Chapter

Importance of Plankton to Fish Community

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Abstract

Zooplankton is the source of life for most of aquatic organisms especially in their larval stages. Its importance come from that most fishes depend on it as a source of life after absorbance of the yolk sac. Moreover, the greatest aquatic creatures like many species of whales are filter feeders where the planktonic organisms form the main bulk of their food. The importance of zooplankton as a main source of nutrition of marine fish larvae has been long professed. Many scientists attributed the ability of a fish population to outdistance through the larval period without vast mortality as one of the primary factors determining the size of the resulting year class and hypothesized that competition for food during the larval time might be a major factor affecting survival and subsequent year class strength.

Keywords: ecology, fish larvae, fisheries, phytoplankton, zooplankton, competition

1. Introduction

The food spectra of the fish family Myctophidae are well-known to be wide, including practically all zooplankton groups, and composed mainly of copepods, euphausiids, and hyperiids, while chaetognaths and decapods are of least importance [1].

Podrazhanskaya [2] studied the feeding habit of the family Myctophidae by investigating a total of 344 stomachs eviscerated from 11 fish species that have been collected from the Northwest Atlantic Ocean; the data revealed that the zooplankton species that occur inside the stomachs of this family with significant biomass were *Calanus finmarchicus*, *Parathemisto norvegica*, followed by *Parathemisto compressa*, then *Metridia lucens*, and some species of the genera *Pleuromamma* and *Conchoecia*. The species *Calanus hyperboreus* and *Metridia longa* (arcto-boreal forms) occurred fairly frequently. Copepods consisted the main food item in the stomachs of *Benthosema glaciale*, *Electrona risso*, *Hygophum benoiti*, *Lobianchia dolfeni*, and *Protomyctophum arcticum*, while *Diaphus rafinesque*, *Myctophum punctatum*, *Notoscopelus bolini*, and *N. elongatus* fed primarily on euphausiids; on the other hand, the dominant food in the stomach content of *Ceratoscopelus maderensis* was the planktonic hyperiids.

It was noticed that the stomachs of *Benthosema glaciale* contained some foraminiferans and algae in addition to the main bulk (copepods), while the predator zooplankton *Sagitta* spp. were recorded in the stomachs of *Electrona risso*. *Tomopteris* (pelagic polychaetes) was found in the stomachs of *N. elongatus* [2].

Boudreau and Dickies [3] established an energy transmit model between contiguous groups in the trophic chain such as zooplankton and fishes based on the following facts:

a. Specific predator biomass is a dependent variable to size.

b. The product of growth efficiency and mortality of the predator imposed on the prey is size vassal.

c. For all neighboring trophic groups, the ratio of the predator to the prey size is constant.

Sprules and Goyke [4] mentioned that *Salvelinus namaycush* (lake trout or large salmon) nourishes on *Alosa pseudoharengus* (smaller alewives) and cisco that utilize a tiny-sized zooplankton as a food. So it is sensible to use the size spectrum of Lake Ontario to prophesy the annual lake production of trout from zooplankton biomass data.

Many researchers suggest that increase in quantity of zooplankton would result in an increase in the quantity of fishes (homeostasis) [5].

The difference in zooplankton production in estuarine, coastal, and oceanic realms has been correlated to the fishery potential of the concerned area. Zooplankton is the main link in the energy transmission at secondary level, they plays a considerable role in the production potency of any aquatic ecosystem. In sum, estimation of zooplankton standing crop gives an index to determine the extent of the sea fertility. To a confirmed extent, the fishery failure and success—specially the pelagic ones—are dependent on the plankton availability. High fish stocks are found in regions of high plankton biomass that in turn are the enrichment regions. In the Indian Ocean and other oceans, there are some reports confirming the direct relation between zooplankton and pelagic fishery production [6–8]; major part of the pelagic fishery is shared by shoaling fishes like sardines, mackerel, etc., which are essentially plankton feeders.

Evaluation of fishery potential is based on the hypothesis that about 10% is the ecological efficiency to transfer from trophic level to the next one. In the ocean food web, around 10% of zooplankton production (secondary production) will be obtainable to fish (tertiary level). Predominantly the validity of such assumption was questioned. Chapman [9] proposed that the value of ecological efficiency is 25%. Around 7.47 is the factor that was used to elevate the value of the carbon to get the fish wet weight [10].

Plankton community can determine or control the fish population; it can assist us in determining (1) seasons and regions of spawning, (2) adult spawners' biomass, (3) adult annual variation (biomass), (4) adult migrations, (5) growth performance and survival rates of larval stages, (6) relation of environmental conditions to abundance and distribution of the mature (adult) and immature (larvae) forms, (7) zooplankton and fish larva trophic relations, and (8) interactions among species throughout larval stage that might thereafter influence stock size.

2. Fish and plankton relationship

What are the reasons that make several fish species superabundant in the sea or why are many types of fish so abundant and successful in the ocean to the degree of attracting human by their abundance? The aquatic biologists can answer this by their broad studies on the ocean environment with assertiveness on the vital plankton role. Plankton has an essential role in the fluctuations happening in the naturalistic survival rates of fish juvenile and larvae and the consequent effects on the adult fish stock. In another mean, tiny organisms control the development of the future fish stock. As larvae grow, many become less dependent on plankton, thereby reducing mortality rates with age [11].

Fish growth and mortality can vary significantly under normal conditions. The laying of expansive number of eggs from which just a few can survive and grow up to become adults is a typical r-strategy. The larva success will be decided by its surrounding environmental conditions and plankton abundance and not by the quantity of parent stock. At many lower survival levels, there is a density reliance where the amount of the available food to each individual plays a fundamental role in determining how many will survive additionally, the production of live food is related to fish nourishment type and it is also a densityindependent operation. Ordinarily spawning sites and seasons were determined by checking the gonad status of fishes held at different times and areas all year round. In any case, later information on component of ichthyoplankton dependent on the real spawned eggs and larvae gathered have supplied us with a full picture of the spawning seasons and sites. Additionally this information has given us the knowledge of fecundity per unit weight and the female's proportion in the fish stock [11].

The following points are worthy of consideration and are consistent with Balachandran and Peter [11]:

- Oceans' fertility is measured by plankton biomass which is considered an index on it. It supplies us with an estimation of the total organic production and helps us to chart out the sites of fishery potential.

- The production of fish can change as a result of the productivity changes with which the plankton is converted into the tertiary production (fishes) rather than the total primary production changes.

- In oceans, plankton are the essential source of food; the inconstancy in their composition (their diversity) influences the fishes' food habits.

- Plankton community structure indicated the central role of such organisms as a vital factor in the fishes spawning.

- A fishery survives and becomes wealthy when a mix of favorable conditions prevails that causes the food to be supplied in adequate amounts and decreased prey density.

- One of the main factors determining the size of the resulting fish stock year class is its capability to exceed the larval stage without massive mortality.

- Predation of zooplankton on fish larval stages influences the following year class quality/fisheries.

- It is important to determine the starved larva percentage which can be used as a signal of eventual year class strength.

- Plankton bioindicator concept means using of certain species of plankton as indicators on the fishery status. Nowadays it is extremely needed as well as very applicable.

3. Fishery management

Plankton play an essential role in management of fisheries that can be as per the following:

A. Size of the spawning stock can be directly gauged from the survey data of the egg and larvae, and when matched to statistics of particular fisheries, catch can be used to determine when the overexploitation level is being near.

B. The traditional method of assessing stock sizes for commercial fisheries was found unsuitable where fisheries nowadays have been unauthorized because of stock depletion.

C. Plankton studies help us to comprehend the natural aquatic ecosystem with a view to answer the prediction question: what amount of fish can be gotten from the ocean?

D. Studies on plankton allow us to grasp the impact of catching large amounts of fishes from the same natural environment.

4. Larval abundance and plankton

There is a correlation between abundance of fish and the plankton abundance. Fishery wealth is commonly depending on the wealth of plankton. The mechanism of depensatory can be obviously noted when a great number of larvae contest so vigorously for a limited food amount that the survivors may turn out to be a more fewer than if less larvae compete initially. The greater the competitors, the fewer the survivors and vice versa [11]. Often predation by planktivorous fish on plankton community may affect the size structure of an aquatic food web [12]. Abundance of planktivorous fish promotes growth of smaller zooplankton and phytoplankters, while larger zooplankton flourished with fewer fishes.

Peter [13] studied the volume of the plankton samples and their relationship to the respective numbers of fish larvae and eggs in the Bay of Bengal and the Arabian Sea. The author found inconsistent relationship. Furthermore an inverse relationship was recorded in some cases. These can be attributed to the samplers used, avoidance of net by larvae, and the nature of sampling (vertical hauls were made instead of oblique hauls). On the other hand, Devi [14] noticed no relationship between the plankton volume and the larva numbers. Identical records were noted by many authors such as [15–18], while George [19] has mentioned that there was a positive correlation in southwest coast of India at the coastal waters. Studies on zooplankton showed a very general relationship between zooplankton and fish larval abundance.

The importance of zooplankton as a principal source of food of marine fish larvae has been long recognized. At the beginning of the nineteenth century, Hjort [20] imputes the fish population ability to exceed the larval time without massive mortality as one of the essential factors determining the future size of the output year class. Saville [21] assumed that the food competition during the period of the larva might be the main factor influencing survival rate and the subsequent strength of year class.

According to Holt and Beverton [22] and Ricker [23], the stock/recruitment relationships proved that the larvae survival can be density-dependent especially at high stock densities because recruitment does not accelerate at levels of high stock. Factors of density dependence may run at either the inter- or intraspecies level through the larval stages. Relatively 2 days after hatching or after yolk reserves exhaustion, the fish larvae become ready to feed as soon as possible.

Hunter [24] mentioned that there are many reasons that can cause larval mortality; the main reason is the larval starvation after absorption of their yolk sac. There are several measurements to detect the larva starvation which include morphology of the larva, morphometric measurements, histological investigations, and chemical analysis.

Larval feeding is effected by several factors including the extent of availability of suitable and sufficient food at a suitable concentration.

5. Fish larvae and plankton

5.1 Predation relationship

Looking at plankton, not as a food for the fish larvae, but as a predators show another aspect of those organisms. The analyzed collections of plankton so far confirmed the existence of carnivorous predator species such as chaetognaths, chondrophores, ctenophores, medusae, and siphonophores sometimes in a great number. Chordates, copepods, decapod larvae, euphausiids, heteropods, pteropods, and polychaetes existed in high abundance in some of the investigated collections.

The environmental factors more or less controlled the abundance of the previously mentioned species. Considerably a great number of different fish larvae in various digestion stages were noticed in the guts of these predator plankton groups.

Comparing with relatively sluggish yolk-sac-bearing larvae, the previous predators preferred the active swimmer fish larvae. As ctenophores drifted at the sea surface or subsurface, their predatory behavior is restricted to this zone, while others like siphonophores are the most active predators as they could swim quickly through the water column. The predatory efficiency of an organism is strongly correlated with its size, while the vulnerability of the prey (any species) is associated with its abundance and size. Around 108 predator plankton species were recorded by Alvarino [25]; she recorded their maximum abundance in hauls where there are no anchovy larvae; in those with aggregations of larvae, she found domination of copepods and/or euphausiids, and larvae were missed in hauls which are predominated by pelagic protochordates.

Predominantly the zooplankters' predatory pressure is being weaker, when there is a high density of copepods which could appear by the analysis of gut content of these zooplankter species. There are several recorded cases of heavy predation on fish larvae by different plankton groups such as chaetognaths and ostracods which were recorded by Lebour [26] and Nellen [27] or by medusa like *Cyanea* and *Aurelia* [28], and the common predation by copepods [29] was also reported. Predation activity can be annually varying and consequently affecting the subsequent year's class strength.

Hunter [24] mentioned that in a recent academic conference related with the mortality of fish larvae, it was summarized that "starvation and predation are the main reasons of larval mortality, and to some extent these two may interact." It is a very well-known fact that larval mortality as a result of predation is decreased when potential predators are lesser in number, and mortality caused by starvation is decreased when fish larvae are found in waters with a suitable food supply. A fisheries enhanced and survives when an appropriate group of factors as above are dominates "e.g. food abundance, predators decreasing, …etc" as in the previous noted case "water of anchovy".

Predators eat a huge number of fish larvae which may explain the great larval mortality. Juveniles formed larger prey items than the eggs but less in numbers. Eating fish larvae for large numbers of plankton leads to faster growth and vice versa. Feeding is necessary for survival of larvae, while it is necessary to increase the growth rates of juveniles, all related with the availability of plankton.

For the planktonologist, the most essential aspect of fish and larvae growth is not only the abundance or availability of any prey or food items but also the presence of the right food type [30], as the growth performance is correlated to the nature and type of food [31]. Leong and O'Counell [32] observed rate of feeding alteration by anchovies by changing the method of prey catching from filter to raptorial nutrition.

5.2 Plankton as indicators of fishery

Plankto-trophic larva is a stage characterized by majority of fishes, their existence indicating the presence of the adult stages which shape the fishery. They also act as bioindicators, whose larval life is prolonged as flat fishes. Nair [33] and Nair and Subrahmanyam [34] linked the fluctuations in the oil sardines with the existence and flourishing of a diatom *Fragilaria oceanica*. Selvakumar [35] found a relation between mackerel fisheries' wealth and blooming of cladocerans *Evadne* and *Penilia*. Sakthivel [36] has commended on the pivotal role played by pteropods as bioindicators and as food for tuna and herring. Alvarino [25] related occurrence of *Sagitta decipiens* along with anchovy larvae.

5.3 Food chain relations

Determining the primary production as well as the quantitative transfer among trophic levels, the assumed production of fish in an area, both in the early stage "zooplankton-eater larvae" and later predators, also can be evaluated with a great importance. As indicated by Gulland [37], contrasted with the all-out yearly primary production in the seas of about 20×10^9 tons of synthesized carbon, the fish catch amounting to 5×10^6 tons of carbon (100×10^6 tons/year of fish) demonstrates a distinction of 4000 multiply. This is on the grounds that the fish being fished are different stages expelled from the primary production experiencing about 90% decrease at various trophic levels.

A report on the data of the world oceans' primary production was recorded by Koblentz-Mishke et al. [38]; the authors observed that the primary production over vast regions of seas was notably low, while productivities were higher, i.e., 2–3 times more, in the closeness of land masses. Platt and Subba Rao's [39] introduced synopsis shows that the total primary production in the world seas is around 31 × 109 tons of carbon every year. This information clearly warrants a crisp taking a gander at past estimates.

5.4 Trophic levels

It is enjoyable to memo that certain species get transferred from one level to another as they grow. We can classify the trophic levels into the following classes as agreed with Petipa et al. [40]:

1. The trophic levels started with autotrophs and saprophages that lie at the first trophic level.

2. The second trophic level includes herbivorous organisms such as copepod nauplii, many copepodite stages, *Oikopleura* spp., and the larvae of many polychaetes and benthic molluscs.

3. At the third level there are the omnivorous fauna which include the premature later-stages of some copepods such as *Acartia* spp., *Oithona* spp., and *Centropages* spp.

4. The fourth level contains the primary carnivores as many adult copepods like *Oithona* spp.

5. The fifth level involves the secondary carnivores like *chaetognaths*.

6. The sixth level comprises the tertiary carnivore as *Pleurobrachia* which nourish on all other zooplankton species.

On the other hand, Ryther [41] divided the trophic levels into three food chains that depend on the different communities which can be described as follows: (1) oceanic level, (2) continental shelf level, and (3) upwelled community level.

1. Oceanic level: Ryther propose that the communities that were known as oceanic have long food chains as an uninterrupted flux of biomass from phytoplankton till fish, with low ecological efficiencies determined by the three or four carnivorous feeding levels. The primary production of the oceanic region mostly slows down annual average value of 50 g carbon/m^2/year which required five trophic levels reaching to production of fish.

2. The second type of food chain "continental shelf or coastal" is found in regions where about 100 g carbon/m^2/year is the average annual primary production; it is composed of three trophic levels whether this is through the pelagic or benthic community.

3. The third chain is upwelling zones with 300 g carbon/m^2/year annual primary production which consists of one and a half trophic level whales feeding directly on euphausiids and adult anchovy feeding immediately on phytoplankton.

A change in the pattern of feeding can reduce the overall efficiency of transfer of energy. The changes in the efficiency may be due to qualitative changes in the zooplankton consumed as in the case with herring feeding on large *Calanus* instead of small *Temora* and *Pseudocalanus* [42].

Plankton have direct and indirect impact on the fisheries' healthiness as they are considered a direct food for some planktivorous fish [43, 44] or because phytoplankton and zooplankton development (plankton-rich water) leads to the flourishment of the fouling community.

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