GUINEA CURRENT LARGE MARINE ECOSYSTEM
(GCLME) PROJECT

ECOSYSTEM-BASED FISHERIES MANAGEMENT WITH EMPHASIS ON FISH DIET

USER'S GUIDE

Edited by

Njifonjou Oumarou

Jacques Abe

Supervised by

Christian Susan

Maxwell Donkor

September 2009

This User's Guide is dedicated to the life and work in the regional fisheries biology of the GCLME Fisheries Experts, late Djama Theodore and Gabche Charles from Cameroon, Catherine ISEBOR from Nigeria, ------------ from Sierra Leone and ------------ from Sao Tome and Principe.

TABLE OF CONTENTS

PREFACE

The recent FAO review on the state of the world marine fishery resources is alarming. In fact, most of the traditional fisheries around the world are either over-exploited or nearly so. The over-capitalization of the fishing industry as well as the open-access regime of ocean resources experienced in the past and the anthropogenic misuse of ocean environment are amongst others responsible for this situation. The developing countries and more especially the sixteen countries of the Guinea Current Large Marine Ecosystem (GCLME) region which extend from Guinea-Bissau in the north to Angola in the south have been impacted severely from the decline of their regional fisheries and the destruction of aquatic habitat. In fact, the conclusions on the status of fisheries stocks of the region, based on assessment undertaken by the Fishery Committee for the Eastern Central Atlantic (CECAF) scientific sub-committee (Lome, Togo 24-26 February 2004) and the sixteenth session of the CECAF committee (Dakar, Senegal 24-27 May 2004) reveal that all (eighteen) demersal stock assessed in the region were either fully exploited or over-exploited. The future is even more threatening as the human population continues to grow thereby putting fishery resources under continuous pressure of exploitation.

However, the ultimate challenge in the GCLME region is to sustain its people with food and improve their social welfare, at the same time conserve the aquatic environment. It is probably for this reason that the mandate of the fisheries component of the Guinea Current Large Marine Ecosystem project (GCLME) is centred on the “Recovery and Sustainability of Depleted Fisheries and Living Marine Resources”.

To achieve these objectives, one of the strategies to develop will be to carry out trophic interaction studies which will determine fisheries ecosystem structure and dynamics. This is usually done by studying the feeding ecology of fishes through analysis of stomach contents. It is important to recall for the purpose that, the trophic interaction studies have only recently been considered in the management of fisheries. Although as said earlier, it is recognized that overcapacity is the major cause of the prevalent worldwide resource over-exploitation, ignoring the importance of fish interactions can partly contribute to the mismanagement of fisheries stocks and consequently considered as another cause of resource depletion. There is a necessity for a change in the orientation of fisheries management, by including these aspects in present management schemes, so as to reverse the situation. This User's Guide should therefore be considered as a modest contribution towards introducing trophic interaction studies into fisheries management.

This manual is first and foremost directed to the fisheries scientists of the Guinea Current Large Marine Ecosystem (GCLME), who for the reasons mentioned above, will have to devote themselves to the analyses of stomach contents to be collected either from Fishery Resource Surveys or from the artisanal and/or commercial fisheries of their countries and/or the region. This will contribute with the addition of other inputs to the recovery of fishery stocks. Other readers would also find this manual useful in the conduct of their daily activities, especially fisheries scientists of the many research institutions of the region, national and/or regional fisheries management bodies as well as institutions of higher learning.

Fish diet studies starts with data collection on fish species

ACKNOWLEDGEMENTS

We acknowledge debt to our colleagues, the fisheries scientists of the Guinea Current Large Marine Ecosystem (GCLME) we have worked with, during many workshops and especially the regional workshop on “Fishery Resources Survey Planning and Methodologies” as well as the regional workshop on “Validation of Fishery Survey Results”. Drafted by late GCLME Fisheries Expert Dr. Djama Theodore, reviewing the draft of this guide was an onerous task and consequently time consuming. Professors Daniel Pauly and Villy Christensen offered their precious time to that task and achieved an impressive job, finding many errors and clarifying many sections of the document.

We would also like to thank scientists the world over, who have long thought of multispecies fisheries management as possible, if not a prerequisite, in the sustainability of the exploitation of fisheries resources in the tropics and elsewhere. Last but not the least, we would like to thank the GEF as funding agency of the GCLME project, UNDP and UNEP, the two implementing UN agencies of the GCLME project and UNIDO the executing organ, without which this guide could not have been produced.

BACKGROUND

The International Conference on the Sustainable Contribution of Fisheries to Food Security was held in Kyoto, Japan, from 04 to 09 December 1995. The declaration issued from the conference, the Kyoto Declaration, was essentially focused on the way forward to a new approach to fisheries management.

In fact, the 95 states represented at the conference recognized the overall status of over-exploitation of most of the world fisheries. They then acknowledged the immediate concern to overcome the situation. To that end, it was recognized that over-exploitation could be minimized if policies, resource management strategies and utilization for sustainable development of the fisheries sector are based, among others, on the "maintenance of ecological systems". The Alinea (3) of the "Action Plan" emphasizes that States have "to conduct, within their competencies, and where appropriate, in cooperation with regional and other intergovernmental organizations, integrated assessments of fisheries in order to evaluate opportunities and strengthen the scientific basis for multispecies and ecosystem-based management" of fisheries (http://www.fao.org/fi/agreem/kyoto/kyoe.asp). Ecosystem-Based Management (EBM) here stands for the "planning of sustainable resource use, while maintaining a healthy and fully functioning ecosystem". In fact, by applying ecosystem-based management in fisheries, one tackles the three keys issues of multispecies fisheries management (multispecies assessment models), trophic interactions and ecosystem conservation. An added advantage in this approach especially when using the Ecopath with Ecosim suite of models is that they allow ecology, economics and social aspects to be brought together to explore the bio-socio-economics of the sustainable management of marine ecosystem resources. In this manual, it should be understood that statement about ecosystem-based management implicates, at the same time, the key issues of multispecies management, trophic interactions, ecosystem health and socio-economics.

It is important to recall that since the inception of fisheries as a science, fisheries management has often been focused on obtaining information on catches and on stock sizes in a species by species manner, as most fisheries in the temperate waters were assumed to be single-species fisheries. However, over time, it has become increasingly clear that fisheries resources interact and their interactions have implications on how fisheries should be managed. A preliminary study, as an example, estimates that, on a global scale, predation outweighs the fishery more than threefold (Christensen, 1996).

Robinson (1978), concluding his review of tropical biology, suggested that in tropical communities, species interactions may be more intensive than in temperate communities, even after accounting for the number of species involved in the interactions. For these reasons, it is becoming obvious in tropical ecosystems and even in the temperate areas (no fish live in isolation), to look for more information on ecosystem structure and dynamics, most notably of their trophic interactions.

As a result of the move towards the understanding of trophic interactions for multispecies and/or ecosystem-based fisheries management, fisheries research in the northern temperate areas has, in recent years, paid increased attention to the impact of species interactions. This has resulted in the development and use of a number of versatile multispecies models.

Conversely, multispecies assessment is in its infancy in tropical waters. Here, emphasis is still on developing and disseminating methods for single species analysis to find solutions pertaining to multispecies fisheries. However, the problem of species interactions, as earlier said, is of even greater importance in the tropics than in the temperate latitudes, as most of the fisheries are multispecies fisheries, and hence there should be a substantial interest in going for multispecies management methods. Furthermore, there is nowadays a worldwide recognition (probably from experience and/or from a theoretical view point), that sustainability of natural renewable resources utilization can better be achieved through ecosystem-based management, where economic and social aspects are also captured. This concept is being applied extensively in forestry management.

It is therefore for these reasons that this manual is believed to be necessary and appropriate for the implementation of multispecies management in the GCLME region. Ecopath with Ecosim (EwE) which is the World's de facto standard for research on ecosystem-based management of fisheries, with 3000 registered users in 124 countries, over 200 hundred published applications, and more than 40 graduate theses completed based on the approach, (see www.ecopath.org) will be widely utilized. Further, multispecies management using EwE is justified, in order to address a range of policy questions, e.g., what are the likely ecological, economical and social consequences of increasing effort for fine-meshed, bottom-trawl fisheries in a given area, how have fisheries, competitors and environmental changes impacted population trends for threatened species, or what is the potential impact of a proposed protected area.

1. GENERAL ECOLOGY

In line with the Kyoto Declaration, which emphasizes the necessity of a scientific basis for multispecies and ecosystem-based management for the sustainability of fisheries, investigations of species interactions is becoming one of the fundamental issues in multispecies fisheries management. The GCLME region is not spared in this respect, as all its fisheries are multispecies fisheries.

Studies of species interactions through stomach content analysis has traditionally been an important field of activity in fisheries biology, but is one in which there are great difficulties in correlating the results with research made in the other fields. Investigations on the food intake of fish cannot be considered in isolation, but have to be discussed in relation to the whole marine environment, of which fishes constitute single elements. Therefore, a brief survey of the most important processes in aquatic ecology must be made, with particular reference to feeding.

Living organisms interact with each others as preys, predators or competitors for space and food. They also interact with their non-living (abiotic) environment in many ways; no organism exists independently of its environment. It is the study of these interrelationships which is called ecology. It is possible to study the ecology of one species in relation to its environment or a whole group of species and their interactions both with each other and their physical surroundings. Thus, ecology is concerned not only with the biological disciplines but also the physical and chemical sciences.

1.1. Ecosystem

Any area in nature where materials are being exchanged between living organisms and their abiotic environment forms an ecological system or ecosystem. This concept is useful as it stresses the interdependence of the components involved. Although it is hardly possible to demarcate any area in nature that is not influenced by neighboring areas, one may, nevertheless, consider a fish pond, a lake or even part of a forest as an ecosystem (Agger, et al. 1974).

To understand the dynamics of such a self-sufficient ecosystem as a functional unit, its component parts must be looked at in some detail first.

1.2. Ecosystem functioning

In general, the functioning of an ecosystem starts with the reception of light energy. This energy is transformed by autotrophic producers into organic material, using inorganic nutrients. Further, the heterotrophic organisms consume the organic material produced by autotrophic producers and finally, the decomposition of the organic material into inorganic nutrients, by saprophytic micro-consumers, chiefly bacteria and fungi.

The autotrophic producers or primary producers are mainly green plants (autotrophic bacteria play a very minor role). The consumers comprise all the other living components present include herbivores, which feed directly on the producers, and the carnivores (predators), which feed on the herbivores or other carnivores. They also include parasites, scavengers (carrion-eaters), saprophytes, bacteria and fungi. It is however convenient to list the decomposers, consisting of bacteria and fungi, as a separate entity because of their specific role and their indispensability in the food chain.

The inorganic nutrients comprise a large number of elements present in the form of dissolved salts. The most important are nitrogen and phosphorus followed by potassium, calcium, sulphur and magnesium. Some elements are needed in extremely minute amounts and are therefore referred to as micro-nutrients.

1.3. Food chains and trophic levels

The production of organic substances (food) by photosynthesis is a process involving transformation of light energy into potential chemical energy. The transfer of this food energy from the producers, through a series of consumers, is called a food chain, thus each organism through which it is passed being a link in the chain. For the sake of simplicity, three different food chains may be recognized:

1. Carnivore chain, where the energy is passed from smaller to larger organisms;
2. Parasite chain, where the energy is passed from larger to smaller organisms;
3. Saprophyte chain, where the energy is passed from dead organic matter to micro-organisms in most cases.

In reality, food may be passed through parts of all three chains before it is finally decomposed into inorganic nutrients by the bacteria and fungi at the end of every food chain. In other words, the species population within a community or ecosystem form many food chains which interconnect, anastomose or cross each other in a complex pattern, which is usually referred to as the food web. Organisms which belong to the same link of the food chain as counted from the producer level are said to belong to the same trophic level. Thus the plants constitute the first trophic level, the herbivores (plant eaters) the second, and the carnivores feeding on herbivores, the third and subsequent trophic level. Secondary carnivores feeding on third level carnivores belong to the fourth trophic level and so forth. However, there is a very definite limit to the number of possible links in a food chain, and consequently also to the number of trophic levels in any ecosystem. The reason for this is that only about 10 percent of the available energy is assimilated in passing from one trophic level to the next. At the top of the food chain, there are usually only one or two major predators. The number of species in each trophic layer increases with approach to the first layer, giving rise to what is called a pyramid of numbers. For the major predators, introduction of small amounts of pollutants into the first trophic layer can have fatal consequences because it is eventually concentrated in them.

1.4. Gross production and net production

The laws of thermodynamics state that, energy can neither be created nor destroyed, and also that it cannot be transformed from one type to another without partial dispersion into heat energy. This means that the transformation of light energy into potential chemical energy in the form of organic compounds in the plants cannot be 100 percent efficient. Only a very small portion of the light energy absorbed by green plants is transformed into food energy (gross production) because most of it is dispersed as heat. Furthermore, some of the synthesized gross production is used by the plants in their own respiratory processes, leaving a still smaller amount of potential energy (the net production) available for transfer to the next trophic level.

The loss of energy is generally referred to as the respiratory loss because the organisms utilize the food energy by oxidizing it. Because of the respiratory losses, the food chains cannot be very long and the number of trophic levels in natural communities is therefore seldom four or five and often only three. It also means that the total amount of food available decreases with increasing trophic level. For this reason, the largest animals are found feeding on either plants or other animals of low trophic levels as, for example, whales on krill and elephants on plants.

Among animals, the gross production corresponds to the food assimilated, which means food ingested and absorbed by the intestine. The net production is here equal to food assimilated minus respiration. While it is recognized that most of the energy lost within an ecosystem is due to the respiratory processes, there are other losses which affect the individual organisms. Some of the potential food is not ingested, but is either decomposed directly, stored or exported out of the system or community. Another source of loss is that not all of the food ingested is actually assimilated; some passes through the alimentary canal and is lost as faeces.

As stated earlier, as the organisms die, they are attacked by the decomposers, which derive their energy from them by reducing their organic contents to inorganic nutrients. As also indicated earlier, these nutrients can then be used by the producers anew with the result that the materials involved are continuously circulating in the system. However, the energy flow is strictly passed along a one-way. To keep an ecosystem going, light energy must be continually supplied.

1.5. Production and ecological efficiencies

As we have seen, true production of organic matter takes place only in the chlorophyll-possessing plants and certain autotrophic bacteria, and this has been referred to as the primary production. However, copepods and euphausids, for example, are sometimes referred to as “flesh producers” or key industry animals because they convert plant material into animal protein that can be assimilated by the larger animals which eat them, but which themselves could not exist on plant material. In reality, of course, they only assimilate and store energy derived from the primary producers. To avoid confusion, it would be better to call them secondary producers, a term which of course fits animals at higher trophic levels just as well because they too - although indirectly - utilize the primary production of the plants.

From a practical point of view, it is often desirable to find out how big the secondary production of certain animals is in a given area, say a fish bank, or even more importantly, whether a known production level can be increased. Production estimates must be based on such factors as standing crop (biomass), rate of removal of materials and rate of growth, including growth of young born or hatched during the census period. The turnover rate is also of interest when short-lived species are involved as is practically always the case within ecosystems in the sea. The biological production must be expressed per unit time. A large standing crop is by no means synonymous with a large production rate. To take an easily visualized example, a pasture grazed by cows may have a very small standing crop of grass because the production is being eaten as soon as it is being produced, but it may nevertheless have a higher production rate than a neighboring ungrazed pasture with a very large standing crop.

Quantitative relations between the various trophic levels can be calculated provided the production rates are known for each level concerned. Relationships of this nature within trophic levels are also of considerable interest. Expressed as percentage ratios, the results of such computations are often referred to as ecological efficiencies because they are concerned with the efficiency of energy transfer at different points along the food chain. Thus, they are important to our understanding of the dynamics in ecosystems. Moreover, most of the efficiency ratios are meaningful with regard to single species populations as well as to whole trophic levels.

Unfortunately much confusion exists in the terminology used by various authors, and it is not always clear to which efficiency ratio an author really wishes to refer. Odum (1959), has made an attempt to define the various ratios, based on his energy flow diagram, and this is certainly a good method of illustrating the complexities involved. Among fishery biologists, the most common way of describing the efficiency is by the conversion factor, i.e., the ratio of the weight of the food consumed by the fish and the growth in weight. Some authors express this conversion factor as the nutritional coefficient. The conversion factor is the reciprocal value of what Odum calls the ecological growth efficiency. The value of the conversion factor is traditionally defined as 10, but in fact it can range widely about this value.

However, it is important to stress that none of the ecological efficiencies are constant for any species population or for a whole trophic level. They are dependent on a number of abiotic factors such as temperature and salinity, as well as biotic factors such as type, abundance and distribution of available food, and the age of the consumers; for example, fish larvae and the young of all species have much lower conversion factors than older animals.

2. FOOD INTAKE IN FISH

As seen in the first chapter, quantitative relations between the various trophic levels can be calculated provided the production rates are known for each level concerned. Studies of food intake in fish in addition to other information on total production and mortality allow this quantification and are therefore becoming very important in multispecies fisheries management. For instance Equation 1 below (Christensen et al., 2000) underlines the importance of predation (food intake) in the overall production system.

$$P_i = Y_i + B_i \times M2_i + E_i + BA_i + P_i \times (1\text{-}EE_i)$$

where Pi is the total production rate of (i), Yi is the fishery catch rate of (i), Bi the biomass of the group (i), M2i is the total predation rate for group (i), Ei the net migration rate, BAi is the biomass accumulation rate for (i) whereas M0i=Pi.(1-EEi) is the "other mortality rate for (i).

Almost all the work that has been done on the food intake of fishes has been qualitative, rather than quantitative. That is, workers have described the occurrence of food found in the digestive tract, usually in the stomach only. This tells what the fish has eaten and approximately in what proportions, but it does not describe how much of each food item is eaten (daily ration). The reason for such shortage in the quantitative analysis of food intake is that it is very time-consuming. However, for the purpose of multispecies fisheries management, qualitative results can be useful, provided that food intake data are expressed in terms of percentage wet-weight prey item.

2.1. Material and methods

This section is not really intended to go in depth on the methods used to study the feeding behavior of fish, but aims at assessing globally, the diet composition of a fish species with the aim of finding their interactions, as this factor is important in the ecosystem management of multispecies fisheries (further details about these methods are given by Stephen H. Bowen (1996).

Samples of fish are obtained during the swept area method for demersal fish and acoustic method for the pelagic. Data are recorded by station, depth and time. As soon as possible after the fish has been caught, the entire digestive tract is dissected, and the material is preserved in small screw cap labeled plastic container with 4 percent buffered formalin. Later in the laboratory, the different sections of the digestive tract are opened and information on the predator is recorded, such as total length and weight in an excel spreadsheet or any other device. The individual groups of organisms are sorted out for identification. This is most easily done with a binocular-dissecting microscope.

In the following, we illustrate some selected methods currently in use and underline their advantages and disadvantages when ever possible. A series of illustrative examples are also provided based on the examination of the stomach contents of two sciaenid fish species, Pseudotolothus typus and Pseudotolothus senegalensis (Djama, 1992).

2.1.1. General characteristics of the stomach

To avoid complications in the interpretation of the results, it is advisable to consider each stomach, either full or empty. For instance a stomach containing one prey item is full as well as the one containing many prey items. A coefficient of emptiness which considers the number of stomachs empty can then be derived. From this, the average number of preys per stomach, as well as the average weight, is obtained from the total number of full stomachs and not from the total number of stomachs. This choice is justified as many stomachs considered empty, are rather regurgitated as a result of the brutal change of the pressure during hauling operations at sea. Table 1 below, illustrates stomach content analysis from samples of *Pseudotolithus typus* and *P. senegalensis.*

Table 1. An example of the general characteristics of the stomachs of Pseudotolithus typus and P. senegalensis (sample collected in 1989, from the industrial fisheries in Cameroon).

Feature of feeding / Species	**P. typus**	**P. senegalensis**
Total stomachs analyzed	577	414
Total empty stomachs	175	143
Coefficient of emptiness	30%	35%
Total number of preys	1138	467
Mean number of preys	2.8	1.7
Total weight of preys (g)	430	377
Mean weight of prey per stomach (g)	1	1.4

It is important to underline here that the total stomach analyzed should not be less than 200 in number for the results to be representative. The parameter expressing the number of prey per stomach is very important as it indicates whether a predator is a selective (one group of preys) or opportunistic feeder (many prey groups).

2.1.2. Number-based method

Two coefficients are often used in the number-based methods the numerical dominance and the frequency occurrence. There are a huge number of references in the literature which provide information on the frequency occurrence of fish items in fish stomachs. Except perhaps in fish larvae, whose food items are all uniformly small, frequency occurrence or the number-based method in general is not a good indicator of how much food items contributes to the diet of a given population. For example, a small copepod that occurs in 50 % of the examined stomachs may contribute much less to the diet than large polychaetes that are found in only 40 % of the stomachs (Froese and Pauly, 2000). It is therefore understood that stomach contents using frequency occurrence should be complemented by diet data in terms of wet-weight, volume or energy. However, the number-based method as said earlier can provide information on the feeding strategy of a fish species that is whether the fish is opportunistic or specialized feeder.

In the numerical dominance *(Fn),* the numbers of each food item are recorded and the results expressed as a percentage of the total number of food items present in the stomach. This method however, overestimates the importance of small food organisms.

$$F_n = \frac{\text{Total number of a given prey item in a stomach}}{\text{Total number of full stomachs}} \times 100$$

In the frequency occurrence method *(Cn)*, each food item is recorded and expressed as the percentage occurrence of all food organisms in the stomach. This method is very quick and easy but underestimates the importance of larger food organisms.

$$C_n = \frac{\text{Total number of stomachs containing a given prey item}}{\text{Total number of full stomachs}} \times 100$$

2.1.3. Weight-based method

Emphasis is made on the expression of the wet-weight of each prey (Cw) as a percentage to the total weight of preys present in the stomach.

$$C_w = \frac{\text{Weight of a prey in the stomach}}{\text{Total weight of all preys}} \times 100$$

This factor describes the relative importance of each component eaten. However, the extent to which these items could be considered major or secondary preys is not well elucidated. Thus, a feeding coefficient Q, has to be introduced (Hureau, 1970), as the product of the percentage occurrence, Cn, and the percentage wet-weight, Cw. The feeding coefficient Q indicates whether a given prey is major, secondary or accidental as follows:

$Q \leq 200$: major prey

$20 \leq Q < 200$: secondary prey

$Q \leq 20$: accidental prey

The feeding coefficient Q is most useful when there is no difference in the digestion rates of the prey items (Table 2).

2.1.4. Total volume method

The entire volume of the stomach contents is measured. The contents are then sorted into different types of food and the volume of each determined. Results are usually reported as a percentage of the total volume. This method is more time-consuming than any of the previous methods but it describes accurately the relative importance of each food species.

2.1.5. Percentage volume method

This method is identical to the previous method, except that the volume of each food item is first expressed as a percentage volume of the total stomach contents from which it was removed and then an average taken for all the fish sampled. The advantage of this method over the previous one is that the final results will be more representative of the feeding habits of a group of fish if one or two individuals in that group have been feeding very heavily on one particular food item. The disadvantage is that the information on the actual volume of the stomach contents is lost.

2.1.6. Points method

Points are given to each item. The number of points depends on whether the organism is very common in the stomach contents (highest number of points), or rare (lowest number) and upon its size (more points for large than small size). The method may also be modified to take stomach fullness into account. It is rapid, easy and requires no special apparatus; with experience the method can be very accurate. The points allocated gives results similar to both the volumetric and gravimetric methods

2.2. Discussion

All these methods describe, with a greater or lesser degree of precision, the qualitative and quantitative aspect of the food items contained in fish stomachs, the best method being obviously the one you understand better. From table 2, one can notice that the two sciaenid P. typus and P. senegalensis feed mostly on shrimps. However, P. typus main prey is the estuarine white shrimp Nematopalaemon hastatus, whereas P. senegalensis feeds on Penaeus atlanticus a purely marine shrimp. This difference in feeding can be justified by the fact that P. typus lives closer inshore than P. senegalensis. Also, the presence of more than one prey in the stomachs of these species is an indication that the two species are not specialized feeders, a characteristic justifying a uniform predation pressure experienced in tropical ecosystems.

It is also important to notice the proportion of unidentified preys in Table 2. In fact, identification of stomach content is often made difficult by digestion. Even recently ingested food items may be ground by jaw or pharyngeal teeth to a point at which recognition of many individual segments is difficult (Bowen, 1996). As a result, it is customary to identify food items by finding some characteristic part of the organism that is resistant to digestion. For invertebrates, various parts of the exoskeleton, such as eye capsules, head shields, and tarsal claws have been used (Ahlgren and Bowen, 1992; Bechara et al. 1993). Fish prey can be identified by the characteristic form of their otoliths (Whitefield and Blaber, 1978). Macrophytes may be identified by a characteristic shape or sculpturing along the edge of the leaves. In contrast, algal cells are usually found intact in the anterior digestive tract, and identification of these presents no special problem.

Table 2. Stomach content analysis of *P. typus* and *P. senegalensis* (Djama, 1992).

Species	***Pseudotolithus typus***					
	Total Number	Fn	Cn	Wg	Cw	Q
Shrimps	1028	95	91	343	80	7280
N. hastatus	836	58	74	121	28	2072
P. atlanticus	125	21	11	198	46	506
P. kerathurus	2	.1	.2	6	2	.4
Penaeus sp	0	0	0	0	0	0
Unidentified	65	16	6	18	4	24
FISH	91	18	8	81	19	152
S. maderensis	44	16	7	?	?	?
Other fish*	47	2	1	?	?	?
Cephalopods	8	2	1	2	2	2
True Crabs	1	.3	1	0	0	0
Others	10	4	5	0	0	0

Species	***Pseudotolithus senegalensis***					
	Total Number	Fn	Cn	Wg	Cw	Q
Shrimps	353	76	77	175	46	3542
N. hastatus	182	28	39	16	4	156
P. atlanticus	103	28	23	129	34	782
P. kerathurus	1	.4	.2	2	1	.2
Penaeus sp	3	.7	.6	12	3	2
Unidentified	64	19	14	16	4	56
FISH	78 21		16	170	45	720
S. maderensis	37	18	14	?	?	?
Other fish*	67	3	2	?	?	?
Cephalopods	8	3	2	7	7	14
True Crabs	9	5	3	1	1	3
Others	22 6		7	1	1	6

It should be understood that, when these characteristic part of the organism that is resistant to digestion is properly identified and the morphometric characteristics of the species are available, one can derive the length of that prey and find its weight through the length-weight relationship. By so doing, bias due to “unidentified” preys can be minimized.

2.3. Quantitative assessment of food intake

Quantitative feeding studies as said in previous chapters take considerable time and are therefore the work of specialists. Only a brief outline of the methods will be given. Firstly the unit in which energy flow is to be measured is chosen, calories and nitrogen being the two commonest. Secondly, feeding experiments are conducted in aquaria with the different food materials which the species under study eats in order to determine how efficient it is in converting the food item into fish flesh. For calories, this means determining the calorific value of the selected food, feeding the fish a known weight of this food, collecting its faeces and determining the calorific value of these. In order to translate field observations on the weights and calorific values of food found in stomachs, digestion rates must be established by feeding fish and then killing them at known intervals. This may need to be done for more than one temperature. MAXIMs is a good method which allows one to get consumption rates from stomach contents.

As stated earlier, quantitative assessment of food intake are important, but for the purpose of using the Ecopath and Ecosim suite of models, data on food intake in terms of percentage weight are sufficient.

2.4. Concluding remarks

As mentioned in previous chapters, one of the most important differences between tropical and temperate multispecies fisheries is the existence in the catch of a multitude diversity of fish species in the tropics. In general, single hauls with 50 species or more are quite frequent in marine tropical ecosystems (Gayanilo and Pauly, 1997). However, and contrary to this obvious reality, acknowledging the existence of these differences between high-latitude and tropical ecosystems has seldom prevented fishery biologists in the tropics from applying principles derived from high-latitude marine ecosystem. This in the past could probably be justified by the nonexistence until the late 1980s of acceptable and easy applicable multispecies stock assessment models. With the recent development of ecosystem approaches such as Ecopath and Ecosim (and probably other models), the continued use of single species stock assessment under a multispecies fisheries context can hardly be justified and tolerated. Trophic interactions which lead to ecosystem dynamics and bio-socio-economics should be well understood in order to guarantee sustainable exploitation of the fisheries resources. Ecosystem-based fisheries management, which considers the conservation of the ecosystem integrity as a basis of sustainability of life in all its form should therefore be encouraged. That is the reason we are producing this modest user's guide on food intake in fish.

4. BIBLIOGRAPHY

Agger, P., O. Bagge, O. Hansen, E. Hoffman, M. J. Holden, G. L. Kensteven, H. Knudsen, D. F. S. Rait, A. Saville and T. Williams, 1974. Manual of Fisheries Science Part 2: Methods of Resource Investigation and their Application. *FAO Fisheries Technical Paper* - 115 Rev. 1.

Ahlgren, M., and S. Bowen. 1992. Comparison of quantitative light microscopy techniques used in diet studies of detritus-consuming omnivores. Hydrobiologia 239:79-83.

Allee, W.C. *et al.,* 1949. Principles of Animal Ecology. Philadelphia, W.B. Saunders.

Bowen, S. H., 1996. Quantitative description of the diet 732:513-532 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda Maryland. 732p

Bechara, J. A., G. Moreau, and L. Hare. 1993. The impact of brook trout *(Savelinus fontinalis)* on an experimental stream benthic community: the role of spatial and size refugia. Journal Ecology 62:451-464.

Boddeke, R. 1971. The Influence of the Strong 1969 and 1970 Year Classes of Cod on the Stock of Brown Shrimp along the Netherlands Coast in 1970 and 1971. ICES, C. M. Shellfish and Benthos Committee. Paper K32:3 p. (mimeo)

Christensen, V., 1996. Virtual Population Reality. *Rev. Fish Biol. Fisheries.* 6: 243-247.

Christensen, V., G. Reck and J. L. MacLean (eds.), 2002. Proceedings of the INCO-DC Conference, Placing Fisheries in their Ecosystem Context. Galapagos Islands, Ecuador, 4-8 December 2000. *ACP - EU, Fish. Res. Rep., (12):79p*.

Christensen, V., C., J. Walters and D. Pauly. 2000. Ecopath with Ecosim: a User's Guide, October 2000 Edition. Fisheries Centre, University of British Columbia, Vancouver, Canada and ICLARM, Penang, Malaysia. 130p.

Clarke, G.L. 1954. Elements of Ecology. New York, Wiley and Sons. 534p.

Daan N. A. (?). Quantitative Analysis of the Food Intake of North Sea Cod. *Gadus morhua*, L. Neth. J. Sea Res., (in press).

Djama, T., and T.J. Pitcher, 1989. Comparative stock assessment of two sciaenid species, *Pseudotolithus typus* (Bleeker, 1863) and *Pseudotolithus senegalensis* (Valencienne, 1833) off Cameroon. Fish. Res. Vol. 7: 111-125.

Djama, T. 1992. Interactions between the Artisanal and the Industrial Fisheries of Cameroon. A thesis presented for the degree of Doctor of Philosophy, University of Wales. 159p.

Djama, T., and T.J. Pitcher, 1997. The Differential Effects of Changing Management Regimes on Yields from two Fisheries Exploiting the Same Resources. *Fish. Res.,* Vol., 29: 33-37.

Froese, R. and D. Pauly, Editors, 2000. FishBase 2000: Concepts, design and data sources. ICLARM, los Banos, Laguna, Philippines. 344p.

Gayanilo, F.C., Jr.; Pauly, D. (Eds), 1997. FAO - ICLARM stock assessment tools. (FISAT). Reference Manual. FAO Computerized Information Series (Fisheries). No. 8. Rome, FAO. 262p.

Hardy, A.C. 1959. The Open Sea; its Natural History, Part 2. Fish and Fisheries with Chapters on Whales, Turtles and Animals of the Sea Floor. London, Collins, 322 p.

Hureau, J. C. 1970. Biologie Comparée de quelques Poisons Antarctiques (Notothemidae), *Bull. Inst. Ocean, Monaco.* Vol. 68, no. 1391: 1 -250 pp.

Laevastu, T. 1965. Manual of Methods in Fisheries Biology. *FAO Man. Fish. Sci.,* (1): pag. var.

Lindeman, R.L., 1942. The trophic-dynamic aspect of ecology. Ecology 23:399-418.

Marshall, N.B. 1966. The Life of Fishes. Cleveland, Ohio, World Publishing Co., 402 p.

Murphy, B. R., and D. W. Willis, editors. 1996. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.732p.

Nikolskii, G.V. 1963. The Ecology of Fishes. London, Academic Press, 352 p.

Odum, E. P. 1959. Fundamentals of Ecology. Philadelphia, W.B. Saunders, 546 p.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torres, Jr. 1998. Fishing down the food webs.. Science 279:860-863.

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

Polovina, J.J., 1984. An overview of the ECOPATH model. Fishbyte 2(2):5-7.

Rounsefell, G.A. and W.H. Everhart, 1953. Fisheries Science: its Methods and Applications. New York, Wiley and Sons, 444 p.

Steele, J.H. (ed.) 1970. Marine Food Chains. Edinburgh, Oliver and Boyd, 552 p.

Whitfield, A. K., and S. J. M. Blaber. 1978. Food and feeding ecology of piscivorous fishes at Lake St. Lucia, Zululand. Journal of Fish Biology 13:675-691.

Youmbi-Tientcheu, J. and T. Djama, 1993. Food Habits of Two Sciaenid Fish Species *P. typus* and *P. senegalensis* off Cameroon. NAGA (ICLARM), Vol., 17, no., 1 : 40-41.