places. They impose an ecological cost, however, and this paper reviews two successful introductions in Africa with strikingly different ecological consequences. The introduction of *Lates niloticus* caused major changes in Lake Victoria, which included the virtual extinction of most of its endemic cichlid species. In contrast, *Limnothrissa miodon* had little impact in Lake Kariba apart from changes to the zooplankton community. These cases emphasize that the riverine fish fauna in human-made lakes is much less vulnerable to change than the lacustrine cichlids of the African Great Lakes. The fish populations in Lake Nasser would not, therefore, be adversely affected by the introduction of a planktivorous fish species, since there is clearly a vacant niche for such a species. Some possibilities are discussed, with clupeids being preferred, and it is suggested that they could increase the fish yield of the lake by at least 30 000 t $year^{-1}$ at relatively little cost.

Introduction

Most human societies rely on alien animal and plant species for the bulk of their food supplies. It is difficult for people living in the Old World today to visualize life without maize, potatoes or tomatoes, what the Americas would be like without wheat and cattle, or for people in Egypt to imagine a time when there were no date palms in the country. Humankind has used these alien species to transform the ecology of huge areas, e.g., natural forests have been replaced by plantations, grasslands by monocultures of cereal crops and herds of antelope by cattle. Given these tendencies, it is surprising that most fisheries differ from terrestrial production systems by still depending on the natural populations of fish that occur in the oceans, lakes and rivers of the world.

This situation may change of course, especially in inland waters where numerous fish introductions have taken place during the last century, involving something like 291 species in 148 countries (Welcomme 1988).

These introductions have been responsible for a number of problems, including predation, competition and hybridization with native species, the introduction of new parasites or diseases, crowding, stunting and degradation of water quality (Pitcher 1995). Nevertheless, introduced fish species have been responsible for major increases in productivity in many areas, and there may be compelling reasons for further introductions, especially where there is a pressing need for increasing protein supplies, as there is in many developing countries. Fish introductions are an especially important management tool in large artificial reservoirs that are relatively immature, with rapidly changing systems. Their fish populations consist of riverine species, many of which are unable to adapt to the new ecological niches that become available following the creation of an artificial lake.

A successful fish introduction will, of course, bring about irreversible ecological changes. In some cases, these changes are relatively slight and affect only some components of the ecosystem, but in others they are widespread with major impacts on all communities. It is therefore critically important that the probable extent of these changes (the "cost") is understood and balanced against the outcome (the "benefit") before any introduction is considered. What constitutes an acceptable cost/benefit ratio will obviously vary according to different viewpoints e.g., something acceptable to national governments as a foreign currency earner may adversely affect smaller fishers, while increased fish production may come at a high cost in terms of biodiversity or ecological change.

Lake Nasser is one of the world's great artificial lakes and a major source of fish but, because it is human-made, it seems to have vacant ecological niches that could be exploited by introduced fish species. There seem to be good reasons to introduce suitable fish species into the lake but, because of its crucial importance to all aspects of life in Egypt, this is a decision that will not be taken lightly. This paper examines the impacts of two important fish introductions elsewhere in Africa and their relevance to the situation in Lake Nasser.

Lake Victoria

The ecology of Lake Victoria, the largest lake in Africa, has changed dramatically for various reasons, not the least of which is the introduction of alien fish species. It was until recently a typical cichlid lake, like Tanganyika and Malawi, with more than 300 haplochromine species, of which 99% were endemic. These species accounted for 85% of the demersal ichthyomass in the lake, and exploited almost every available food source, as each had its own unique combination of food and habitat preferences (Greenwood 1974; Goldschmidt et al. 1990; Witte and van Oijen 1990). The haplochromines were of only local importance in the fishery, however, and made up < 25% of the total catch. The most abundant and valuable species were *Oreochromis esculentus*, *O. variabilis*, *Bagrus docmac* and *Labeo victorianus*, which together made up 62.7% of total catch (Table 1).

Table 1. The composition of the fish catch (% by mass) from Lake Victoria in 1958.

Taxon	%
Oreochromis esculentus	23.2
Bagrus docmac	21.0
Haplochromines	18.0
Labeo victorianus	10.5
Oreochromis variabilis	8.0
Protopterus aethiopicus	6.0
Clarias gariepinus	3.5
Synodontis sp.	2.9
Schilbe intermedius	2.7
Mormyrids	2.3
Barbus sp.	1.1
Alestes sp.	0.6
Other species	0.2
Total	100.0

From Kudhongania and Chitamwebwa (1995), with some names changed to reflect current taxonomic views.

These fish were already under severe pressure and the catches of *L. victorianus* fell from 10.5% of the catch in 1958 to only 1.0% in 1970. Overfishing for this species also affected 13 other anadromous species living in the lake (Whitehead 1959). The catches of *O. esculentus* had already fallen precipitously by 1958, and four exotic tilapiine species were introduced in the early 1950s (Kudhongania and Chitamwebwa 1995). Competition and hybridization between them served to deplete the indigenous species even further and only one species, *Oreochromis niloticus*, is now abundant in the lake.

The Nile perch, *Lates niloticus*, was introduced in the 1960s but only started to appear in the catches during the 1970s. The impact of Nile perch was dramatic and led to the almost complete destruction of the haplochromine stocks in the lake (Table 2). Other species declined as well, although, at least in some cases, factors other than predation by Nile perch may have contributed to their decline. The food web of Lake Victoria has been greatly simplified by the loss of the haplochromines. Before the Nile perch introduction, the major food chains, starting with phytoplankton and bottom deposits were: (a) through haplochromines to piscivorous haplochromines and catfishes; (b) through zooplankton and insect larvae to zooplanktivorous species (mostly haplochromines) and piscivores; (c) through insect larvae to various zoophagous fishes (haplochromines, mormyrids, *Barbus*, *Alestes*, *Synodontis*) and then to piscivores; (d) through molluscs to various molluscivores (*Protopterus*, haplochromines, *Barbus altianalis*); and (e) utilized directly by various tilapiines (principally *O. esculentus*), some of which were taken by piscivores. The food web now has Nile perch as the sole predatory species, including cannibalism with large Nile perch feeding extensively on smaller ones. Phytoplankton and bottom deposits are processed: (a) by the previously scarce shrimp, *Caradina nilotica* (now very abundant), which is preyed upon by large and small Nile perch; (b) by zooplankton, which are utilized by the cyprinid *Rastrineobola argentea* (now very abundant), which is preyed upon by large and small Nile perch; (c) by insect larvae, which are eaten by small Nile perch; and (d) directly by the sole abundant tilapiine, *O. niloticus*, presumably taken by Nile perch from time to time.

Table 2. The abundance of important fish species (kg ha^{-1}) in bottom trawl catches from Lake Victoria before and after the introduction of Nile perch.

	1969-1970	1989-1990
Haplochromis spp.	35.80	0.54
Oreochromis niloticus	0.01	0.83
Lates niloticus	0.00	32.70
Other species	20.96	0.42

From Ochumba (1995).

The ecology of the lake changed at the same time, with the appearance of conditions usually associated with eutrophication. A persistent, de-oxygenated layer has developed in deep water, and movements of this layer have led to massive fish kills in some areas (Ochumba 1990). Blooms of blue-green algae and the extensive invasion of water hyacinth, *Eichhornia crassipes*, are further indications that nutrient cycling in the lake has changed and that it has become more eutrophic (Ochumba and Kibaara 1989; Ochumba 1995). How far Nile perch has contributed to this situation is still debated. One view takes the "top-down" approach, suggesting that Nile perch altered the food web by its destruction of the haplochromines that fed on zooplankton, benthic insects and detritus. This prevented recycling from the benthos to the water column (Witte et al. 1992) and the accumulation of organic matter in the bottom waters led to their deoxygenation. The other view takes the "bottom-up" hypothesis, which is that nutrient inputs have increased, leading to algal blooms and a cycle of deoxygenation that is characteristic of eutrophic systems (Ochumba 1990). There is evidence that the lake was becoming eutrophic in the early 1960s, prior to the introduction of Nile perch (Hecky 1993), and so these problems may have developed without it. Whatever the case, it is difficult to argue that the drastic change in the fish community brought about by the Nile perch had no effect on nutrient cycling, and the Nile perch probably accelerated the rate at which eutrophication took place.

This account has so far dealt with the costs of the Nile perch introduction which include, clearly, the destruction of the endemic cichlid community and, more equivocally, the ecological changes that occurred afterwards. The benefits of the introduction were obvious, a major increase in fishery productivity from about 100 000 t year^{-1} in 1970 to about 500 000 t year^{-1} in 1990 (Table 3). The fishery now produces mostly *L. niloticus*, *O. niloticus* and *R. argentea* that are all preferred by local communities around the lake, and therefore more valuable, while the haplochromines were widely disliked. The increase in fishery production has also had a major economic impact on the countries around the lake, since the gain in productivity brought about by Nile perch was estimated to be around US$280 million in 1975-1989 (Reynolds et al. 1995). The most immediate consequence was an increase in earnings and employment in the fishing industry (Table 4), but the growth of the industry has had a wide regional impact by increasing the availability of fish over a larger area, increasing export earnings, and stimulating improvements in the infrastructure around the lake (Reynolds et al. 1995).

Table 3. The total catch, and the catch of *Lates niloticus* (t) from Lake Victoria, 1970-1990.

Year	Total catch	*Lates niloticus*
1970	100 000	0
1975	80 000	0
1980	100 000	<10 000
1985	245 000	125 000
1990	500 000	300 000

From Bundy and Pitcher (1995).

Table 4. Employment in the fisheries sector around Lake Victoria before (c.1978) and after (c.1989) the expansion of the Nile perch fishery.

	c.1978	c.1989
Number of canoes	11 100	21 987
Crew size	4.4	4.8
Catch per canoe (t year^{-1})	7.91	23.06
Direct employment	52 800	105 500
Secondary employment	105 600	316 500
Secondary: primary employment ratio	2	3
Total fishers + dependents	475 200	1 266 000

From Reynolds et al. (1995).

Lake Kariba

The first of the giant African reservoirs, Lake Kariba was created when the Zambezi River was dammed in 1958. It has an area of around 5 400 km^2 when full (although it has been smaller than this during the last decade because of persistent droughts in southern Africa) and a mean depth of about 30 m. Most of its catchment area consists of nutrient-poor Kalahari sands (Coche 1974), and the lake is oligotrophic with a relatively low primary productivity. It was quickly recognized that none of the native fish species would colonize the open waters of the lake and the clupeid *Limnothrissa miodon* (kapenta) was introduced from Lake Tanganyika (Bell-Cross and Bell-Cross 1971). The introduction was successful and the fish was present in all parts of the lake by 1970, and also in the Zambezi River below the dam (Junor and Begg 1971).

The ecological impact of kapenta seems to have been very slight, with only the zooplankton having changed significantly (Marshall 1991). Prior to the introduction of kapenta, the zooplankton was dominated by large cladocerans, of which *Ceriodaphnia* was the most abundant, while small cladocerans like *Bosmina* were relatively scarce, as were rotifers and nauplius larvae (Table 5). After the introduction, the larger species decreased and the zooplankton now consists almost entirely of *Bosmina*, rotifers and nauplius larvae; the ratio of cladocerans to copepods, which may be a good indicator of the extent to which the plankton is being utilized by fish (Duncan and Schiemer 1988), decreased from 4.2 in 1967-1968 to 0.8 in 1976.

Other ecological impacts are less obvious. There may have been some cascading effects on the phytoplankton, which consists primarily of small species (Ramberg 1987), but no definite conclusions are possible because there are few data

Table 5. Changes in the composition (% by numbers) of the zooplankton in Lake Kariba, before and after the introduction of *Limnothrissa miodon* in 1967-1968.

	1967-1968	1970	1972	1975-1976
Diaptomids	14.2	0.2	0	+
Cyclopoids	4.6	12.5	10.1	13.8
Nauplii	1.1	16.4	17.1	3.1
Bosmina	7.3	15.9	17.1	10.5
Ceriodaphnia	69.1	14.3	0	0.3
Diaphanosoma	2.1	0.2	0	+
Daphniids	0.8	0.2	0	+
Rotifers	+	40.3	55.7	72.3
Cladocera:copepod ratio	4.2	2.4	1.7	0.8

The symbol + indicates values of less than 0.01%. From various authors cited in Marshall (1991).

on phytoplankton before the kapenta introduction. Soon after Lake Kariba was created, the exotic fern *Salvinia molesta* spread rapidly, covering as much as 22% of the lake's surface in 1962, but its population collapsed at about the same time as the kapenta population was expanding. The factors that caused this decline are unclear, although it has been argued that kapenta brought about a change in the way nutrients were cycled in the pelagic waters of the lake (Marshall and Junor 1981). Whatever the case, the pelagic communities of Lake Kariba are now very different from those of the pre-kapenta period (Table 6).

Finally, a number of species benefited from the introduction, the most important of which was the tigerfish, *Hydrocynus vittatus*, a species that is valuable in both the commercial and sport fisheries. Between 1970 and 1971, their diet shifted from small inshore fish to kapenta, which became their most important food item, and tigerfish rose from about 5% to 10% of the gill net catch (Junor and Marshall 1979). The abundance and mortality of tigerfish closely follows that of kapenta, which have become crucial in maintaining the populations of this predator (Marshall 1985). Other native species have probably benefited as well, since many of them prey on small fish to some extent (Marshall 1995). Some bird species, notably gulls, terns and kingfishers, also feed on the kapenta and have increased in numbers as a result of their introduction (Marshall 1991).

The ecological costs of the kapenta introduction into Lake Kariba have therefore been small, but the economic benefits have been considerable. Lake Kariba is intrinsically unproductive because (a) nutrient concentrations are low and (b) the inshore fish species are restricted to the edge of the lake, in water 10-15 m deep (Coke 1968). The kapenta transformed this situation, increasing the commercial catches by about 10 times (Table 7). This has created new economic activities and employment in an area that was formerly remote and undeveloped.

Table 6. The community structure of the open waters of Lake Kariba before and after the introduction of *Limnothrissa miodon*.

Community	1967-1968	1980-1983
Salvinia molesta	1.27×10^6	0
Phytoplankton*	193	310
Zooplankton	2 280	28
Limnothrissa miodon	0	196

From various sources cited in Marshall (1991) with *Salvinia* data from Mitchell (1973). The value for *Salvinia* is in mg m^{-2} and is based on the assumption that the plant covered 15% of the lake's surface, while all others are in mg m^{-3}. (*Only large forms like *Volvox* and *Microcystis*; smaller ones were not determined).

Table 7. The mean catch of fish (t) from Lake Kariba for 1991-1996.

	Zambia	Zimbabwe	Total (t)	Yield (t km^{-2})
Inshore	1 596	1 171	2 767	0.59
Open water	7 187	18 022	25 209	5.36
Total	8 783	19 193	27 976	5.95

The inshore fishery is based on the fish species native to the Zambezi River, while the open water fishery takes the introduced clupeid *Limnothrissa miodon*. The yield (t km^{-2}) is based on an average lake area of 4 700 km^2. From data in Chitembure et al. (1997).

The success of the Lake Kariba introduction was greater than anyone could have anticipated because the kapenta were able to invade Lake Cahora Bassa, a second reservoir on the Zambezi (constructed in 1975), downstream from Kariba. The ecological impacts, especially on the zooplankton, were very similar to those in Lake Kariba (Gliwicz 1984), and a major new fishery has developed on that lake since the end of the civil war in Mozambique. Catch statistics are not readily available, and may not be reliable, but there is no doubt that the catch has risen rapidly (Table 8). Lake Cahora Bassa is located in an extremely poor area with low agricultural potential, and the kapenta fishery is particularly important as one of the few opportunities for employment available to the local people.

The significance of the riverine fauna

These introductions have taught us a great deal about the fauna in African lakes and their response to changing environments. The specialized endemic cichlids in Lake Victoria were very susceptible to change. The haplochromines tend to have narrow trophic specializations, as well as complex reproductive patterns and low fecundity, which left them poorly equipped to survive in the face of intensive predation. The response to predation was the same whether it was in the form of intensive fishing by humans, or intensive hunting by Nile perch; in both cases the stocks declined markedly (Kudhongania and Chitamwebwa 1995), although predation by Nile perch is probably more drastic in the long term. The same probably applies to the endemic tilapiines (*O. variabilis* and *O. esculentus*) since they collapsed under fishing pressure before Nile perch was introduced.

While the African Great Lakes differ from each other in many respects, and might respond differently to introductions, it is best to assume that they are all as vulnerable to change. The even more diverse cichlid fauna of Lake Malawi may be more at risk than the one in Lake Tanganyika, because in the latter, four endemic *Lates* species co-exist. On the other hand, these *Lates* species may be more specialized than *L. niloticus* in their feeding habits, having evolved in a lacustrine rather than a riverine environment, and therefore have a smaller impact on the haplochromines. It would therefore be irresponsible to introduce anything into these lakes since we have no way of predicting the consequences.

The situation in the human-made lakes is very different. Three of the five great reservoirs, Volta, Kainji and Nasser, are located in the northern Nilo-Sudan ichthyological region while the other two, Kariba and Cahora Bassa, are in the southern Zambezian region (Roberts 1975). Their fish faunas are similar in many respects, with 10 families in common, accounting for 73-76% of the species in Volta, Kainji and Nasser; and 95% of the species in Kariba and Cahora Bassa (Table 9). Characteristic species of the northern faunal region are *L. niloticus*, *Heterotis niloticus* and *Gymnarchus niloticus*. The southern faunal region is characterized by some distinctive cichlids, principally serranochromids in the genera *Serranochromis* and *Sargochromis*. The tilapiines are rather more diverse, with several species of *Oreochromis* in the region. Many of the species in the two zones are ecologically similar, which gives rise to some distinctive species-pairs like *Hydrocynus forskahlii/H. vittatus*, *Mormyrus kannumel*, *M. longirostris* and *Tilapia zillii/T. rendalli*.

Table 8. The catch (t) of "dagaa" in Mozambique.

Year	Catch
1993	689
1994	925
1995	3 093
1996	6 000
1997	10 000

Dagaa is a term used by FAO to describe small clupeids or clupeid-like fish from African lakes. Cahora Bassa is the only source of dagaa, i.e., *Limnothrissa miodon* (kapenta), in Mozambique. Data for 1993-1995 from FAO (1996); data for 1996 from unpublished sources; 1997 values are speculative but based on personal knowledge of the fishery.

Table 9. The number of species in each family found in Lake Nasser/Nubia and in Lake Kariba.

Family	Volta	Kainji	Nasser/Nubia	Kariba and Cahora Bassa	Genera (or species) common to all lakes
Protopteridae	1	1	1	1	*Protopterus**
Polypteridae	-	4	1	-	
Anguillidae	-	-	-	1	
Osteoglossidae	1	1	1	-	
Mormyridae	8	19	7	4	*Mormyrus, Mormyrops anguilloides, Marcusenius*
Gymnarchidae	1	1	1	-	
Clupeidae	2	2	-	-	
Hepsetidae	-	1	-	1	
Characidae	6	10	6	4	*Hydrocynus, Brycinus (Alestes)*
Distichodontidae	2	3	3	2	*Distichodus*
Citharinidae	1	3	2	-	
Cyprinidae	4	6	13	12	*Barbus, Labeo*
Bagridae	5	9	7	-	
Schilbeidae	4	5	3	1	*Schilbe intermedius*
Clariidae	3	3	3	2	*Clarias gariepinus, Heterobranchus*
Malapteruridae	1	1	1	1	*Malapterurus electricus*
Mochokidae	5	17	6	4	*Synodontis*
Cyprinodontidae	-	-	-	1	
Cichlidae	7	7	2	11	*Oreochromis, Tilapia*
Centropomidae	1	1	1	-	
Anabantidae	1	1	-	-	
Channidae	1	1	-	-	
Gobiidae	1	-	-	-	
Tetraodontidae	1	1	1	-	
Total	56	97	59	45	

Data from Ali (1984), Ita (1984), Latif (1984) and Marshall (1984) with some modifications.
(*Extinct in Kariba, and probably in the other lakes as well).

The ichthyological zones in which these reservoirs have been constructed lie in the savannah belts north and south of the Equator. The rivers are characterized by a highly seasonal rainfall and the flow in the rivers follows the seasonal pattern. Both zones are affected by droughts of varying severity and the flow in the rivers can vary substantially from one year to another. Floodplains are important in some sections of the larger rivers and the biology of many fish species is adapted to the regime imposed by the seasonal cycle of flood and drought (Welcomme 1988). In particular, they are adapted to withstand high mortality by having a flexible breeding biology, which is determined by river flow coupled with high fecundity. This is especially true of the tilapiine and serranochromine cichlids, whose breeding biology is directed towards the production and survival of numerous fry, in contrast to the specialized haplochromines of the Great Lakes. They also tend to be generalist and opportunist feeders, although within broad niches for each species, which also sets them apart from fish in the Great Lakes that tend to be specialists.

The riverine fish faunas are therefore very resistant to change and it is difficult for introduced species to compete against the native fauna. The Nilo-Sudan region has not been much affected by fish introductions, but the Zambezian has been subjected to a number of them. In Zimbabwe, for example, at least 20 exotic fish species have been imported into the country but few have become established or widespread (Bell-Cross and Minshull 1988; unpublished data). Significantly, all of those that have done so occur in reservoirs and they seem to require these artificial habitats to be successful since they lack the adaptations needed for survival in the harsh riverine environments in the region. A notable exception to this generalization is the most recent arrival, *O. niloticus*, which is spreading rapidly throughout the country. Conditions in the rivers are little different from those in its native range and it is well adapted to survive in them.

The smaller reservoirs, in which exotic species can establish themselves, tend to have only a few fish species, sometimes no more than four to five, which probably makes it easier for exotic fish to take hold. In contrast, the very large reservoirs have a much more diverse fish fauna, derived from the original stocks in the river. Of course, their relative abundance has changed, as species that were unable to adapt to the lacustrine conditions declined, while others flourished. In Lake Kariba, for example, species that decreased include the lungfish *Protopterus annectens* (now extinct in the lake basin), cyprinids (*Labeo* sp., *Barbus* sp.) and others (e.g., *Distichodus*); while cichlids increased in abundance. New species have appeared from elsewhere in the catchment but, so far, these do not include exotics like largemouth bass, *Micropterus salmoides*, or common carp, *Cyprinus carpio*, that are present in some of the tributary streams. Only highly specialized exotic species, like *L. miodon*, with its specific feeding niche are likely to be successful.

Should anything be introduced into Lake Nasser?

Is there a vacant niche?

Before considering the introduction of any fish species to the lake, the vacant niche that it might occupy should be identified. In the case of Lake Nasser, there is almost certainly a vacant niche for a zooplanktivore since, like Lake Kariba, it lacks a specialist plankton feeder. Of course, many of the native fish species feed on zooplankton to some degree, especially some of the smaller characids like *Brycinus* and *Alestes* (Paugy 1986). The fact that *Brycinus nurse* is more abundant in Lake Nasser than it is in Lake Nubia, where *Alestes dentex* and *A. baremose* were more numerous, suggests that it might feed on plankton more than they do (Table 10). Nevertheless, their impact is probably small since large cladocerans are still abundant in the zooplankton of Lake Nasser (Mohamed 1993), and they normally decline following the introduction of a planktivorous fish (Table 5). This view is supported by the fact that the cladocera: copepod ratio in Lake Nasser (1.5) is much higher than that in Lakes Kariba (0.2) and Cahora Bassa (0.1) which both have *L. miodon* as a specialized planktivorous species.

Other vacant niches are less obvious. There may be a large population of oligochaetes in the deeper waters, at least in winter when the lake is isothermal, and it is not clear if any fish utilize them. One problem is that oligochaetes probably fragment quickly once they have been eaten and are therefore not obvious in the stomach contents of fish. Another problem is that they tend to be in deeper water and are inaccessible to most fish especially if those in Lake Nasser, like those in Kariba (Coke 1968), do not penetrate >10-12 m depth.

Would filling this niche have any impact?

The most obvious unfilled niche in Lake Nasser is that of an open water zooplanktivore, and the remaining discussion will center on these fish. The impacts of these animals on the zooplankton are well-known and usually entail a reduction of the larger species, especially the cladocerans, and their replacement by smaller ones, which essentially represents a transition from a riverine plankton to a more typically lacustrine one. There might also be some cascading effects on the phytoplankton, including the replacement of large species like *Volvox* or *Microcystis* by smaller species that can compete more effectively after being freed from grazing by larger cladocerans. This in turn might alter the nutrient cycling in the lake, but it is unlikely that water quality would be altered significantly.

Table 10. The proportions (% of catch) of *Brycinus nurse*, *Alestes dentex* and *A. baremose* in gill nets set in Lakes Nasser and Nubia.

	Lake Nasser	Lake Nubia
Brycinus nurse	40	7
Alestes (dentex + baremoze)	5	45

From Latif (1984).

There are no other fish species that would be adversely affected. It is possible that *Brycinus nurse* might decline to some extent, but as it is essentially omnivorous it would use other food sources and maintain its numbers, at least in shallow waters. This is comparable to the situation in Lake Kariba, where it was thought that *Brycinus lateralis* would have become an openwater planktivore prior to the introduction of kapenta (Balon 1974). In fact, the sardine appears to have had no impact on *B. lateralis*, which is still abundant in the shallow waters of the lake (Marshall 1991). Other species, especially predators like *Lates* and *Hydrocynus*, would benefit from the introduction of a planktivore and their importance in the fishery would increase. This would be especially important to the development of sport fisheries on the lake, which can increase the value of certain fish species far beyond that given to them in the market place.

Would the new species improve the fishery?

The ultimate objective would be to increase fishery production from the lake and there is little doubt that a major increase in productivity would be possible with a planktivorous species. The fisheries of Lakes Kariba and Cahora Bassa, and also Lake Kivu (which is similar in many ways to a reservoir in its lack of a planktivorous species) have been transformed by the introduction of *L. miodon* and it is likely that the same would happen in Lake Nasser. If an openwater fishery, with a productivity similar to that of Lake Kariba (5.36 t km^{-2}), then Lake Nasser/Nubia, with an area of 6 216 km^2, would produce around 33 000 t $year^{-1}$. The productivity of Lake Nasser/Nubia would probably be considerably higher than that of Kariba which is oligotrophic, and 6-8 t km^{-2} might be possible, in which case yield would increase by anything from 37 000 t to 50 000 t $year^{-1}$. Pitcher (1995) estimates an even higher yield, 57 000-79 000 t. The economic significance of this extra catch would be dramatic.

Which species might be suitable?

This paper has referred extensively to the clupeid *L. miodon* and the successes that have been achieved with it. Indeed, the introduction of this species into Lake Kariba has been described as the most cost-effective fishery management project ever carried out in Africa (Eccles 1985). Kapenta has been particularly effective because of certain features of its life history, such as early maturity and a short life cycle that allow it to withstand high mortality rates. While this may be an adaptation to high levels of predation, it also enables it to sustain a very intensive fishery (Marshall 1993). The characteristics of *L. miodon* in Lake Kariba are quite different from those it displays in Lake Tanganyika; the Kariba fish, in fact, closely resemble the other clupeid in that lake, *Stolothrissa tanganicae*. The importance of this is that African clupeids may, as a rule, be able to vary their life history according to the environmental conditions in which they live. Thus, hypothetically at least, any species could be translocated to Lake Nasser and perhaps be as successful as *L. miodon*, so consideration could be given to other species like *Pellonula afzeliusi*, which is native to Lakes Volta and Kainji. In Lake Kainji, at least, it supports a valuable fishery which now yields around 10 000 t $year^{-1}$ or 7.8 t km^{-2} (Turner, pers. comm.).

While clupeids are likely to be the most productive planktivores, some other species could be considered. They include pelagic cyprinids like *R. argentea* or *Engraulicypris sardella* which are beginning to support productive fisheries in Lakes Victoria and Malawi, respectively. The so-called river sardine, *Mesobola brevianalis*, has adapted well to small reservoirs in Zimbabwe, and other mesoboline cyprinids might do so as well. The numerous pelagic cichlids species that occur in Lake Malawi, especially the herring-like *Diplotaxodon* species, deserve some consideration, but their biology is still poorly known and their productive potential has not yet been determined. An important tilapiine cichlid from Lake Malawi, *Oreochromis lidole*, has been proposed as a candidate for introductions since it feeds on phytoplankton, and there are few riverine species that do so (Pitcher 1995). It might have difficulty establishing itself in most reservoirs, however, as it would have to compete for nesting sites with native tilapias like *O. niloticus*.

Conclusions

Introduced fish species have been responsible for major increases in the fishery productivity of several large African lakes and reservoirs, although Lake Victoria has paid a high price in the loss of biodiversity and ecological changes. The reservoirs are much more resistant, and there is a good case for introducing a planktivorous species into Lake Nasser. A suitable species could probably double the lake's production, at a small ecological cost, and the time may have come to give serious consideration to the idea. Indeed, it is probably the simplest and most effective way of increasing fishery production and would cost a fraction of what would be needed to improve productivity through stock enhancement or aquaculture.

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DISCUSSION

Q. In Lake Victoria, what was the impact of introductions compared to overfishing?

A. Overfishing was only on native *Oreochromis* species. Successful introductions were made in Lakes Kariba and Victoria. *Lates niloticus*, a top predator, destroyed over 100 species in Lake Victoria. The pelagic *Limnothrissa miodon* made a large, positive contribution to the Lake Kariba fishery without harming local species.

Q. What species would you suggest for introduction into Lake Nasser?

A. Freshwater clupeids. There may be other candidates for introduction, e.g., *Oreochromis rendalli* (chambo) from Lake Malawi, although it may hybridize in Lake Nasser.

Q. What is the sustainable yield for an introduced fishery using Lake Kariba as an example?

A. Sustainable yield of 70 000 t $year^{-1}$ is possible.

Q. Will introductions affect water quality?

A. In Lake Victoria, deterioration of water quality was accelerated by the introduction of Nile perch. However, most danger comes from industrial, human and other toxic discharges. An introduction of pelagic fish will probably not change the water quality.

Socioeconomic Policy Issues in the Management of the Fishery

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ABSTRACT

Despite being less important in Egypt's overall economy, the fishery in Lake Nasser has expanded to a remarkable extent over the years. Two aspects of fisheries management in the lake, namely fishing rights allocation and fish marketing, have been analyzed in this paper. Both of these have strong implications for optimal fishery production and sustainable management of the lake fishery. Major issues such as governance and participation, economic and social welfare of labor fishers, settlement and population growth around the lake, and factor share and resource rents are discussed in the context of a management policy for sustainable fish production. Based on a review of the experiences from some other lakes in and outside of the region, this paper concludes that a competitive and more realistic price and marketing structure is needed to replace current marketing and price control. Similarly, government-sponsored programs, such as cage culture, restocking, recreational fisheries and tourism, to improve income as well as to attract new investment in the industry, will require participation by a wider group, not just boat owners.

Introduction

Fisheries are an important component of all African lakes, whether human-made or natural. They provide an important source of high-quality animal protein and make significant contributions to the local and national economy in terms of income, employment and food supply.

Unlike natural lakes, the significance of fisheries in human-made lakes has nearly always had secondary significance, often a potential to be exploited in the future. The proponents of Lake Nasser did not have fisheries in mind as an option for development when it was first created. The main objective of its creation was water supply security for all of Egypt. Barrania and Saad (this vol.) emphasized that the direct use of water for agricultural, household, industrial and other commercial purposes is the principal priority of the Egyptian Government in the use of Lake Nasser. Hence, unlike some of the major human-made lakes where generation of hydro-electricity was the main objective of construction, electricity production was considered to be of secondary importance in Lake Nasser, as was fish propagation and fishery development.

Nevertheless, the lake has become an important source of fish protein for Egyptians. The fishing industry in the lake has expanded significantly. Manshard (1975) observed that within four years (1965-1969), the number of fishers in the lake increased from 200 to 3 200. By official accounts, about 4 000 fishers are currently engaged in fishing, and they catch about 22 000 t. An unofficial estimate puts the potential yield from the lake as >50 000 t. The total inland fishery production in Egypt is currently about 220 000 t. The annual domestic consumption of fish in Egypt is quite substantial, 7.2 kg per person (FAO 1997) which is quite high by African standards.

Socioeconomic characteristics of the Lake Nasser fishery

Fishing operations take place from as many as 500 fishing camps located along the shores or on small islands in the lake. A more detailed description of the fishing operation can be found in Barrania (this vol.). However, in the context of development and sustainable management of the fisheries, two aspects of fisheries management of the lake have strong socioeconomic and policy significance that need some analysis. These are (a) fishing rights allocation and fishing labor, and (b) marketing management.

Fishing rights allocation and fishing labor

Unlike other African lakes (such as Lakes Volta and Kariba) where fishing villages sprang up spontaneously, Lake Nasser did not attract any permanent settlement. Instead, the fishing industry was developed along commercial lines, utilizing the surplus labor force from other parts of Egypt. Fishing rights were allocated to owners of boats and gear through licences issued by the lake authority. The boat and gear owners, who are usually wealthy and powerful people, recruit fishers from various parts of the country to work as fishing laborers.

The labor force comes from as far as 300 km from the lakeshore. Usually, the boat owners employ this migrant labor on a periodic basis. Fishers stay in the fishing camps for a certain period of time as contractual employees of the boat and gear owners. The boat owner supplies food and other essential items required during fishing. At the end of the contract period, fishers are paid and go home. Hence, the common fishers have no ownership over their catch. The entire revenue from fish sales belongs to the owner. The net amount after payment of labor, fishing inputs and other related expenses is profit. According to Barrania (this vol.) these ("semi-feudalistic") boat owners control most fishing areas in the lake.

There is, however, little information on the structure and conduct of the labor market, and on the socioeconomic background of the fishing labor force. It is suggested that boat owners dictate employment conditions, and laborers get an inequitable share of the total fishing income.

Marketing management

Government-owned agencies control fish marketing in Lake Nasser. According to Barrania (this vol.), two state-owned companies collect the catch of fresh fish from individual fishing units and process them into frozen fish fillets before selling to national and international markets. Fishers are offered a fixed price for their catch, which is currently 2.2 Egyptian pounds per kg. It is alleged that the price for this type of fish in the open market could be three to four times higher. This has resulted in illegal sales to private buyers and under-reporting of the fish catch by licensed fishers.

State control of fish marketing from human-made lakes is not uncommon. Fishers in many such lakes are required to land their catch at designated landing centers managed by government agencies. There are instances where a portion of the catch is taken by the management authority as rent once the boat brings the catch to the landing site, for example in Kaptai Lake in Bangladesh (Khan 1998). Authorities may pay a fixed price for the catch and include some charges as user fees, for example in Nam Ngun Reservoir in the Lao People's Democratic Republic (Burapha Development Consultants 1992). However, such practices by government authorities have led to serious conflicts with respect to management of the stock and recording of catch. Fishers often resort to sale through illegal channels to avoid paying taxes or selling at a lower price. In Kaptai Lake, it was observed that high-value species were under-reported in the catch composition in official records.

The fishery of Lake Cahora Bassa in Mozambique is another example of monopolistic control on fish marketing by government agencies. The government fisheries agency (PESCOM) operates a contracting system that provides the fishers with gill nets in exchange for exclusive rights to purchase the catch at fixed prices. The fishers' negotiating power for a better price was confiscated by this arrangement. This caused severe conflicts between PESCOM and private purchasers, as well as between PESCOM and fishers in the early 1980s (Bernaesek and Lopes 1983).

As for Lake Nasser, it has been observed that fishers resort to selling fish outside the official channel in order to get a higher price for their catch. As a consequence, the use of data on landings as the basis of catch statistics became more and more unreliable. In recent times, the system of state control in marketing has been abandoned by most governments around the world in line with their policies for reducing inefficiency and waste in public resources management.

Major issues for an efficient and equitable management of the fisheries in the lake

Governance and participation

Experiences throughout the world have shown that regulatory management by state authorities has not only failed, it has also become more and more counterproductive. It has failed to enforce the rules and save the resources from overexploitation. It has not ensured an equitable and just distribution of benefits to those who provide their labor and who are engaged in the actual harvesting of the fish. Lake Nasser is not any different in these respects. For instance, monitoring and surveillance of fishing activities along the several thousand kilometers of shore of the lake is an impossible undertaking on the part of the lake authority. At the same time, given the existing control of the government over the landing and marketing of the catch, estimation of total catch is virtually impossible.

To optimize the fish harvest on a sustainable basis, it is important to achieve a higher degree of compliance of fishing regulations, as well as to collect a reliable estimate of the catch. Management options, such as a property rights system, common property management, and decentralization and power sharing between government and resource users, have become popular in recent years in small-scale fisheries in developing countries (Pinkerton 1989; Ahmed et al. 1996). However, experiences suggest that a clearly defined and homogeneous stakeholder group and strong motivation to participate in the management of resources, linked with other rural sectors, largely determine the success of decentralized and local level management efforts (often known as participatory management).

The strength of both civil society and government also play a crucial role in the success of decentralized management, such as co-management and community-based management. Many people argue that the existence of a strong civil society is a pre-condition for success of the above. Unfortunately, in many developing countries, especially those in the African continent including Egypt, the strength of the civil society is gradually eroding. In many cases the governments are equally weak, although Egypt has a relatively stronger government compared to many African neighbors. However, attempts are being made in some countries, particularly in Asia, to improve the strength of civil society through capacity building and empowerment strategies by national and international NGOs.

Other pre-conditions for a higher success of participatory management include the existence of scope for horizontal integration with other sectors such as agriculture and tourism, and the ability to produce a higher benefit from such integration.

Price and marketing

Throughout the world, state intervention in fish marketing has contributed little to rational management and maximization of the benefits from the fishery. Perhaps, at the beginning of the development of a fishery when a well-organized marketing system was yet to be established, government-owned agencies provided a form of economic security such as a guaranteed price for the catch. But as the industry matured and private sector marketing and infrastructure (e.g., roads and preservation or processing establishments) developed, the role of most government marketing agencies diminished. The Egyptian Government should review its current regulation on fish marketing, including the price-fixing in the Lake Nasser fisheries. Price-fixing as practiced in Lake Nasser forms a negative economic incentive. The impact of such a negative incentive on the fishing effort, and consequently on the state of fish stocks should also be investigated.

Economic and social welfare of the labor fishers

Fishing in most African lakes began with the spontaneous establishment of fishing villages within a short period after the creation of the lakes. Initially, when dams were built, people moved out. As the fishery developed, people moved back. Soon with the introduction of species, restocking, aquaculture and vertical economic activities, and the development of roads, infrastructure and markets, the fisheries produced a significant source of food and income. For instance, in Lake Volta, numerous fishery development programs were initiated by the government over the years, including vertically integrated activities such as landing centers, input supplies and postharvest activities in order to maximize fishery benefits and improve the welfare of the fishers (Kapetsky and Petr 1984). These certainly attracted more people, often different from those displaced. It also led to uneven competition and conflicts over access to lake resources. In Lake Nasser, the situation was different. Although fishing started to develop within a few years of the lake formation, no attempt was made to establish permanent settlements or any form of welfare program for the fishers. The welfare of the fishing labor force and its role in management of the lake is an important issue. There is at present very little information available on the condition of the fishers. Analysis of the labor market and productivity, together with the socioeconomic conditions of the labor fishers and their families, should be an important research focus in this regard.

Factor shares and resource rent

A particular aspect to be considered with respect to marketing of fish is that the current low price offered by government affects the boat owners' share of the fishing income. The government can see it as a means of collecting resource rent on and above the fee paid by boat owners as licence fee, which the government might see as a nominal entry fee. While it is true that the current low price offered by the government deters boat owners from putting all their catch for sale to the government marketing agency, it is hard to argue against it on the ground that the government is taking the fishers' share away.

The majority of the fishers, who in this case are labor fishers, are not part of this transaction. One can even argue that the wage rates paid to labor fishers are independent of the unit price of fish received by the boat owners. Despite the above, it is important to review the role and performance of the state-owned marketing agency, including its own economic efficiency. If the collection of resource rent is one justification for low fixed prices, there may be other means of collecting rent. Rather than indirectly charging an arbitrary rent in the form of lower price for their catch, a more direct and transparent approach would be more appropriate.

Research is needed to determine the factor productivity, so that efforts can be made to correct discrepancies, if there are any, in the current allocation of factor shares, including resource rent.

Settlement and population growth around the lake

When the Aswan High Dam was built, it displaced several thousand people. Over 100 000 from the Nubian provinces of Egypt and Sudan were resettled (Manshard 1975). However, after the lake was formed, no new settlements were established. Around many other African lakes, new settlements were developed within a few years. For instance, in Lake Volta, Ghana, fishers from the Lower Volta area moved upstream and established their own villages without any outside assistance (Kapetsky and Petr 1984). In Asia, settlements around lakes were equally quick to be established, especially where fishing and agriculture could be combined. The areas around Lake Nasser are sparsely populated. People live mostly in fishing camps separated from their permanent home base and families. There are no permanent communities around the lake. People who work as fishers and in fishing-related trading live in about 500 camps scattered around the lake or on islands. Infrastructure and facilities are minimal, and there have been no efforts in the past to develop other means of livelihood to support a permanent settlement. This issue is very complex for Lake Nasser from the point of view of maintaining the quality of the lake water vis-à-vis optimal management of fisheries and the need to provide security to those involved in the fisheries. From the perspective of developing partnerships for a sustainable fishery management, the establishment of a more settled community around the lake may be useful. Development, such as a culture-based fishery and restocking, will need much closer links with beneficiaries and resource users. Furthermore, research is required to determine whether or not the establishment of human settlements is socially and economically feasible. The effects of human settlement and other land-bound activities around the lake on the quality of lake water should also be carefully investigated.

Conclusions

The creation of artificial lakes by dam construction has negative as well as positive impacts. In this case, it displaced people who were culturally distinct, destroyed habitats and biodiversity, and altered the ecology and environment both upstream and downstream. The formation of Lake Nasser was no different from many other lakes in these regards although the scale of the impacts may have been outweighed by the benefits it provided to Egypt's national economy including the fishery However, much of the potential benefit from the fishery has been either lost or remained untapped due to the absence of a sustainable management strategy, which includes sound policies and institutions that link people or beneficiaries closer to the resource. State intervention through control over access, exploitation and marketing lead to ineffective regulation, costly and inefficient management, illegal practices and inequity, and inaccurate statistics.

A competitive and more realistic price and marketing structure is needed for improving the economic benefits from the fisheries in Lake Nasser. Also, any government-sponsored program to improve income as well as to attract new investment in the industry, such as restocking, cage culture, development of a pelagic fishery, recreational fisheries and tourism, will require participation by a wide group, not just the boat owners. Appropriate institutional and policy environments are needed.

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DISCUSSION

Q. How do changes in the natural environment affect the behavior of fishers, i.e., their socioeconomics? Environmental variations create uncertainty for them about their catch and thus income. The role of the fishery in the household economy should be addressed.

A. The natural ecological variations and their relationship to the fishery and fishers are not well understood. The household is traditionally used as a sample unit but the community level can also be used as a unit.

Q. Do you think we will lose time with community management as the fishers have little education?

A. Co-management was only mentioned as an option. There are, however, examples where fishers are educated and empowered. More focus is required, for example, on why people fish illegally.

Q. Who benefits from poaching and by how much?

A. There are only a few people involved in the Lake Nasser fishery so it should be possible to find this out.

Q. How do we appraise the positive and negative effects of the reservoir formation?

A. There have been many benefits from the impoundment. For example, the effects of the severe drought that ended in 1988 were mitigated in Egypt by the reservoir. However, displacement of people in general had negative consequences. Although new villages were built and there was compensation for the Sudanese, population density was low, there was resistance among people, and they are thought to be unhappy with their displacement. Nubians did not want to live in the new villages so these were converted into military villages. A social study is required on the number of people involved and a history of the events and their impact on the population.

Requirements for Fisheries Assessment and Management

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Pitcher, T.J. 2000. Requirements for fisheries assessment and management, p. 161-164. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p

ABSTRACT

Data requirements and the design of a frame survey for monitoring resources are discussed. Single-species stock assessments are outlined using either production or dynamic pool models. Quantitative management targets need to be identified for each commercial species. Multispecies assessment can include the impacts of harvest on a range of alternative ecosystems. A detailed fisheries management plan should be drawn up for the lake, including systematic documentation of the quantitative assessments of the principal commercial species. There is a need to design appropriate and enforceable instruments to implement management targets aimed at maximizing the benefit to society of the lake's fisheries. Because of the remoteness of the lakeshore, co-management between government and the local community is advised to maximize compliance with regulations.

Introduction

This paper is a brief outline of the present state of knowledge about research that could be used to estimate the exploitation status and management of Lake Nasser's fish resources from the workshop in Aswan held in June 1998. Statements here are based only on research material presented and discussed at the workshop; other work and information may be available, and so this paper may serve to identify material not presented there.

Catch data

Fishery assessment needs accurate catch data by species, place and time. Time series of catch data were presented for tilapia (*Oreochromis niloticus*) and Nile perch (*Lates niloticus*). For many Lake Nasser stocks, it will be important to obtain estimates of catches in Lake Nubia, since the fish populations extend across the international border. At present, Lake Nubia catch figures do not seem to be available.

Landings of each fish species should be estimated using a frame survey, which has to be planned with statistical rigor. In the workshop, it was not made clear how catch data had been gathered, whether statistical confidence limits had been estimated, and where in the lake fish had been caught. Moreover, it seems likely that much of the catch data comes from the official government landing site in Aswan, but the visit to this site suggested that more careful records need to be taken, particularly of the less abundant species, such as large catfish and cyprinids. It was not clear whether catch data were assembled only at Aswan, or whether attempts had been made to estimate catch at the point of origin. Illegal catch was reported at the workshop as being at least equal to the legal catch, estimated from informal interviews with fishers. Clearly, some effort should be made to obtain improved estimates of the true catch from the lake. Two methods of doing this might be: (a) to ask "what must catch have been to reduce biomass to the present level?" This requires estimates of B_0 and B_{now}, and (b) to employ confidential interview techniques, using survey statistics methods with internal cross validation and methods to detect lies. Market records of prices at the government-landing site at Aswan miss the obviously extensive trade in fish that occurs outside the government system. This is important because underestimates of catch may provide false signals that resources are in good shape and encourage depletion and overfishing.

Effort data

Many forms of fish stock assessment require estimates of fishing effort. Data required are the number of vessels by gear type, vessel size, place and time. Unfortunately, very little material on the composition, gear types and catching power of the fishing fleet was presented at the workshop. This information would be provided and monitored in the future by a frame survey program, although this would not improve the historical record of catches needed for assessment. Fish landed by carrier boats are transported down the lake to Aswan, and carrier boat loads and trip numbers would provide a good crosscheck on landings data.

Stock assessment—parameter estimates

Critical parameters for stock assessment are growth and mortality by species, location and season. In addition, data are required on biomass, reproductive status and diet.

Growth

At the workshop it was clear that both age-based and length-based methods have been used quite effectively to estimate growth parameters such as L_{00}, W_{00}, and K for many Lake Nasser fish. It would be valuable to compile a comprehensive database of this work so that any gaps can be identified. The auximetric growth parameter, Phi-prime, generally has not been estimated. This should be done, as it can assist the validation of other estimates. In most cases, various preprogrammed software packages had been used to fit growth parameters, but simple techniques of fitting using spreadsheet methods might be encouraged because of the ease of obtaining confidence limits by Monte Carlo methods (see Pitcher 1999).

Mortality

Very few estimates of total mortality, Z, were presented at the workshop, which is surprising because of the simplicity of obtaining approximate estimates of Z from aged catch curves or from length-based catch curves. Most presenters had used Pauly's (1980) empirical equation to obtain natural mortality, M, but estimates of current F were very few.

Reproductive cycle

It is important to estimate fecundity and the timing and frequency of spawning, or brood production in tilapia, but little of this material was presented at the workshop. The location and relative abundance of juveniles of species with high conservation status such as the cyprinids might be monitored with specially designed surveys.

Biomass

Biomass estimates are required, not only as a part of conventional stock assessment, but also for ecosystem modelling. Estimates that are independent of stock assessment procedures and of fishery-based data are especially valuable. In the Aswan workshop, almost no biomass estimates for fish stocks were presented. Regular surveys of relative biomass using specially designed sampling gear or adaptations of gear used by commercial fishers should be designed and carried out. Tagging can help as part of a mark and recapture survey. Regular acoustic surveys can also be valuable and may be carried out reasonably cheaply using modern portable equipment.

Diet

For ecosystem modelling, quantitative information on the diet of the fish, including noncommercial species has to be assembled. These data should preferably be gathered by season and at several locations in the lake. As there are several different methods for scoring fish stomach contents, a diet survey needs to be carefully designed in relation to resources and humanpower.

Stock assessment—single-species assessment

Single-species assessments may be carried out using a variety of approximate and standard methods. It is often best to employ the widest range of methods possible, to allow for cross validation. Many methods these days may be performed using spreadsheets, and uncertainties estimated using Monte Carlo simulation.

Approximate methods for potential yield

Approximate methods of estimating potential yield have been applied to Lake Nasser, such as the Morphoedaphic index (MEI – Ryder 1982) and Pitcher's target lake method (Pitcher and Bundy 1998). Beddington and Cooke's (1983) method and the approximate catch/effort "Walter" plot (Walters 1986) technique have not been used on the lake's fisheries.

Production models

Nonequilibrium methods for production (= surplus yield) models can be employed only when time series of catch and effort are available, although some short cuts are possible. The surplus production, or a semi-age-structured form, such as the delay-difference model (Hilborn and Walters 1992) with environmental drivers may be used to estimate current biomass and unexploited biomass. The latter concept in a human-made lake such as Lake Nasser is of interest (it represents a kind of virtual population size that was probably never achieved in the past).

Dynamic pool models

Equilibrium age structured models of yield-per-recruit, biomass-per-recruit and mean mass of fish in the catch are simple to draw up, and some analyses for tilapia were presented at the workshop (see Khalifa et al., this vol.). When implemented on a spreadsheet, many model parameters can have uncertainties attached using Monte Carlo simulation methods (Pitcher 1999). Nonequilibrium dynamic pool models require a submodel describing stock and recruitment which may be difficult to obtain, but nevertheless may be employed to evaluate a range of management scenarios (see Beverton 1998; Pitcher 1998). To set quotas, they may be used with a series of age structured catch data that may be analyzed with virtual population analysis (VPA) (see Pitcher and Hart 1982) or more modern catch-at-age analyses.

Management targets

When used carefully, single-species dynamic pool assessments can provide relative estimates of current biomass in relation to target biomass, how catches (quotas) of different size will impact stock dynamics and recruitment volatility, and the status of current values of F in relation to a target F, such as $F_{0.1}$ or $F_{0.2}$. Although care has to be taken in their interpretation, these analyses should be completed for all the main species of fish caught in the lake. More sophisticated management targets, such as F_{med}, are in use in ICES and elsewhere (Sissenwine and Shepherd 1987), but these could be estimated later.

Stock assessment—multispecies and ecosystem-based assessment

Multispecies yield per recruit (YPR) analysis

Multispecies yield per recruit (YPR) analysis sets up a simultaneous set of YPR surfaces weighted by relative biomass per recruit (BPR) (see Murawski 1984). By including fish prices, value per recruit is obtained. ('Beam' software can be obtained from FAO [Sparre and Willman 1993]), or it is possible to implement on a large spreadsheet). The individual-species YPR analysis uses the length-based Thompson and Bell equations (see Sparre and Venema 1992), and the management axes are mesh size and F. The optimal mesh size for a multispecies trawl fishery can be estimated with this technique. The analysis is therefore suitable only for net or trawl fisheries.

Ecosystem-based assessment using ECOPATH and ECOSIM

Methods of using mass-balance models to investigate the dynamics of fished ecosystems are described by the author elsewhere in this volume. Although this is new departure, these models can also be employed to assess the status (economic as well as biological) of fisheries in relation to their ecosystem impacts. Alternatives that might be compared are the present lake fisheries, possible lake fisheries where some resources might be overfished or not fished, and different lake ecosystems with introduced species.

Instruments

At the workshop there were almost no details about the instruments that might be used to achieve fishery management policies. There appears to be a limit on the number of fishing vessels and some minimum size regulations. Quotas, closed seasons or closed areas have been implemented (El Shahat, this vol.).

Gear restriction

It was not made clear if there are any place, time, type or gear restrictions, and whether by-catch reduction devices have been considered for targeted fisheries; however, see El Shahat (this vol.).

Catch restriction

It is evident that annual catch quotas have not been estimated or implemented.

Effort restriction

There appears to be a limit on the number of fishing vessel licences, but it is not clear how this figure was arrived at in relation to the catching power of vessels and the lake stocks of fish. Moreover, the relationship between the licensed number and the actual number of vessels fishing was not described at the workshop.

Closed season

No information was provided on closed seasons. Although this is not a concern for tilapia and Nile perch, cyprinids and catfish stocks might benefit from closure of the breeding grounds during the spawning seasons. Once quantitative assessments are in place, investigations of the effect of closed seasons might be made.

Closed areas

The area adjacent to the Aswan High Dam is closed to fishing vessels for security reasons, although it is not clear how well enforced this regulation is. Closed areas can act as a valuable hedge against uncertainty in fisheries management and should be considered seriously for several areas of the lake. Spatial information on catches, effort and biomass would make spatially partitioned stock assessment easier.

Community management

Because of the remoteness of the lakeshore, co-management between government and the local community is advised to maximize compliance with regulations. As shown in Fig. 1, the efficacy of regulations drawn up by central government institutions is generally high, but compliance by local fishers is low. Compliance with regulations drawn up by local fishing communities is often high, but generally not very efficacious. A balance between the two, represented by co-management, maximizes the benefit to the resource.

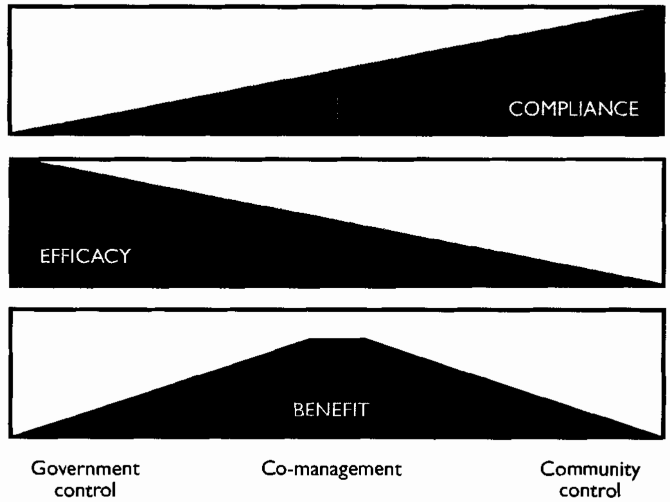

Fig. 1. Co-management achieves a balance between government and local design and control of regulations for fisheries.

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DISCUSSION

Q. Is it important to know that the values derived from fishery models should not be assumed to be correct, just useful tools?

A. Agreed. This is why confidence limits should be calculated.

Q. By-catches are probably very low in Lake Nasser, so should they be considered?

A. Long lines and gill nets are not the most efficient at catching only the target species. Observations are required at fishing sites as these data are required in modelling.

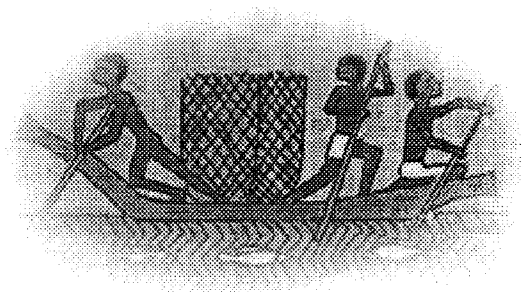
Q. Would fish attraction devices (FADs) be of value?

A. FADs would be very useful and desirable particularly if not fished but left as sheltering areas (closed areas) and sanctuaries. Sanctuaries should be at least 10% of the total fished area and possibly permanently enforced.

Q. What is the best method for estimating biomass?

A. Several methods should be tried on a species by species basis if possible.

V



Planning

Planning: Project Recommendations and Implementation Plans

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Craig, J.F. 2000. Planning: project recommendations and implementation plans, p. 167-170. *In* J.F. Craig (ed.) Sustainable fish production in Lake Nasser: ecological basis and management policy. ICLARM Conf. Proc. 61, 184 p.

ABSTRACT

Suggestions arising from the workshop discussions for implementing the project are listed, including tasks and requirements for identified subprojects.

Summary of the discussions following the reports of the working groups on development of the Lake Nasser Project

Several common features emerged from the presentations made by the various working groups in relation to the sustainability and enhancement of the fishery in Lake Nasser. These included the following:

- The base for the project should be in Aswan.
- There is a need to set priorities. This process is complex. However, training, the establishment of a database, and dealing with existing knowledge should come first (see Craig, this vol., p. 107). Further, essential activities may emerge after the Workshop proceedings have been circulated.
- Information gaps should be clearly identified (see Craig, this vol., p. 105).
- Contact should be made at an early stage with policymakers, Sudanese authorities (important to consider the lake as a whole) and local fishers (make them feel part of the project).
- Training is essential in new methods and techniques. This would be achieved by short courses, possibly in Aswan or elsewhere (e.g., ICLARM). There is also a need to improve staff qualifications. Master's or doctorate degrees for the staff could be obtained overseas or, if cost is a problem, in Egypt with short periods outside.
- A Lake Nasser Fishery Management Research Group should be formed. The linkages between trophic groups were, with a few exceptions, seldom stressed at the workshop. Since this project takes a multidisciplinary approach, it is important that the workers involved develop their research with a view to strengthening these linkages. The multidisciplinary approach becomes particularly important where there is an interface between human and biological aspects of the fishery; and there may be a need for training in multidisciplinary projects. ICLARM has experience in this field. Tasks and requirements for research are listed below.
- Several groups gave what amounted to a "wish-list" of equipment needs, which is probably unrealistic at present. All the institutions involved in research on Lake Nasser should therefore assess what equipment they already have and determine the extent to which it can be shared.
- Access to the literature was identified as a major constraint. Everyone working on Lake Nasser is finding it very difficult to keep up-to-date, but there may be ways in which this project could meet that need.
- There is a need for improved communications, which includes access to the Internet. There is a general need for more outside consultation, including advice from experts, and it was suggested that an advisory group be set up to review reports and proposals before submission.
- The establishment of a newsletter would improve communications. This would be distributed locally and internationally.
- It was accepted that it is difficult for local workers to travel to international meetings, but some funds should be used for this purpose. It is also possible that overseas students might be able to work on Lake Nasser, while establishing links with local scientists.

- Most of the sampling in the lake seems to have been done in the central channel. It is necessary to sample in all areas, including the khors, on a multidisciplinary basis. The Nile valley was well-mapped before it was flooded.
- Postharvest techniques were well below acceptable standards, resulting in unnecessary spoilage and a product unsuitable for export. Training and improvement of the facilities are required.

Tasks and requirements for each discipline as identified in the workshop

Fishery management research group

Tasks
- Oversee the activities of all subprojects.
- Provide guidelines to ensure an ecosystem approach to the study and integration of topics.
- Compile and synthesize all existing and new research data.
- Develop management tools for the lake, taking into account ecological, economic and social factors.

Physical and chemical limnology

Tasks

Collect and analyze:
- Available data from remote sensing.
- Meteorological data from at least two representative weather stations, including temperature, wind, evaporation, relative humidity and precipitation.
- Hydrological data (calculate water balance).
- Water temperature and dissolved oxygen data (calculate profiles including stratification patterns).
- Light data including the effect of suspended matter.
- Nutrient, pH, total dissolved solids (TDS), etc., data.

Requirements
- Conductivity/temperature/depth probe (CTD) with additional facility for measuring light (photosynthetic active radiation, PAR) and O_2 concentration
- Van Dorn-type sampling bottles and suitable winch for deployment
- Laboratory equipped with basic glassware, chemicals and analytical instruments for nutrient analysis
- Research vessel time

Bacteria

Tasks
- Monitor sanitary quality of the lake water for drinking, irrigation, agriculture and fish production.
- Determine the role of bacteria in nutrient cycles.

Requirements
- A well-equipped microbiology laboratory

Phytoplankton

Tasks
- Determine spatial (vertical and horizontal) distribution and standing crop of chlorophyll *a*.
- Determine primary production for planktonic and benthic algae.
- Measure sunshine and PAR.
- Collect satellite data on lake surface temperature and suspended sediment values (with possible addition of chlorophyll *a* measurements).

Requirements
- Researcher, field assistants and technicians
- Fluorometer
- Inverted microscope and counting chamber
- Hand-held oxygen meter and incubation vessels
- Data from physical and chemical limnology studies including meteorological data
- Research vessel time

Macrophytes

Tasks
- Determine spatial and temporal distribution and standing crop (chlorophyll *a* and dry weight).
- Determine primary production particularly in the shallow water zone (down to one meter) and of the charaphytes.

Requirements
- Researcher, field assistants and technicians
- Drying oven, oxygen meter, conductivity meter, spectrophotometer and balance

Zooplankton

Tasks
- Perform qualitative and quantitative studies, including taxonomy and estimates of biomass and production.
- Estimate zooplankton consumption of phytoplankton.
- Estimate fish consumption of zooplankton.

Requirements
- References and expert advice for identification
- Plankton nets
- Research and stereoscopic microscopes
- Aquaria

Benthic invertebrates

Tasks
- Estimate biomass and production.
- Determine seasonal cycles in abundance.
- Apply data to ecosystem models.

Requirements
- Scientist, assistant and technician
- Equipment (unspecified)
- Training in taxonomy

Fish-eating reptiles and birds

Tasks
- Estimate abundance of predators.
- Determine the fish species eaten and their size range by examination of the predator's stomach content.
- Quantify the biomass of fish eaten.

Requirements
- Two biologists for bird surveys
- One biologist and one hunter for crocodile and other reptile surveys
- Research vessel time
- External expert on reptiles to train local staff
- Training in gut content analysis and relating bony structures remaining in the gut to the size of fish consumed
- Cameras with zoom telephoto lenses
- Tagging equipment
- Life insurance for the crocodiles biologist!
- Laboratory space with dissection equipment, etc.
- Training in statistics

Fishery biology and aquaculture

Tasks
- Examine the potential benefits and hazards of introducing a new fish species to utilize the openwater area.
- Determine the genetic composition of Nile tilapia used in stock enhancement and the natural, wild fish and determine the cost/benefit of the enhancement program.
- Culture threatened endemic fish for re-introduction.

Requirements
- Access to a genetics laboratory
- Boat with facilities for live fish transportation
- Truck for live fish transportation
- Training, especially in genetics

Fishery assessment

Tasks
- Estimate sustainable harvest (yield) by species.
- Improvement of fishery statistics through camp (fishers, gears, boats, etc.) and landed and salted fish (composition, length, frequency, etc.) surveys.
- Estimate biomass by hydroacoustics.
- Gather biological data on age and growth, reproduction, food and feeding, demographic structure, etc.
- Develop a database.
- Apply analytical and ecosystem models.

Requirements
- Researchers, assistants and field technicians
- Database manager
- Stereo microscope for ageing by otoliths, scales, opercula, fin rays, etc.
- Research microscope
- Research vessel time
- Echo-sounder (integrated system)
- Training in hydroacoustics

Sociology

Tasks
- Review literature concerning social aspects of human activities in the lake to identify knowledge gaps. In particular, the relationship between human behavior and the natural ecosystem and how human behavior is affected by change in the fish resources base.
- Collect qualitative data (interviews, group meetings, etc.) on issues such as markets and marketing.
- Collect quantitative data (stratified sampling) on how the process of production is organized, the relative importance of fisheries to the fishers' household economy, allocation of the catch value, catch distribution to the consumers, the conditions of workers in the processing plant, organization of the fishing cooperatives, their success and legal status, living conditions in the campsites, the potential role of sport fishing, formulation of policies and enforcement regulations, and quota setting.

Requirements

- Project leader and two research assistants

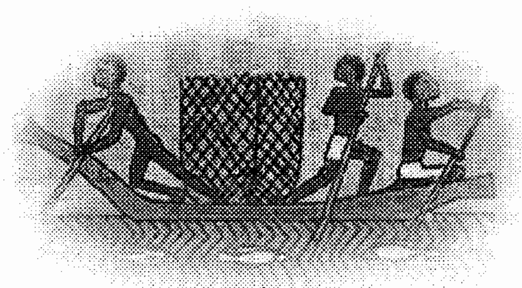
Economics

Tasks

- Collect and analyze data on:
  - Policy and institutional aspects including national plans for lake development and legal and institutional aspects.
  - Economics of production including fishing technology and impacts, labor force participation and fishing operations and fish processing.
  - Fish marketing including demand and supply of fish; patterns in human consumption of fish, fish markets, channels and margins; fish prices and pricing policies.
  - Income and its distribution including scarceness of income of fishers' families and sharing of fishing income and distribution.
- Establish policy recommendations.

Requirements

- One senior economist, two research assistants and six field data collectors
- Tape recorders and calculators
- Training in research methods, research design, field data collection, computers and databases



Indices and appendices

Species Index

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Appendix 2. Workshop Program

19 June 1998

19:00	Meeting of all chairs and rapporteurs at the Isis Island Hotel

20 June 1998

9:15	Welcome and introduction to the activities of the Authority M.H. Tolba, Chairman of High Dam Lake (Nasser) Development Authority
	Session 1: Introduction Chair: J.F. Craig (ICLARM). Rapporteur: O.A. Habib (FMC)
9:30	Lake Nasser overview. .... M.M. El Shahat (FMC)
9:45	Lake Nasser: conflicts between users. .... M.B.A. Saad (HRI)
10:00	Aims and objectives of the workshop .... J.F. Craig (ICLARM)
10:15	Ecosystem modelling .... T. Pitcher (UBC)
11:00-11:45	Coffee
	Session 2: Present state of knowledge Chair: M.M. El Shahat (FMC) Rapporteur: A Barrania (INP)
11:50	Physical limnology .... A.A. Mohamed (FMC) and R.G. Abdallah (NIOF)
12:10	Chemical limnology .... R.H. Goma (FMC)
12:30	Bacteriological studies .... S. Rabeh (NIOF)
13:00-14:00	Lunch
	Session 3: Present state of knowledge, continued Chair: H.K. Badawi (NIOF) Rapporteur: M.M. Mohieddin (UM)
14:00	Primary production of phytoplankton .... O.A. Habib (FMC)
14:20	Average changes in the distribution of phytoplankton chlorophyll *a* in the eutrophic zone and *Microcystis aeruginosa* Kutz water blooms .... I.O. Mohamed (FMC)
14:40	Aquatic macrophytes in Egyptian Nubia before and after the formation of Lake Nasser .... M.M. Ali (SVU)
15:00	Secondary production .... O.A. Habib (FMC) and G.M.El Shabrawy (NIOF)
15:20	Macrobenthic fauna .... M.R.A. Fishar (NIOF)
15:40	Fish-eating birds .... M. Tharwat (ASU)
16:00-17:30	Break
17:30	Depart for Nubian Museum and Temple of Philae (organized by FMC).

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7:00	Depart from hotel
	Field trip to the lake, the fish landing site, fish processing plant, hatchery, FMC and research vessel. Fish lunch on the lake. (Organized by FMC).
13:15	Return to hotel
	Session 4: Present state of knowledge, continued
	Chair: R. Rowe (ICLARM)
	Rapporteur: J.F. Craig (ICLARM)
14:00	Fish biology .... H.A. Adam (FMC) and M.Z. Agaypi (FMC)
14:20	Population dynamics .... U.S.A. Khalifa (NIOF)
14:40	Net cage culture of silver carp without artificial feeds ...... B.Z. Shenoda (FMC) and M. Naguib (FMC)
15:00	Fisheries management and enhancement .... M.M. El Shahat (FMC)
15:20	Harvesting, transporting, processing and marketing of Lake Nasser fish .... A. Barrania (INP)
15: 40	Socioeconomic aspects. .... M.M. Mohieddin (UM)
16:00-18:00	Break
	Session 5: Constraints analysis
	Co-ordinated by J.F. Craig (ICLARM)
	Rapporteur: M.S. Abdullah (FAO)
18:00	Introduction. J.F. Craig
18:30	Round-table discussions
	Session 6: Project planning—evaluation and setting new objectives and strategy
	Coordinator: T. Pitcher (UBC)
	Rapporteur: H.A. Adam (FMC)
19:00	Introduction—rapid appraisal techniques. .... T. Pitcher (UBC)

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	Session 7: Project planning—evaluation and setting new objectives and strategy, continued
8:30	Ecosystem studies
	Overview and Chair of discussions: G. Patterson (NRI)
	Rapporteur: B. Marshall (UZ)
9:30	Aquaculture
	Overview and Chair of discussions: M. Nomura (NFDA)
	Rapporteur: R.H. Goma (FMC)
10:30	Coffee
11:00	Stock enhancement
	Overview and Chair of discussions: B. Born (FAO)
	Rapporteur: R. Rowe (ICLARM)
12:00	Fish introductions
	Overview and Chair of discussions: B. Marshall (UZ)
	Rapporteur: M. Ahmed (ICLARM)
13:00	Lunch

Session 8: Project planning—evaluation and setting new objectives and strategy, continued

1400	Socioeconomics Overview and Chair of discussions: M. Ahmed (ICLARM) Rapporteur: B. Born (FAO)
15:00	Fisheries management Overview and Chair of session: T. Pitcher (UBC) Rapporteur: G. Patterson (NRI)
16:00-19:00	Break

Session 9: Project planning—evaluation and setting new objectives and strategy, continued

Chair: J.F. Craig (ICLARM)

19:00-21:00	Identification of research proposals and selection of working groups

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Session 10: Project recommendations and implementation plans

Chair and Coordinator: T. Pitcher (UBC)

Rapporteur: B.E. Marshall (UZ)

8:30-10:30	Small working groups to develop detailed subproject workplans
10:30-13:00	Reports of working groups on tasks and requirements Recommendations for implementation Formalization of project proposal
13:00	End of workshop Lunch and departure

Acronyms

ASU	Ain Shams University (Egypt)
FAO	Food and Agriculture Organization of the United Nations
FMC	Fishery Management Center (Egypt)
HRI	Hydraulics Research Institute (Egypt)
ICLARM	International Center for Living Aquatic Resources Management
INP	Institute of National Planning (Egypt)
NFDA	New Fish Development Association (Japan)
NIOF	National Institute of Oceanography and Fisheries (Egypt)
NRI	Natural Resources Institute (UK)
SVU	South Valley University (Egypt)
UBC	University of British Columbia (Canada)
UM	University of Menoufia (Egypt)
UZ	University of Zimbabwe (Zimbabwe)

Steering committee

J.F. Craig (ICLARM)	Workshop organizer
M.M. El Shahat (FMC)	Local organizer
T. Pitcher (UBC)	

Sustainable fish production in Lake Nasser: ecological basis and management policy. J.F. Craig, Editor. 2000. ICLARM Conf. Prof. 61, 184 p.

TITLE OF RELATED INTEREST

A guide to the ECOPATH II software (version 2.1). 1992. V. Christensen and D. Pauly. ICLARM Software 6, 72 p.

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