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THE ROLE OF PLNKTON RESEARCH IN FISHERIES DEVELOPMENT

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ABSTRACT

A survey of literature reveals the large-scale investigations carried out to assess the quantum of fish resources that can be harvested from the sea. However, the answer to the basic question concerned with what makes some species of fish superabundant in the oceans remains unanswered. Recent studies on the associations between the plankton community and fisheries illustrate how the biological oceanographic data may be utilized in understanding the mechanisms contributing to the survival of fish. Many authors have indicated clearly defined relationships between the environmental parameters and the fishery. In this paper an attempt is made to assess the role of plankton that can contribute towards fisheries development.

Studies on Indian Ocean plankton based on I. I. O. E. meterial showed that the most important factor that influences the fisheries of a region is the nature and extent of plankton production because of the fact that the survival of fish and fish larvae in a locality is dependent on the type and availability of food. The period of successful fishery, especially the plankton feeders such as mackerel and sardine, have been found coinciding with the period of good plankton production. Thus the survival-density dependence at larval stages in terms of the amount of feed per organism may play a determinant role. The question to be considered is whether fish larvae are too dilute or not to affect the density of their food organisms. It can be concluded that fish larvae are probably too dilute during the early phases to affect their food but as larvae grow this tendency is reversed, and food becomes a limiting factor. However, the production food organisms relative to fish feeding is largely a density indepandent process.

INTRODUCTION

The International Indian Ocean Expedition surveyed Indian Ocean during 1961-'65, the Research Vessel *Varuna* during 1961-'70 surveyed the south-west coast of India Including Lakshadweep Seas and the UNDP/FAO Pelagic Fishery Project surveyed the southwest coast of India during 1971-1975. The main objective of these surveys was to determine accurately and precisely the distribution and abundance over space and time, of plankton with emphasis on Ichthyoplankton. These data can be of use in the prediction and quantitative evaluation and potential fertile fishery grounds and management of the presently exploited and future fisheries. Plankton biomass is considered as an index of fertility of the oceans. Also they are important as they form the base of the food web upon which larger organisms including fishes ultimately depend. It is the nature of plankton community that determines or controls the fish population of that area. Thus the effective plankton cum ichthyoplankton surveys can help us to determine- 1) spawning areas and seasons, 2) biomass of adult spawners, 3) annual fluctuations in adult biomass, 4) migrations of adults, 5) growth and mortality of larval stages, 6) Relation of oceanographic conditions to distribution and abundance of both adults and larvae, 7) trophic relations among fish larvae and zooplankton and 8) species interactions during the larval stage that may subsequently affect stock size.

ZOOGEOGRAPHY

The first stage necessary, to achieve the above objectives, is to obtain the necessary basic knowledge on the taxonomy and then on the distribution and ecology of the different components of the planktonic community. Hundreds of publications have come out on the above lines. To mention a few among them are IIOE collected reprints 1965-'72 by UNESCO, UNDP/FAO Progress Reports 1-18 (1971-'76) and the papers, presented at the Symposia held at Kiel (1971), Cochin (1971) and Goa (1976) and those published in various journals.

Based on above studies about ten zoogeographical regions can be recognized in the Indian Ocean and adjacent seas. These areas are characterized by special faunal associations though they also share taxa with adjacent areas. A number of species migrate into or out of the areas, depending on the prevailing currents.

Distributional studies on the zooplankton of Indian Ocean (IOBC, 1968 a, b) based on IIOE data revealed highest biomass in the Arabian Sea between Lat. 10° and 25°N and Long. 50° and 65°E, more clearly in the area off the Somali coast and the coast of Saudi Arabia. Southwest coast of india is characterized by the pattern of high zooplankton production during and shortly after the south west monsoon and subsequently low plankton densities from November/December to March/April· Also Plankton biomass level showed yearly variations.

LARVAL ABUNDANCE AND PLANKTON

Based on the distribution of fish larvae in the northern Indian Ocean nine different zoogeographical areas reflecting the hydrographical regimes were diffentiated (Peter, 1982). The areas of highest abundance of larvae, though overlapped at certain places with areas of zooplankton abundance, did not always coincide with the regions of their highest density. Compared to the Arabian Sea, Bay of Bengal recorded higher numerical abundance of larvae indicating presence of hitherto unexploited pelagic fishery resources in the Bay of Bengal. Swarms of fish larvae were observed at restricted areas, perhaps owing to the social behaviour of the pelagic (nektonic) fishes leading to continuous distribution of eggs. Studies on zooplankton showed a very general relationship between zooplankton and fish larval adundance, eventhough a definite monthly correlation between fish larvae and zooplankton was lacking. Eventhough a direct relationship between certain fish larval and zooplankton abundance was not apparent, data collected within a specific zoogeographic area on zooplankton abundance still had relevance to larval distribution.

Studies by Peter (1982) on the relationship between the number of fish eggs and larvae and the volume of the respective plankton samples in the Arabian Sea and Bay of Bengal (Figs. 1 & 2) were found to be inconsistent. Moreover an inverse relationship was noticed in certain cases. These can

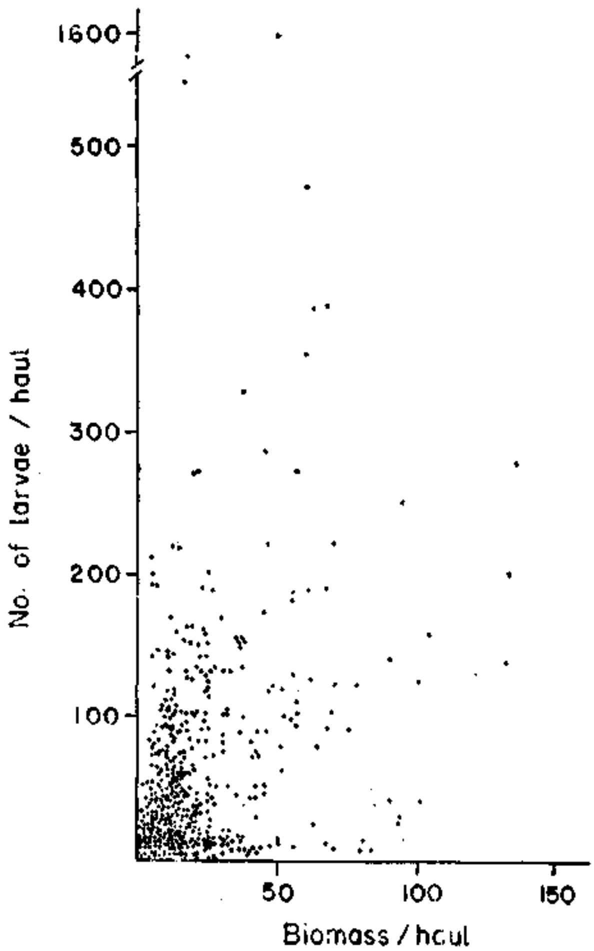

Fig. 1. Relationship between number of eggs and plankton volume in Arabian Sea.

be attributed to the samplers used, avoidance of net by larvae and the nature of sampling (vertical hauls were made instead of oblique hauls). These factors inherent in the IIOE sampling could have caused these inconsistencies. Devi (1986) found no relationship between the volume of the plankton and the number of bothid larvae. Similar observations were reported by many (Strasbery, 1960; Nakamura and Matsumoto, 1966 and Alikhan, 1972). However George (1979) has reported a positive correlation from the coastal waters of southwest coast of India.

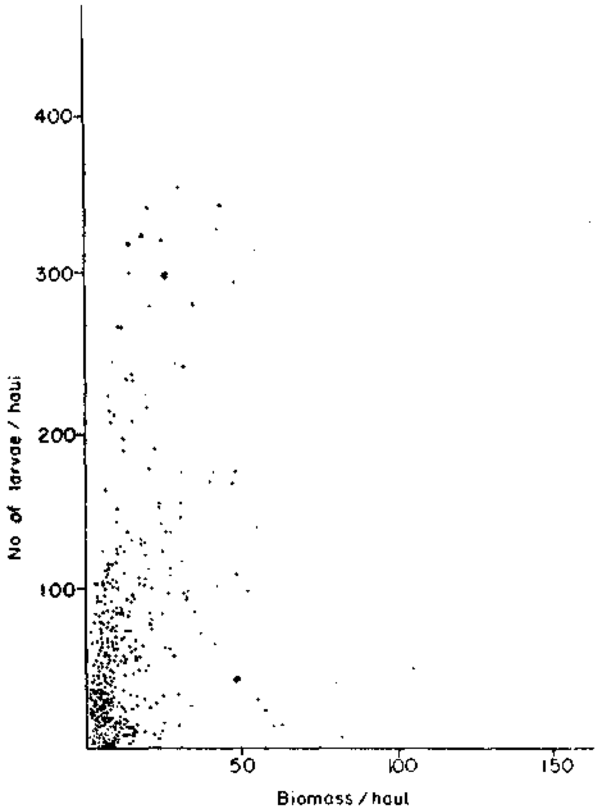

Fig. 2. Relationship between number of eggs and Plankton volumes in Bay of Bengal.

Recent studies showed that the ratio of larval fish to their food organisms varied from place to place, and that their number can be too less to affect the density of food or vice-versa. Owing to a daily rough mortality of 5 to 10% and under the diffuse process in the sea, fish larvae may become reduced in number with age. When food is scarce it leads to a reduced growth rate resulting in a long term predatory mortality. Also eggregation of predators was found responsible for the reduced number of fish larvae. Similarly absence of fish larvae can lead to survival of prey organisms, while an absolute reduction in number of patches of food organisms can be effected by the appearance of fish larvae. Cushing (1983) concluded that fish larvae are probably too dilute during the early larval phases to affect their food but as the larvae grow this tendency is reversed and larvae progressively have more and more effect on their food.

PLANKTON AND FISHERIES

Fishery includes conventional fin and shell fishes and non-conventional associated edible biota. Development means among other consideration enhancement of known resources and location of new ones ensuring continued availability This leads into two complex problems. Regarding the question as to how much fish can one take from the seas; fishery scientist answer this, by estimating the fish stocks of the sea. Also it depends on the harvesting capacity based on the economic considerations. The remaining basic problem is concerned with, what makes some species of fish superabundant in the ocean or why some species of fish were so successful in the sea so as to attract man by their abundance? The biological oceanographer can answer this by his extensive studies on the environment of the seas with emphasis on the role of plankton. Plankton has a major role in the variations occurring in the natural survival of larval and juvenile fish and subsequent recruitment to adult stock. Also plankton controls growth of fish. Survival of fish larvae increases with age. Both martality and growth may vary considerably under natural conditions. The laying of large number of eggs from which only a few adults survive is a typical r-strategy. The success of which will be governed by plankton and its environmental parameters and not by the number of parent stock. At some lower levels of survival, density dependence in terms of the amount of food per organism may play a determinate role. However, the production of food organisms relative to fish feeding is still a density independent process. Normally spawning areas and seasons were located by examining the gonad condition of fishes caught at various times and places throughout the year. But recent data on ichthyoplankton component based on the actual spawned eggs and larvae collected have given us a true picture of the spawning areas and seasons. Also these data have provided us with the absolute measure of stock size, once fecundity per unit weight and the proportion of females in the stock are known. Saville (1981) and Berrien *et al.* (1981) estimated absolute size of spawning stock size (assessment) directly from egg and larval survey data. These data when compared to catch statistics of particular fisheries can be used to indicate when the level of over exploitation is being approached.

LARVAL SURVIVAL

The importance of zooplankton as a principal source of food of marine fish larvae has been long recognized. Steele (1974) pointed out the need for more knowledge on food web cycle for the prediction of fisheries. Relatively little is known regarding the relation between prey density, growth of larvae and survival.

As early as 1914, Hjort attributed the ability of a fish population to pass through the larval period without excessive mortality as one of the primary factors determining the size of the resulting year class. Saville (1975) hypothesized that competition for food during the larval period might be a mojor factor affecting survival and subsequent year class strength. The stock-recruitment relationships of Beverton and Holt (1957) and Ricker (1958) indicate that the survival of larvae may be density dependent at high stock densities because recruitment does not increase at high stock levels. Density dependent factors could operate at either the intra- or inter-species level during the larval stage.

LARVAL MORTALITY

Fish larvae are ready to feed soon after the exhaustion of yolk reserves or in about two days time after hatching. According to Hunter (1976a) one of the principal causes of the marine larval fish mortality may be attributed to their starvation after yolk absorption. Starvation can be detected by morphometric, histological and chemical criteria. Feeding is effected by availability of sufficient, suitable food at a threshold concentration (Shelbourne, 1957; Lasker, 1975; Lisivenko, 1961; and SYSOEVA and Degtereva; 1965); selectivity (Blaxter, 1963 and Resenthal and Hempel, 1970) etc. Occurrence of many fish larvae showing symptoms indicative of starvation in the ocean, was reported by Balachandran (1980). This as reported also by O'Counell (1981) implied that circumstances of insufficient food were responsible for their occurrence.

Also the proportion of larvae observed to be starving may be a useful indicator of ultimate year-class success as it indicates a substantial part of total daily mortality of the larvae. Zweifel and Smith (1981) have estimated that the average daily mortality rate for anchovy larvae of less than 10mm SL was 21% over a period of years. If starvation contributes substantially to total mortality. the proportion observed to be starving may relate reasonably well to eventual recruitment.

LARVAL PREDATION

Apart from drawing food from plankton fish larvae offer themselves as food for others. The plankton collections analysed so far revealed presence of predator species such as Chaetognaths, Siphonophores, Chondrophores, Medusae and Ctenophora at times in large numbers. Prochordates, polychaetes, heteropods, petropods, euphausiids, copepods and decapod larvae also occurred abundantly in some of these collections. The abundance of the above species was controlled more or less by the environmental parameters. Frequently a large number of fish larvae in various stages of digestion was observed in the guts of these predators. Compared to the relatively passive yolk-sac larvae, the above predators preferred actively swimming fishlarvae. As ctenophores float at or near the surface, their predatory activity is confined to this zone. But siphonophores are found to be the most successful predators as they could move swiftly through waters. The predatory potential of an individual is roughly proportional to its size, whereas that of a species is related to both size and abundance. Alvarino (1981) recorded 108 predator species and noted their major abundance in hauls lacking anchovy larvae in those with aggregations of larvae. She found domination of anchovy waters by copepods and or euphausiids and larval absence in hauls dominated by pelagic prochordates.

Often the predatory pressure of zooplankters is found weaker, when there is an abundance of copepods which could be evidenced by the gut content analysis of these zooplankters. Heavy predation on fish larvae by chaetognaths and ostracods (Labour, 1923 and Nellen, 1973), by medusae like Aurelia and Cyanea (Fraser, 1969) and by copepods (Lillelund and Lasker, 1971) was reported. Predation can be seen varying annually affecting subsequent years class strength.

In a recent colloquium dealing with larval fish mortality it was concluded that "major causes of larval mortality are starvation and predation, and these may interact" (Hounter, 1976*a*).

It is a known fact that mortality from predation is reduced when potential predators are less in number and mortality from starvation is reduced and when fish larvae occur in waters with an adequate food supply. A fishery survives when a favourable combination of factors as above prevails as is the case reported for "anchovy water".

PLANKTON AS INDICATORS OF FISHERY

Most of the fishes have plankto-trophic larvae, their presence indicating the occurrence of the adult species which constitute the fishery. They also function as indicator organisms, whose larval life is protracted as in the case of flat fishes. Nair (1953) and Nair and Subrahmanyam (1955) correlated fluctuations in the oil sardines to the presence of a bloom of a diatom *Fragilaria oceanica*. Selvakumar (1970) realised a relationship between mackerel fishery and cladocerans—*Evadne* and *Penilia*. Sakthivel (1972) has commended on the pivotal role played by pteropods as indicators and as food for tuna and herring. Alvarino (1981) related occurrence of *Sagitta decipiens* along with anchovy larvae.

JUVENILE FISH SURVIVAL

The large number of fish larvae eaten by predators may account for the high larval mortality. Compared to the 10^6 eggs, 10^2 juveniles formed much larger prey items, but few in numbers. The more plankton those juveniles eat, the faster they grow and vice versa. While feeding is a matter of survival for larvae, it is a matter of growth rate for juveniles, all dependent on plankton availability. The most important aspect of a fish's growth for the planktonologist is not only the availability of absolute abundance of prey items but also the access to the right type of food (Parsons and Lebrasseur, 1970), as the growth efficiency is related to the nature of food (Paloheim and Dickie, 1966 b). Leong and O'Counell (1969) noticed alteration in the rate of feeding by anchovies by changing the method of prey catching from filter to reptorial feeding.

FOOD CHAIN RELATIONS

Knowing, the primary praduction and the quantitative transfer between trophic levels, the potential production of fish in an area-both first stage carnivores (zooplankton eaters) and predators, can be estimated. According to Gulland (1970), compared to the total annual primary production in the oceans of about $20x10^9$ tons of carbon synthesized, the fish catch equivalent to $5x10^8$ tons of carbon ($100x10^6$ tons/year of fish) shows a difference of 4,000 fold. This is because the fish being harvested are several stages removed from the primary production undergoing about 90% reduction at different trophic levels Koblentz Mishke *et al.* (1970) reporting on primary productivity data for world oceans noted low primary production over large areas of oceans and higher productivities ie. 2 to 3 times more in the proximity of land masses. The summary given by Platt and Subba Rao (1975) indicates that the total primary productivity in the world oceans is about $31x10^9$ tones carbon per year. These data obviously warrants a fresh look at previous estimates.

Recent studies show that fish production can change appreciably, most probably due to changes in the efficiency with which the primary production is converted into fish rather than changes in the total primary production. The world's catch of marine fish in 1966 was about 44 million tons (FAO, 1967) in addition to 5 million tons of crustaceans, molluscs etc. This catch almost doubled to 85 million tons (FAO, 1987) in 1985, expanding at around 5% per year. The present catch is close to the global estimate of 100x10^6 tons/yr. This tremendous difference in catch data can be attributed to one of the three factors low estimation of production, factual increase in production or an intensive fishing, removing an accumulated stock so far not exploited by altering the size spectrum harvested.

Slobodkin (1961) indacated a value of ecological efficiency at about 10%. Schaefer (1965) considering the effect of ecological efficiencies ranging from 10 to 20%, noted an order of magnitude of increase in the production of fish at the fifth trophic level. In general, the trophic levels iucluded are-autotrophs and saprophages at the first trophic level; herbivorous organisms as nauplii of copepods, some copepodite stages, Oikopleura and the larvae of some benthic molluscs and polychaetes at the second trophic level; omnivorous organism as later stages of copepods, Acartia, Oithona and Centropages at the third level; primary carnivores as adult Oithona at the fourth level; secondary carnivores as Chaetognaths at the fifth level and the tertiary carnivore Pleurobrachia at the sixth level feeding on all other zooplanktons (Petipa *et al.*, 1970). It is interesting to note that certain organisms get transferred from one level to the other during their growth.

Ryther (1969) considered the number of trophic levels in three communities which may be described as oceanic, continental shelf and upwelled. He suggested that oceanic communities have long food chains as a continuous flow of biomass from phytoplankton to fish, with low ecological efficiencies decided by the three or four levels of carnivorous feeding. The oceanic area generally with slow annual primary production average value of 50g C/m^2/yr required five trophic levels leading to the production of fish. The second food chain described as coastal or continental shelf occurring in areas where the total annual primary production is about 100g C/m^2/yr, consists of three trophic levels whether this is via the benthic or pelagic community. The third chain of upwelling areas with a primary production of 300g C/m^2/yr represents as one and a half trophic levels - adult anchovy feeding directly on phytoplankton and whales feeding on euphausiids

In the above three communities ecological efficiencies at each trophic level were assumed to be highest when governed largely by phytoplankton/herbivore associations and lowest for communities in there which were secondary and tertiary carnivores. Consequently a 10, 15 and 20% efficiency was assigned to be oceanic, costal and upwelling food chains respectively. From this Ryther estimated the potential fish production of 36,000, 340 and 0.5 mg C/m^2/hr. for the upwelling, shelf and oceanic areas respectively.

A change in the pattern of feeding as the case with anchovies which usually feed on phytoplankton but at times feeding on zooplankters, can reduce the overall efficiency of transfer of energy from phytoplankton to zooplankton feeders. Similarly plaice larvae feeding on some large diatoms as *Biddulphia* and *Coscinodiscus* in the earlier feeding stage, can be seen abruptly changing to a zooplakton diet of Oikopleura. The changes in the efficiency may be due to qualitative changes in the zooplankton consumed as is the case with herring feeding on large *Calanus* instead of small *Temora* and *Pseudocalanus* (Steele, 1965). Eventhough there seem to be no relation between the total food supplies and the larval fishes, certainly food supplies, possibly of a particular type at a particular time—eg. When the yolk sac supplies are finished—may be critical.

An important property of food web is its stability that is the ability of a system to maintain itself after a small external perturbation (hurd *et al.*, 1971). Mac Arthur (1955) has postulated that development of many species (ie. a high diversity) is the principal component in establishing community stability. But productivity for unit biomass will be low as the complex food web requires more energy. Thus the tropical plankton communities and food web with high diversity and stability lead to low productivity in general. In contrast the plankton community in temperate waters with low stability and diversity leads to high productivity, contributed by one or two species. Stabilization was also maintained by the imposition of a limitation on the predator, by periodic migration of the predator away from its food source, by the patchiness of the prey distribution and by the imposition of a threshold concentration below which the prey is not consumed by the predator. Examples can be found in the diel migration of zooplankton into the euphotic zone (Mc Laren, 1963 and Balachandran, 1980); in the ability of zooplankton such as euphausiids, to change from carnivores to herbivores (Parsons, and Le Brasseur, 1970); and in the occurrence of a threshold prey concentration in phytoplankton/zooplankton relationships (Parson *et al.* 1967); On the other hand instability may be imparted in a plankton community by time delays (Dickie and Mann, 1972) as is the case with the branacle community depending on timing of *Skeletonema* bloom for the release of its larvae (Barnes, 1956).

In an aquatic ecosystem, a perturbation applied to the top of a food chain (as removal of predators) would have more effect resulting in an increased biomass (fish production) than one applied to the bottom of the food chain (as added nutrients). In the marine environment as the exchange of water may remove organisms in the study area, it is difficult to establish density dependent relationships between the growth of planktivorous fish and plankton growth rates. Abundance of fish is generally related to the abundance of plankton. The depensatory mechanism can be noted when a large number of fish larvae compete so heavily for a limited amount of food that the survivors may become much smaller than if fewer larvae were present intially. Similar definite reduction in growth rate of haddock larvae was noted by Gulland (1962) and Beverton and Holt (1957), during period of high stock abundance (Raitt, 1939). Often predation by planktivorous fish on plankton community may affect the size structure of an aquatic food web (Brooks and Dobson 1965). Abudance of planktivorous fish promote growth of smaller zooplankton and phytoplankters, while larger zooplankton flourished with fewer fishes.

CONCLUSIONS

The follawing inferences can be arrived at from the above observations:

a) The highlight of this study on the role of plankton in the fisheries development is that helps us to answer the basic question in biological oceanography, as to why some species of fish are superabundant in certain areas.

b) Plankton biomass act as an index of fertility of the oceans, giving us an estimate of the total organic production and helping us to chart out the areas of fishery potential.

c) Fish production can change due to changes in the efficiency with which the primary production is converted in to fish rather than changes in the total primary production.

d) The spawning stock size can be estimated directly from the egg and larval survey data.

e) Plankton offer themselves as the principal source of food, the variability in their composition affecting food habits of the fishes.

f) Plankton assemblages indicated the role of plankton as a deciding factor in the spawning of fishes.

g) A fishery survives when a favourable combination of factors prevails, adequate food supply and reduced prey density.

h) One of the prime factors deciding the size of the resulting year class is its ability to pass through the larval life without excessive mortality.

i) Zooplankton preadtion on fish larvae affect subsequent year class strength/fisheries.

j) The percentage of starved larvae can be an indicator of ultimate year class strength.

k) Certain planktonic species act as Indicators of fisheries.

l) A multitude of factors control the extent of variations noted in the survival of larval and juvenile fishes.

FISHERY MANAGEMENT

The role of plankton in fisheries management can be as follows:

a) The spawning stock size directly estimated from the egg and larval survey data, when compared to catch statistics of particular fisheries can be used to indicate when the level of over-exploitation is being approached.

b) The conventional method of estimating stock sizes from commercial fisheries was found inapplicable where fisheries have been prohibited due to depletion of stock.

c) Studies on plankton allow us to understand the natural ecosystem in order to answer the question—how much fish can be caught from the sea.

d) Plankton studies help us to the understand the effect of removing large quantities of fish from the same natural ecosystem.

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