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ON

LIVING RESOURCES

of

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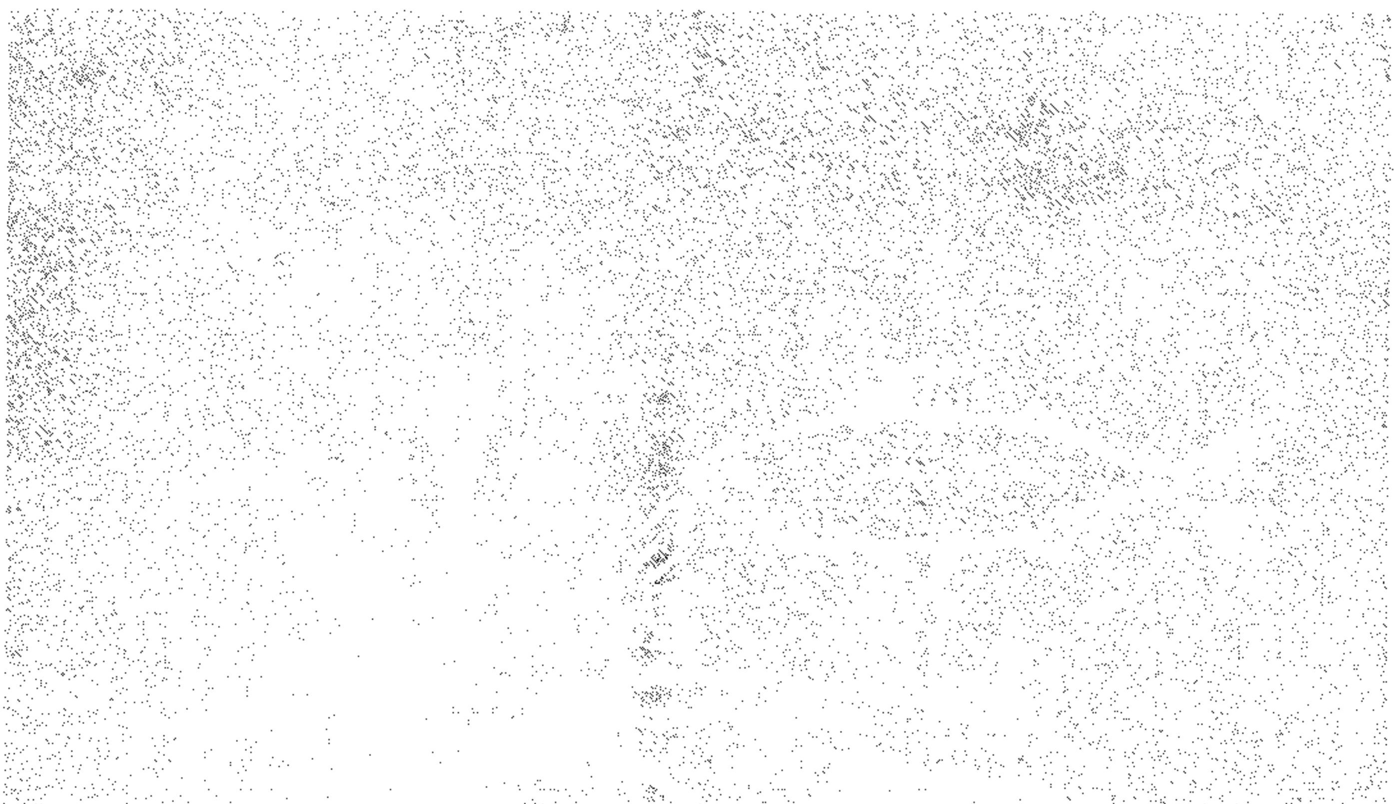

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FLUCTUATION IN THE INDIAN OIL SARDINE FISHERY—AN EXPLANATION

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ABSTRACT

Fluctuation in annual catch of the Indian oil sardine are related to the fluctuations in the strength of the new year-class recruited in the fishery. The strength of the recruit class does not seem to depend only on the strength of the spawning stock, but on the total stock. Thus an exceptionally strong recruit class may vitally affect the strength of the recruit class of subsequent years. An analysis of year-class composition of the commercial catch and a knowledge of the strength of the recruit class may help to predict the fishing success for subsequent one or two years. Intensive fishing of an unusually strong year-class rather than general restriction in fishery seems to be a solution for stabilizing the widely fluctuating fishery.

INTRODUCTION

THE fishery of the oil sardine *Sardinella longiceps* Val. ranks high, contributing to the bulk of the marine fish landings in India. There have been tremendous variations in the annual yields. Both regular and casual variations in the catches of the oil sardines in certain years have been the cause of anxiety and hardship to those engaged in the industry. Many attempts were made in the past to explain the fluctuations in the fishery. Overfishing, migration and mortality of larvae were suggested as some of the causes behind the fluctuations by Devanesan (1943), Devanesan and Chidambaram (1948). Chidambaram (1950) felt that depletion of immature sardines by the commercial fishermen brings about large-scale changes in abundance. Sekharan (1962) has stated that the year-class strength is a leading factor in determining fluctuations. While reviewing the Indian oil sardine fishery Nair and Chidambaram (1951) suggested regulative measures to safeguard the industry from fluctuations. In the present study, an attempt is made to scientifically forecast the extent of availability during the different years. It is based on observations of recruitment and availability of various year-classes into the fishery during extremely productive as well as lean years.

An attempt at predicting the fishery, biologically, was made by Nair and Subrahmanyan (1955). According to them the diatom *Fragilaria oceanica* may be considered an indicator of abundance of the oil sardine. A bumper fishery for juvenile oil sardine corresponds with a bloom of the diatom. Incidentally, it is evident from past observations that during exceptionally productive fishing years the juveniles dominate the catches (Bennet, 1966). However, advance predictions could not be made based on the observations of Nair and Subrahmanyan.

LIFE-HISTORY OF THE OIL SARDINE

Nair (1959) states that the spawning season for the oil sardine begins in July or August. According to Prabhu and Dhulkhed (1967) it might extend even to December. It is likely that small groups spawn even earlier than July. The exact commencement and duration varies during different years, perhaps, according to environmental conditions. At least three generations (year-classes) of sardines take part in the spawning each year. The rate and level of reproduction varies between year-classes. Younger and smaller fish produces less number of eggs than older and larger fish. In certain years the number of virgin spawners are comparatively less than in other years. The extent of the reproduction capacity of the oil sardine stock is not uniform every year. The fewer the fish in the stock the higher the reproductive capacity, and thereby the more the stock tends to increase in number. But, production of eggs has little effect on the population strength, as many eggs and young larvae are likely to be destroyed by eliminating factors in environment and by predators.

The new recruits appear intermittently between June and October and contribute very little to the fishery by way of weight. They are extremely erratic to be obtained and may be seen only for one or two days and disappear all of a sudden from the fishing grounds. Though there are divergent views about size-age relationships in the oil sardine, the age-size relationships stated by Nair (1959) has, with slight modifications, been followed for the purpose of further analysis in this paper. Observations of Prabhu and Dhulkhed (1967) and my own observations at Calicut are in general agreement with the views of Nair (1959) and Chidambaram (1950) in the subject. According to Nair (1959) oil sardine attains 10·0 cm during the first year, 15·0 cm during the second year and 19·0 cm during the third year. However, present studies on length frequency of oil sardine show that fish of 19·0 cm. is four-year-old and oil sardine attains a length of 17·5 cm. when it is three years. Towards the end of the second year and at size of about 15·0 cm the fish mature for the first time.

During a bumper year for oil sardine the one-year olds appear in great numbers. The abundant year-class influences the fishery for two or three successive years. First it influences the number of the 1-year fish, next year the 2-year fish and the third year still larger fish. After three or four years the abundant group has run its course and no longer influences the quantity of the fish caught. Similarly any less-than-normal or weak year-class also pass through three or four years. Their presence is not felt in the fishery but they contribute a great deal to the fluctuations in the fishery.

Stress of Generations

Considerable disagreement exists among sardine workers regarding the age of the fish at first maturity (Prabhu, 1967 ; Nair, 1953). Bennet (1966) is of the view that the oil sardine follows a two-year cycle from recruitment to maturity. It starts spawning towards the end of its second year of life. From then on spawning takes place every year. Naturally, had there been no annihilating factors, a bumper year-class of virgins are expected to produce still more numerous young ones. At that rate there need not be any case of fluctuations in the fishery but on the other hand there should be steady increase in fishery. Once in two years a new generation from the strong year-class will show its mark on the fishery. In a similar way during the intervening years the weaker year-class is expected to pass through the fishery.

The periods of rise and fall in the general stock level, as evidenced from catch statistics (Table I), during the course of years has a general pattern. It may thus be inferred that fluctuations in the stocks were caused mostly by the same factors. An examination of the phenomenon of fluctuations in the oil sardine fishery would reveal that the main cause for the fluctuations may be attributed to the " stress " exerted by the overabundant year-class recruited into the fishery. Owing to a number of reasons one or other generation is recruited in greater numbers than usual. This might create adverse eliminating factors in the environment particularly a shortage of food. The increased demand for food by the increased number of large fish might cause deterioration in the development of subsequent generations. The effects of the stress are more telling on the younger fish causing them to reduce in numbers. Thus an abundant year-class of sardine produces a weaker generation which causes an unexpected failure in the fishery. Present studies indicate that the stress exerted by an exceptionally strong year-class might decide the size of the successive year-classes. In this connection reference may be made to Ricker's (1958) formulation of the relation between parent stock and resultant progenies. According to him, the recruitment is at its maximum, when the spawning stock is at some intermediate level of abundance, *i.e.*, it is neither too small nor too large.

TABLE I

Total landings of oil sardine in tonnes

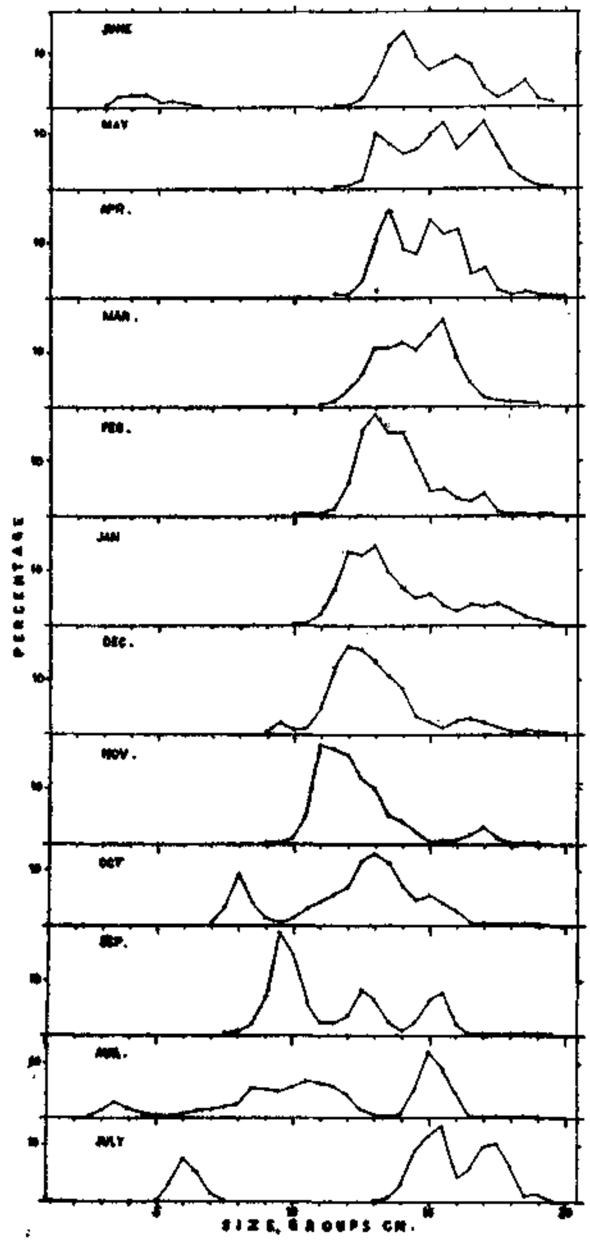
Year (July to June)	In India	At Calicut
1957–58	2,49,147	8,257
1958–59	82,224	3,133
1959–60	35,345	1,533
1960–61	2,63,255	7,988
1961–62	97,642	8,292
1962–63	1,30,922	3,299
1963–64	57,406	263
1964–65	3,59,291	9,782
1965–66	2,01,913	4,752
1966–67	2,07,523	2,989
1967–68	2,15,458	4,460

The ability of a fish to maintain the abundance of its species is the sum total of the number of eggs deposited, the state of the spawning ground, the power of survival of young fish and the death-rate before attaining sexual maturity. The total number of fish in the population cannot exceed the limits determined by food resources and the rate of its reproduction. If the numerical strength of the population is almost completely filled up by one very strong generation and as long as it is not reduced the other, weaker, generations cannot increase in number. This explains the prolonged numerical superiority of abundant generations. The weak generations cannot re-establish themselves for many years, in spite of the production of large number of eggs. The effect could be obtained by concentrated fishing of overabundant generations of sardines when they first enter the commercial fishery at 1-age. It may be possible to balance the numerical relation of strong and weak generations by more concentrated fishing of the stronger generation while limiting the catches of the weaker generations.

Food resources of the sea can by no means be considered inexhaustible. On the contrary, just those main food components of the plankton like *Fragilaria oceanica, Coscinodiscus, Biddulphia, Pleurosigma,* Dinoflagellates, Tintinids and Copepods may largely decrease through consumption by sardines and other plankton feeders. Nair and Subrahmanyan (1955) and Dhulkhed (1962) suggest positive correlation between abundance of plankton organisms and oil sardine yield. Large populations of sardines moving from place to place definitely deplete food organisms in the region. Instances have been cited as to how in the Sea of Japan large sardine population slowly moving northward leaves areas in its wake almost completely devoid of plankton (Kusmorskaya, 1948). At present little information is available about the spawning grounds of the oil sardine. It is possible that accumulation of spawned fish at the spawning grounds might do great harm to the young fry.

CALICUT FISHERY

Application of the life-history and availability of *Sardinella longiceps* for successful prediction of abundance may be explained by observations made on the oil sardine fishery at Calicut between 1964 and 1968. As it is, Calicut is located in the heart of the oil sardine 'zone' and the fishery is prosecuted all round the year. Examination of the oil sardine catch over the years gives the impression that the vicissitudes experienced in the oil sardine fishery along the coast are very likely reflected in the Calicut fishery.



G. 1. Length frequency polygons showing the sizes of *Sardinella longiceps* taken each month of the year at Calicut by commercial fishermen. The frequency was derived from an average of four years data from 1964 to 1968.

From Table II it will be seen that the 1964–65 fishery was supported by three year-classes, *i.e.*, 1963, 1962 and 1961 year-classes. The 1963 year-class in the fishery was one-year old and were the new recruits in the 1964–65 fishery. The 1963 year-class supported record landings in numbers during the year. The fishery of 1965–66 contained five year-classes from 1966 to 1962. The 1966 and 1965 year-classes were in the pre-full-recruitment stage and contributed only little to the fishery by way of weight. The new one-year-old recruit was represented by the 1964 year-class. But, by far the most dominant group in the fishery of 1965–66 was the 1963 year-class and was the mainstay of the fishery. The 1962 year-class contributed only little to the fishery. During 1966–67 the 1965 year-class entered its full recruitment stage. The two-year old 1964 year-class and the three-year old 1963 year-class fish gave additional support to the fishery. Small quantity of 1966 year-class fish also was encountered in the catches at the early part of the season. The 1967–68 commercial fishery witnessed the appearance of five year-classes (1957 to 1963) of sardines in the landings. The 1965 year-class with increased landings than during the previous year contributed more to the success of the fishery than all the other year-classes combined. The largest fish during the season were formed by the 1963 year-class while the 1967 year-class formed the smallest fish in the landings. Though the 1965 year-class contributed to over 90 million fish at its first full recruitment stage in 1966–67, its increased landings in 1967–68 with 196 million fish is surprising. This might explain the stabilised nature of the oil sardine fishery during 1967–68, in spite of the failure of the 1966 year-class. The strength of the 1967 year-class which enters the full recruitment stage in 1968 may be inferred from a study of the stress exerted by all the older year-classes on the 1967 fry.

TABLE II

Year-class composition of Sardinella longiceps *catch at Calicut from* 1964 *to* 1968

Fishing years (July to June)	Number of fish by year-class (in thousands)								
	1968	1967	1966	1965	1964	1963	1962	1961	1960
1963–64*	00	00	00	00	00	00	39	2,328	667
1964–65	00	00	00	00	00	5,13,572	855	20,286	00
1965–66	00	00	1,427	18,931	89,849	1,31,943	455	00	00
1966–67	00	00	4,500	90,416	75,155	12,924	00	00	00
1967–68	00	69,732	22,356	1,96,573	18,498	4,480	00	00	00
Totals ..	00	69,732	28,283	3,05,920	1,83,502	6,62,919	1,349	22,614	667

* Includes data from January to June 1964 only.

It is the result of this stronger year-class pressure on the fry of the subsequent year-classes that causes a gradual reduction in the landings after one or two years of extremely good fishery. Whether the fluctuations caused by the stronger year-class stress on the fry are short-lived or prolonged depend on certain factors which are very little studied:

(1) Disproportionate effect of the older fish pressure on separate sub-populations of oil sardine. If the oil sardine population of the coasts composed of many sub-propulations any undue stress on one sub-population will not adversely affect the other sub-populations. On the other hand, if the oil sardine stock of the coasts is composed of only one population any adverse effect by overabundant year-class or other eliminating factors at one place, particularly the spawning grounds, will have their detrimental effect on the landings at other places also.

(2) Catastrophic annihilation of eggs or young ones in the spawing grounds due to unknown causes. Destruction of large quantities of eggs inside the ovary may not have much effect on the population strength, as in certain existing conditions of environment fecundity more or less relates to the sum total of all the influences affecting the ability of the fish to maintain its abundance.

(3) Strength of the " carry over " of the bumper year-class. An innumerable group of ' carry over ' after spawning, from one strong year-class will exert greater pressure on subsequent generations for many years until fishery depletes it to the safer level. Only in this respect can the fishery exert certain regulatory control. By fishing the overabundant group in large numbers fishery can reduce the ' carry over ' strength to the required level for a successful recruitment next year. Regulatory measures by restricting the mesh size of nets or by prescribing any closed season for the oil sardine fishery as was done by the Madras Government during 1943 to 1947 will have no effect on the fluctuations. The restrictive measures will protect both the strong as well as weak generations. It will only aggravate the situation further, in addition to denying a fairly good quantity of fish to the commercial fisherman.

Considering the matters discussed above it is possible to predict to a great degree of accuracy the fluctuations in abundance in the oil sardine fishery. The life-cycle of the oil sardine forms the main consideration in the study and prediction is linked to the recruitment and abundance of the year-classes of sardine. An increase in stocks can be expected when the stress of the older fish decrease during the spawning season. The increase in stocks begins to outstrip the level of the older fish from the overabundant generation. The adverse factors in the environment while reducing the sardine population simultaneously promote an improvement of its qualitative composition. Because of the abundance of food in the sea a stock which has been numerically reduced is better nourished, grows better, has greater fecundity than a more numerous stock. The greater the number the smaller is the size, weight and fecundity. That is why there is no basis for expecting a steep increase after a bumper year. However, it is safer to have adequate information on the population or sub-populations comprising the oil sardine stock before making any outright predictions.

Summary

A method of predicting the Indian oil sardine fishery based on its life-cycle is briefly discussed. Oil sardine starts spawning towards the end of its second year of life and at size of about 15 cm. Overabundant and weaker generations of oil sardine are often recruited. Production of eggs has little effect on the population strength, as many eggs and young larvae are likely to be destroyed by eliminating factors in environment and by predators. Fluctuations in abundance are caused mainly by the stress exerted by overabundant year-classes on the fry of successive year-classes thereby reducing their numbers. Both strong and weak generations are affected by the abundant year-class pressure. After years of fishing depending on the size of strong year-class survival a stage is reached when the threat from the overabundant generation is no longer effective. Any year-class recruited at this juncture will have a good chance to become abundant. Based on a study of this phenomenon it might be possible to accurately predict the fluctuations in the *Sardinella longiceps* fishery.

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