Estimating the Food Consumption of Fishes: One Step in Linking a Species with its Ecosystem

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Estimating the food consumption of animals is a valuable piece of knowledge of their ecology, and it is even more important if one attempts to assemble the jigsaw puzzle, i.e., to make a species part of the ecosystem from which it was taken. Research on food consumption is being done in ICLARM's Capture Fisheries Management Program, in the course of which some new methods were developed. Some of them, pertaining to (i) the estimation of daily ration for a specific size group and (ii) the estimation of food consumption of an entire population, have been implemented in a new software package called MAXIMS (with due respect to gourmets).

Estimating Daily Ration

Following an approach of K.J. Sainsbury of CSIRO, Australia, the daily ration of animals of a particular size group can be estimated from a 24-hour cycle of stomach content weights[1]. This approach was extended[2] and is now implemented for one or two feeding periods per day[3], accounting for animals feeding during the day or during the night only (i.e., once per day) or during dawn and dusk (i.e., twice per day). This covers the main feeding cycles of fish, which show various morphological and behavioral adaptations to light conditions, but are usually only adapted for activity during either day or night. Such morphological adaptations include the spectral sensitivity of the photoreceptive cells in fishes' eyes to the light conditions at different times of the day; behavioral adaptations include schooling of small fish with its "confusion effect" on predators, or seeking shelter nearby. Conversely, many piscivorous fish hunt during *twilight*, when their prey becomes more vulnerable to them.

General data requirements for the estimation of daily ration with MAXIMS are a diel (i.e., 24-hour) cycle of stomach content weights, which may be accumulated from data from several cycles of day and night. Samples should be taken at least every three hours for species with one feeding period per day, or at least every two hours for species feeding twice per day. The reason for the increased data requirements for species with two feeding periods per day is not only the fact that two more parameters are estimated (the beginning and end of the second feeding period), but also that the daily ration is integrated over the duration of the feeding period, which, for dawn and dusk feeders, is limited to about two to four hours. Sampling to cover the beginning of the feeding period and the beginning of the nonfeeding period in smaller time intervals will thus greatly increase the reliability of the daily ration estimate.

The "raw" stomach content weights obtained from the animals sampled should be standardized for an "average" animal of the investigated size group, by dividing the stomach contents weights by the animal's body weight and then multiplying this relative stomach contents weight with the average body weight of the animals in the entire (24-hour) sample. This procedure accounts for variability of the stomach content weights which is due to the size of fish, but not to the actual fullness of the stomach.

The software estimates the feeding times, the rates of ingestion and evacuation and related parameters. This amounts to a total of four to seven parameters, depending on the model selected. At present, the software is based on a simple equation for stomach evacuation, and two different models of ingestion, the first ("Model I") assuming a constant ingestion rate throughout the feeding period, and the second ("Model II") assuming a feeding rate inversely proportional to the stomach content. An additional routine is still being implemented which will generalize these ingestion and evacuation models, and also include a method (the "jackknife") for estimating the reliability of the estimate of daily ration obtained.

Two applications of the program are shown in Figs. 1 and 2. The first pertains to Peruvian anchoveta *Engraulis ringens*

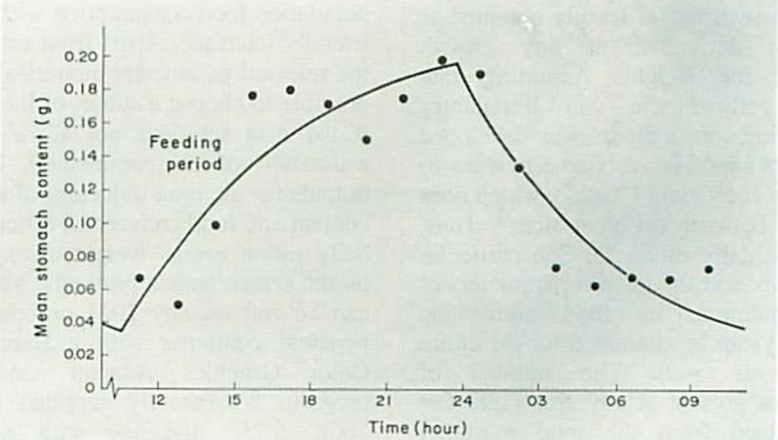

Fig. 1. Time trajectory of stomach contents of the Peruvian anchoveta *Engraulis ringens*, showing one feeding period per day, as fitted with MAXIMS (adapted from Pauly, D., A. Jarre, S. Luna, V.C. Sambilay, Jr., B. Rojas de Mendiola and A. Alamo. 1989. On the quantity and type of food ingested in Peruvian anchoveta, 1953-1982, p. 109-124. *In* D. Pauly, P. Muck, J. Mendo and I. Tsukayama (eds.) The Peruvian upwelling ecosystem: dynamics and interactions. ICLARM Conf. Proc. 18, 438 p.).

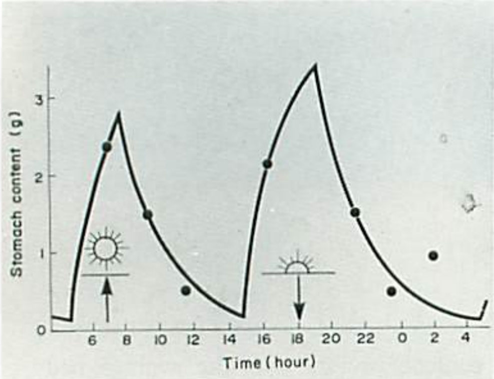

Fig. 2. Time trajectory of stomach contents of Baltic cod, showing two feeding periods per day, as fitted with MAXIMS. Note that the data represent the lower limit of requirements. (Data from Arntz, W.E. 1974. Die Nahrung juveniler Dorsche (*Gadus morhua* L.) in der Kieler Bucht. Ber. dt. wiss. Kommn. Meeresforsch. 23:97-120.)

with one feeding period per day, and the second one to juvenile Baltic cod *Gadus morhua*, which feed during dawn and dusk, i.e., twice per day.

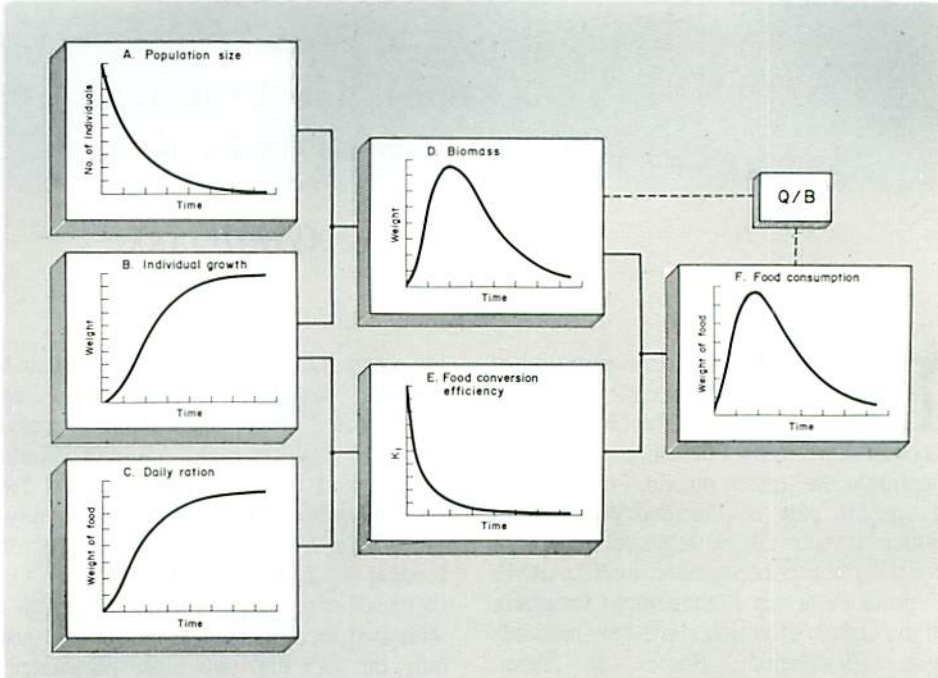

Fig. 3. Schematic representation of the functions relevant to the estimate of population food consumption Q/B described in the text. All functions are shown *vs* age. A. Simple exponential decrease of a population, as obtained from the total mortality coefficient Z; B. von Bertalanffy growth function; C. Population biomass as product of weight and actual numbers; D. Decline of gross food conversion efficiency; E. Increase of individual daily ration; F. Food consumption of a population, which, divided by biomass, yields the parameter Q/B.

Estimating the Food Consumption of an Entire Population

The daily food consumption of a population can be computed as the product of the daily ration of each of its constituent size groups and the numbers of specimens present in this size group. However, daily ration estimates covering the entire size range of a species are hard to obtain; it is easier to express daily ration as the ratio of growth rate of a particular size group and its food conversion efficiency.

The growth rate is readily obtained as the first derivative of any growth equation for weight. Assuming that growth follows the von Bertalanffy growth function, a model was developed which links food conversion efficiency to size via a coefficient ("beta"), which does not vary between different sizes[4]. Thus, given the daily ration for one particular size group, and the growth parameters of the population, its food conversion efficiency can be estimated for the entire lifespan as well. The number of specimens present at any size (age) can be obtained from the total mortality coefficient. Hence, given the parameters of the von Bertalanffy growth equation, the total mortality coefficient, and at least one size-specific estimate of daily ration, the food consumption of a population can be estimated[5]. Dividing this by the biomass yields the parameter "Q/B" as an estimate of consumption which is independent of the actual size of the population (Fig. 3).

The MAXIMS Software

MAXIMS implements the above models for estimating daily ration and population food consumption with a user-friendly interface. Apart from estimating the relevant parameters numerically, it is possible to choose a subset of them (e.g., if the data set does not allow for the estimation of all parameters). Graphic outputs for the time trajectory of stomach content and food conversion efficiency or daily ration *versus* weight are available on the screen and as printouts. MAXIMS can be run on any IBM or compatible personal computer with a Hercules or Color Graphics Adapter card. The program is presently supplied on two 360K 5.25" diskettes with a user's manual and is available from the ICLARM Software Project as ICLARM Software 4 for US$20 to cover shipping and material costs. Ordering details are on p. 16.

Further Reading

[1] Sainsbury, K. 1986. Estimation of food consumption from field observations of fish feeding cycles. J. Fish Biol. 29: 23-36.

[2] Jarre, A., M.L. Palomares, M.L. Soriano, V.C. Sambilay, Jr. and D. Pauly. 1989. Some improved analytical and comparative methods for estimating the food consumption of fishes. Paper presented at the ICES "Symposium on Multispecies Models Relevant to Management of Living Resources", 2-4 Oct. 1989, The Hague, Netherlands. 19 p. (*In press* in Rapp. P.-V. CIEM).

[3] Jarre, A., M.L. Palomares, M.L. Soriano, V.C. Sambilay, Jr. and D. Pauly. 1990. A user's manual for MAXIMS: a computer program for estimating the food consumption of fishes from diel stomach contents data and population parameters. ICLARM Software 4, 27 p.

[4] Pauly, D. 1986. A simple method for estimating the food consumption of fish populations from growth data and food conversion experiments. Fish. Bull. 84(4): 827-840.

[5] Palomares, M.L., and D. Pauly. 1989. A multiple regression model for predicting the food consumption of fish populations. Austr. J. Mar. Freshwat. Res. 40: 259-273.

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