TUNA RESEARCH IN INDIA

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FISHERY, BIOLOGY AND STOCK ASSESSMENT OF SKIPJACK TUNA IN INDIAN SEAS

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INTRODUCTION

In India the oceanic skipjack, *Katsuwonus pelamis* (Linnaeus) forms a significant fishery only in Lakshadweep islands. Here itself the catch is only an insignificant component in the total annual catch of this species from western Indian Ocean. The infrastructural facilities now available in these islands are insufficient to expect any major improvement in its fishery. As this group of islands are increasingly coming to focus in the national context with a view for further devlopment, the fisheries sector will have to get its due importance. Tunas constitute 78.7% of the total marine fish catch from Lakshadweep. Skipjack tuna is the most important component of tuna catch with a percentage contribution of more than 75. Hence, this species is of prime importance in any planning for development of fisheries here. Silas and Pillai (1982 and 1985), James and Pillai (1991), James *et al.* (1987 and 1989), Pillai and Gopakumar (1989) and Pillai (1991a and 1991b)had proposed development of the fishery using modern fishing methods and extending the present area of fishing. CMFRI, being the agency to study the status of stocks of fishes available for exploitation, has done detailed investigations on the fishery, biology and stocks of this species. This paper is a review of the results of these studies for guidance in planning future research.

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HISTORIC RESUME

CMFRI with its active presence in Minicoy island of Lakshadweep since 1958 has closely monitored skipjack fishery of this island and the studies have resulted in many valuable scientific contributions. Details of pole and line fishery for skipjack, craft and gear used and utilisation are given by Jones and Kumaran (1959), Silas and Pillai (1982), Madan Mohan *et al.* (1985) etc. Tuna shoals associated with floatsam in the offshore waters of Minicoy were studied by Madan Mohan (1985). Livingston (1990) has given a critical study of craft and gear in skipjack fishery and suggested improvements. Raju (1964 a and 1964 b) made detailed study of the fecundity and spawning of skipjack. Spawning studies were also made by Madan Mohan and Kunhikoya (1985 a). Food and feeding habits of the species were studied elaborately by Thomas (1964 a) and Raju (1964 c). Age and growth studies were made by Appukuttan *et al.* (1977) and Madan Mohan and Kunhikoya (1985b). Relation between length and weight of the fish was estimated by Madan Mohan and Kunhikoya (1985 c) and Silas and Pillai (1985 a). Population parameters of the fish were estimated and stock assessment was made by Silas *et al.* (1985) and James *et al.* (1986).

Live-bait fishes used in skipjack fisherey by pole and line were studied in detail by Jones (1958, 1960 and 1964), Madan Mohan and Kunhikoya (1985 d), Pillai *et al.* (1986), Thomas (1964 b) and Kumaran *et al.* (1989).

BIOLOGY

Sex-ratio

Raju (1964 b) observed significant change in the sex-ratio of skipjack caught in Minicoy with males predominating during the period February-May corresponding to active spawning period of the fish. During spent-recovering or spent-resting period, viz, July to September the females dominated. Predominance of males were more in the larger size groups from 541-880 mm. In smaller size groups from 381-460 mm, generally, females dominated. He attributed this to either moving away of females when spawning approaches or they do not take bait. Madan Mohan and Kunhikoya (1985 a), however did not observe such significant difference in the sex-ratio.

Size at first maturity

Raju (1964 b) observed maturing ova in skipjack measuring from

400-450 mm in total length. That will be around 383-431 mm in fork length. He further stated that fish measuring 350-450 mm had ovaries that mostly appear to be immature.

Fecundity

The following relation was given by Raju (1964 a) between total length and fecundity of skipjack after studying 63 specimens of length varying from 400-750 mm.

$$Y = -109.0 + 0.00000342\ L^3$$

where Y is the number of ova in thousands in most advanced mode and L, total length in mm according to which the total number of ova ranged from 317600 to 1332900 in skipjack with a total length from 500 mm (479 mm in fork length) to 750 mm (718 mm in fork length). The corresponding relation between weight and fecundity is :

$$Y = -67.69 + 67.01\ W$$

where Y is the number of ova and W, weight in pounds.

Madan Mohan and Kunhikoya (1985 a) after studying the fecundity of 23 specimens gave the following relation :

$$Y = -918.57049 + 23.27525\ L$$

where Y is the number of mature ova in thousands and L, fork length in mm. Taking the b value 23.27525 as a printing error and accepting it as 2.327525 the fecundity of fish mearuring from 479-718 mm will range from 196000-753000 only. Corresponding relation with weight given by them is:

$$Y = -20.00365 + 99.48753\ W$$

Spawning

Jones (1959) collected larvae of skipjack during the months from December to April from Minicoy waters and remarked that January to March appears to be the peak breeding season of the fish in the area. Raju (1964 b) after studying the gonadial condition of the fish caught in Minicoy put the peak spawning season as February to July. He came to this conclusion based on the higher percentage of ovaries in mature condition during this period. His classification of ovary as mature most probably corresponds with stage V given by Madan Mohan and Kunhikoya (1985 a) who had pooled stages IV and above and classified them as mature to study the spawning season. As they got ovaries in this stage throughout the season they considered skipjack as round the year spawner. But, if the percentage of observations on ovaries in stage V and above were taken it shows a spawning peak around March-April period and probably a minor peak in December. Raju (1964 b) observed fractional multiple spawning in skipjack which was further supported by the observations of Madan Mohan and Kunhikoya (1985 a)

Food and Feeding

Raju (1964 c) examined 2609 stomachs of skipjack and found crustaceans, cephalopods and larval and juvenile fishes as their chief food after ignoring the bait-fishes found in plenty in their guts. He also observed an increase in stomach content's volume per stomach and decrease in volume per unit weight of body with increase of body length. Fishes below 550 mm were fed more on crustaceans and those with sizes above that were fed more on larval and juvenile fishes and cephalopods. Fishes were observed as chief food item of skipjack by Thomas (1964 a), crustaceans coming second in importance, followed by squids, medusae, molluscs and plant matter.

Growth

Appukuttan *et al.* (1977) used probability plot technique and Peterson's method of length frequency analysis to determine the age of skipjack tuna and concluded that the size at age 1, 2, 3 and 4 is 404 mm, 494 mm, 563 mm and 621 mm respectively in fork length. Based on this conclusion they estimated growth parameters as:

$L\infty = 842$ mm $\qquad K = 0.22314$ (annual) $\qquad t_o = -1.93$ years

The abnormally large value of t_o estimated by them indicate a rate of growth in the first year, so fast that it cannot be explained well by a VBG curve and hence, the K value given by them can be underestimate. Madan Mohan and Kunhikoya (1985 b) estimated the growth parameters as:

$L\infty = 900$ mm $\qquad K = 0.4898$ (annual) $\qquad t_o = -0.06$ years

giving the size of 1, 2, 3 and 4 year old skipjack as 367 mm, 573 mm, 690 mm and 777 mm respectively. They based their observations on the smallest

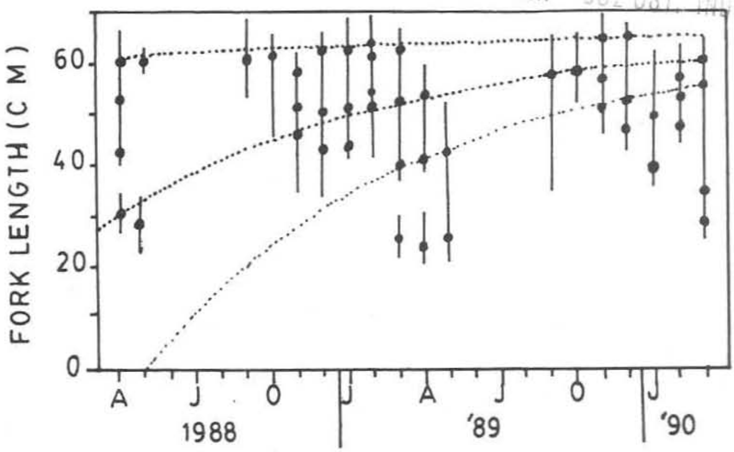

Fig. 1. Range and modal values in the length frequency distribution of skipjack in the commercial catches of Minicoy and Agatti

prominent mode at 360 mm appearing in November of both the years of observation to conclude that they are one year olds.

From the scatter digram (Fig. 1) of range and mode in length frequency distribution of skipjack in the commercial catches of Minicoy and Agatti during the years 1988-89 and 1989-90 the progression of modal sizes of different year-classes were traced. The data when subjected to analysis for growth parameters gave the following values:

$L\infty = 660$ mm $\qquad$ $K = 1.1$ (annual)

according to which skipjack attains average sizes of 440 mm, 587 mm, 636 mm and 652 mm by the end of 1st, 2nd, 3rd and 4th year of their life respectively.

Length-weight relationship

Silas and Pillai (1985 a) estimated length-weight relationship of skipjack using 38 specimens caught by drift nets on board *R. V. Varuna* as follows:

$Y = 0.00000384\ X^{3.41541}$

Madan Mohan and Kunhikoya (1985 c) studied 440 skipjack and estimated length-weight relationship as :

$W = 0.00000155\ L^{3.39301}$

where W is the weight of fish in grams and L, fork length of the fish in mm.

Detailed estimates of catch of skipjack from all islands of Lakshadweep are not available. Varghese (1991) has given tuna catch from this area for the period 1972-86. From 513 tonnes in 1972 the tuna catch rose to 4807 tonnes by 1986 due to mechanisation of crafts and increase in effort. The average annual catch for the period from 1983-'86 amounted to 3938 tonnes. This constitutes 78.72% of the total fish catch from these islands. As the skipjack form the bulk of the tuna catch here, taking their percentage contribution as 75, the annual average catch of skipjack during the period works out to 2987 tonnes.

Appukuttan *et al.* (1977) studied the skipjack fishery of Minicoy for the years from 1966-69. The total annual catch fluctuated from 229 to 523 tonnes in pole and line fishery. Month to month variations in catch was very pronounced. Peak was in March with a minor peak in December. November to March was the peak season.

During the 4 year period from April 1988 to March 1992 the total annual catch of skipjack at Minicoy fluctuated between 422 and 1059 tonnes (Fig. 2). With an annual average catch of 683.5 tonnes it formed 90.99% of the total tuna catch which in turn was 97.9% of the total fish catch here.

98.71% of the catch was contributed by pole and lines. Average monthly pole and line effort and catch of the fish are given in Fig. 3. Catches steadily increase from September to a peak in December. Then it decreases in February and once again goes to another minor peak in March. Pole and line fishery almost comes to a standstill by the middle of May due to monsoon and inaccessibility of lagoon to the mechanised boats employed in fishing. Fishing activity restarts by August or September. The increase and decrease in effort also follow the same pattern of catch except in November-January period when effort reaches a maximum point beyond which it cannot go. Hence, the CPUE also reaches a peak in December. During this peak period the units come back by noon with boat full of skipjack, unload the catch and go again for fishing to return with another boat full of catch in late evening hours.

The sudden drop in catches in February is not always due to non-availability of fish shoal or bait-fishes. Often during this period skipjack do not respond to chumming, a condition also observed by Raju (1964 c) and

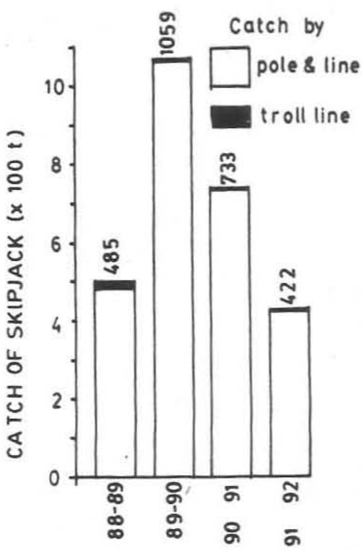

Fig. 2. Total annual catch of skipjack in Minicoy

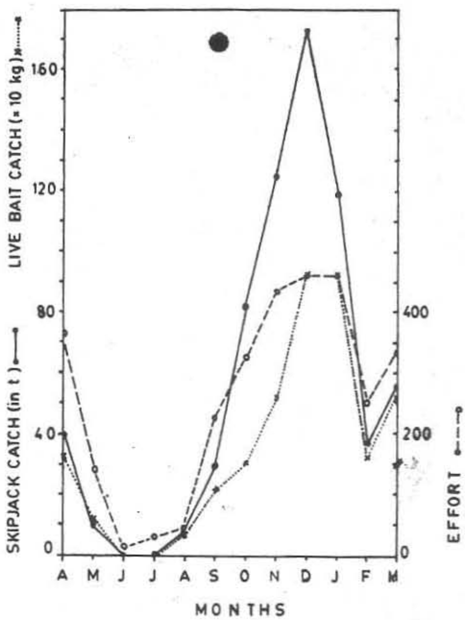

Fig. 3. Average monthly variations in pole and line effort and catch of skipjack and live-baits

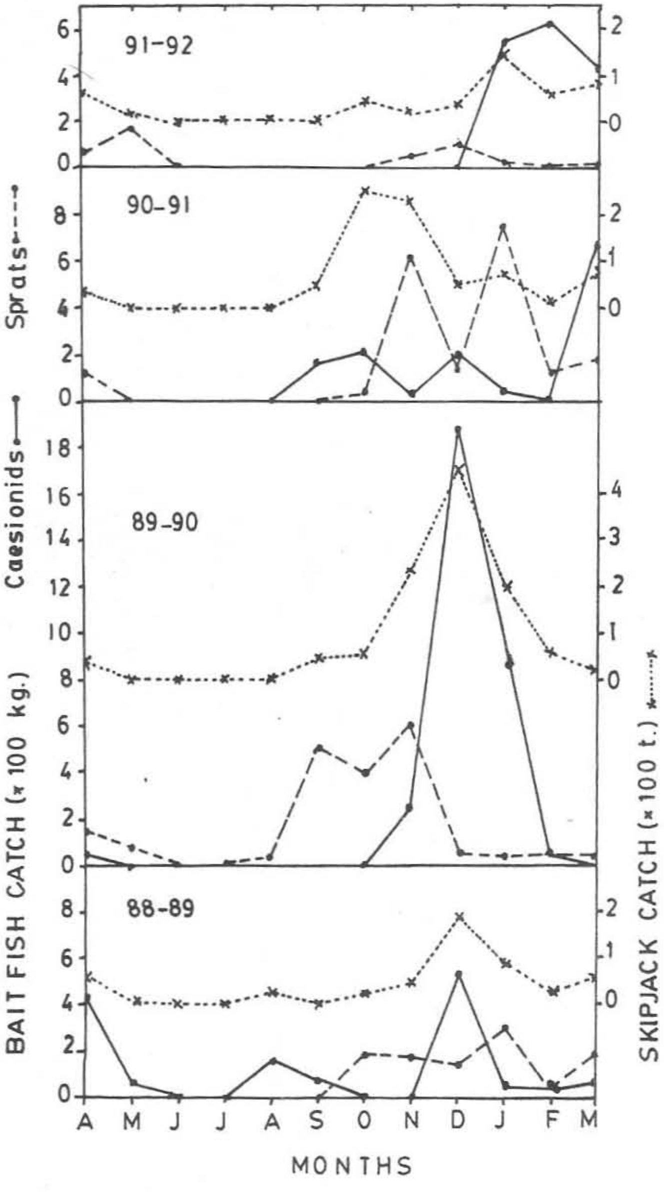

Fig. 4. Monthly variations in skipjack catch and catch of important live-baits during different years

Mathew and Gopakumar (1986). Fig. 3 also shows the monthly variations in the catch of live-baits used for the pole and line fishing which naturally follows the trend of effort and catch.

Year to year variations from this general pattern is shown in Fig. 4. Peak catches in the first two years came in the month of December. But, in third year (1990-91) the peak was in October and in the next year in January. Caesionids and sprats are the two most important groups of bait-fishes used in Minicoy. The figure also shows the variations in the catch of these two groups. It can be seen that peak catch of caesionids almost coincides with the peaks of skipjack catch. Sprats inhabit the lagoon throughout their life, but caesionids are migrant species and their appearance in the lagoon and around the island in large numbers is always followed by abundant skipjack shoals to feed on them. When skipjack is available in the fishing area sprats are considered to be the most efficient bait-fishes. The relation between catch of skipjack and catch of sprats and caesionids used in the pole & line fishery is shown in Fig. 5. It can be seen that the relation is perfect.

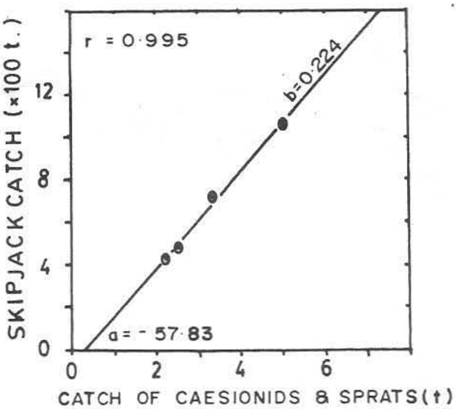

Fig. 5. Relation between catch of important live-baits and skipjack

In Agatti island catches are generally better. In 1988-89 the total skipjack catch here was 2651 tonnes against 485 tonnes landed in Minicoy. In 1989-90, however, the catch was only 1948 tonnes against 1059 tonnes in Minicoy. Fig. 6 shows the comparison of monthly catches from Minicoy and Agatti. In Minicoy peak catches are made in December whereas in Agatti it is in January. Fig. 7 shows the monthly CPUE at Agatti and Minicoy. As in

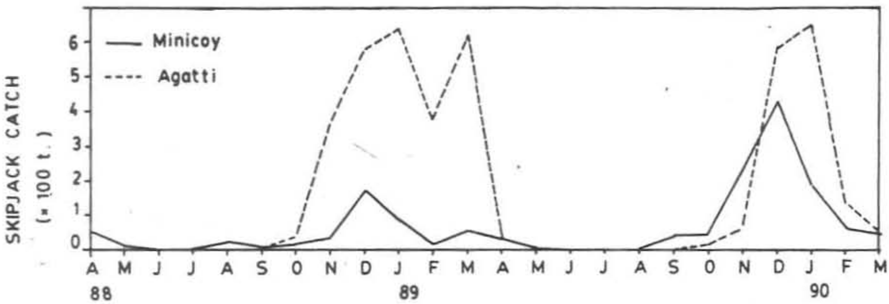

Fig. 6. Comparison between skipjack catch of Minicoy and Agatti

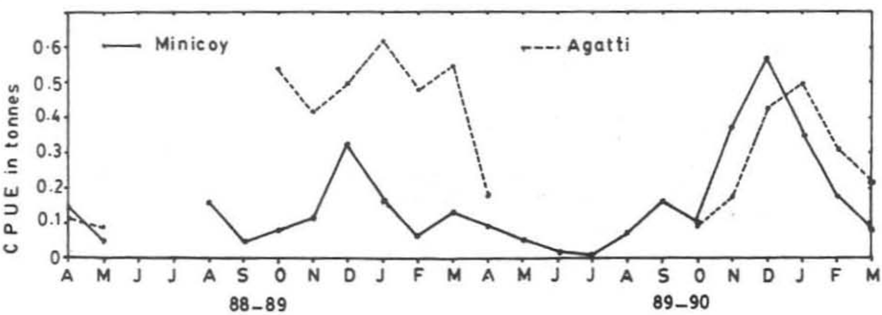

Fig.7. Comparison between CPUE of skipjack in Minicoy and Agatti

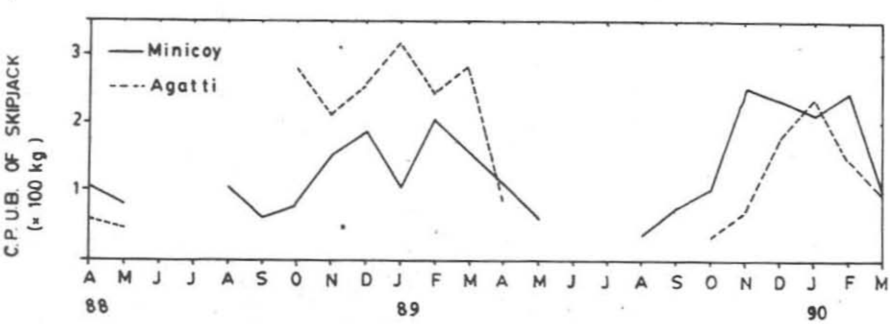

Fig. 8. Comparison between catch per unit bait of skipjack in Minicoy and Agatti

the case of catches CPUE also was maximum in December at Minicoy whereas it was in January at Agatti. Fig. 8 shows the comparison of catch per unit bait (CPUB) at these two centres. In 1988-89 peak CPUB was in December and February in Minicoy, but it was in January and March in Agatti. Thus, the peaks in all these parameters occur early in Minicoy which is the southern most island in Lakshadweep. They occur in Agatti which lies far north, approximately one month later. The fishery was exceptionally better in Agatti in 1988-89, but in 1989-90 the fishery in Minicoy was almost as good as that of Agatti.

Length frequency distribution

Fig. 9 shows the average length frequency distribution of skipjack for the 4 year period from April 1988 to March 1992 at Minicoy and Agatti. In Minicoy the size of the fish ranged from 200-700 mm in fork length. Three

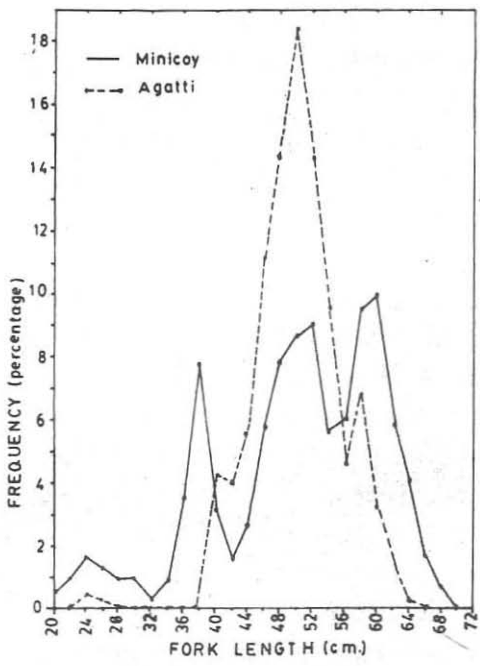

Fig. 9. Average length frequency distribution of skipjack in the commercial catches of Minicoy and Agatti

prominent modes are discernible; first one at 380 mm, the second one at 520 mm and the third and the most prominent at 600 mm. Size groups above 400 mm dominated the catch with a contribution of 75%. In Agatti the size of the fish ranged from 220-660 mm with a dominant mode at 500 mm.

STOCK ESTIMATES

Taking $L\infty$, K and length-weight relationship estimated by Madan Mohan and Kunhikoya (1985 b and 1985 c) Silas *et al.* (1985) estimated the population parameters as follows:

$W\infty = 16.372$ kg $K = 0.4898$ $l_c = 54$ cm

$l_r = 30$ cm $Z = 2.555$

Taking M as 0.75 and F, 1.805 the present rate of exploitation was estimated as 0.71. Yield per recruit studies showed that the MSY will be reached at an exploitation rate of about 0.8 indicating that we have not reached the MSY level and exploitation is not affecting the stock.

James *et al.* (1986) using the same population parameters estimated a lower Z (1.89). With the same M value the present exploitation rate will be 0.6 only increasing the scope for further exploitation.

Taking the present value of $L\infty = 660$ mm and $K = 1.1$, total mortality (Z) was estimated using the length frequency data from Minicoy for the 4 year period from April 1988 to March 1992 by catch curve method given by Pauly (1983). The result is shown in Fig. 10. The Z value (1.176) appears to be an underestimate. The reason can be the shoaling behaviour and migratory nature of the fish as well as the dependance of the fishery to a small area around the island and the limitations of fishing. The most dominant mode in the fishery at Minicoy was at 600 mm size which is very near to the $L\infty$ of the fish. (Pillai and Gopakumar, 1989).

M was estimated independently using the method of Pauly (1983) :

$\log_{10} M = -0.0066 - 0.279 \log_{10} L + 0.6543 \log_{10} K + 0.4634 \log_{10} T$

Taking the average sea water temperature as 28.5^0 C the M estimated was 1.54. As suggested by him (Pauly) in the case of strongly schooling pelagic fishes the M value was multiplied by 0.8 and got a revised M value of 1.23.

From Fig. 9 the length at capture was taken as 380 mm and 520 mm. $W\infty$ was estimated using length-weigtht relationship given by Madan Mohan and

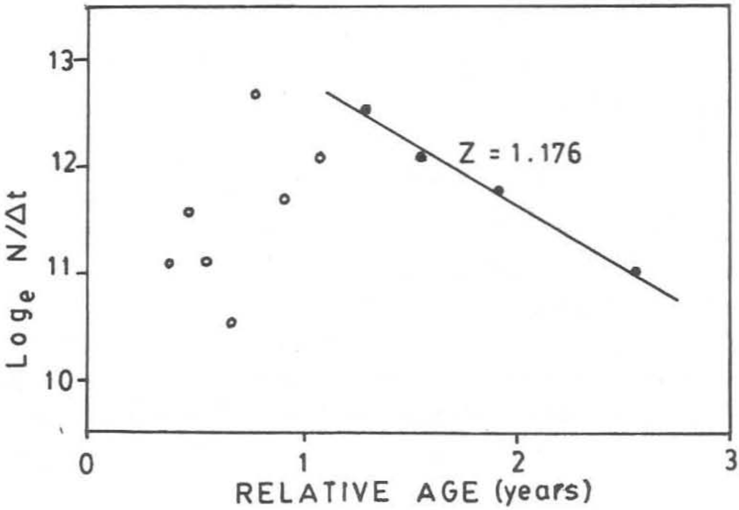

Fig. 10. Estimation of total mortality (Z) of skipjack by catch curve method

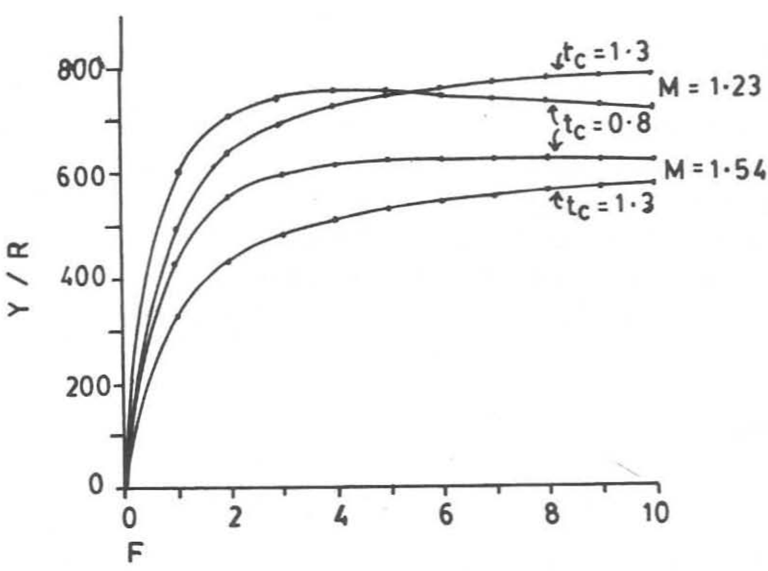

Fig. 11. Yield per recruit estimates of skipjack

Kunhikoya (1985 c). A study of Y/R was made using the following parameters:

$W_\infty = 5715.7$ g $K = 1.1$ $M = 1.54$ and 1.23

$t_c = 0.8$ and 1.23 years $t_r = 0.37$ year

The result is given in Fig. 11. For a value of $t_c = 0.8$ the *Fmax* is at 4 and 6 for values of M, 1.23 and 1.54 respectively. For t_c value of 1.2 *Fmax* is beyond 10.

ENVIRONMENT

Information on the monitoring of the environment of skipjack fishing grounds of Minicoy is given only by Mathew and Gopakumar (1986) who gave the results of studies on the surface temperature, salinity, dissolved oxygen, zooplankton biomass and forage fishes of skipjack, conducted during November to May period of 1985-86. They observed higher secondary production in January and February which was followed by abundance of bait-fishes in March-April, which in turn resulted in abundance of tuna shoals in the area during that period. They also had observed that the abundance of forage can result in negative chumming response.

CONCLUSIONS

Studies so far made indicate that skipjack spawn when they reach a size of about 44 cm in fork length which they reach by the end of first year of their life. At a size beyond 36 cm they appear in the fishing area for forage, abundance of which are controlled by certain environmental factors. Variations in these factors cause variations in the abundance of skipjack shoals in the fishing area from time to time. The period of their peak abundance varies from October to March-April. 75% of the catch is comprised of fishes above the age at first spawning. The total mortality effected by pole and line fishing on the population is negligible and presesnt catch is much below the maximum sustainable yield. The population can withstand heavy fishing mortalities. The present age at first capture can be considered as well above optimum.

INDICATIONS FOR FUTURE RESEARCH

Table 1 gives the annual catch of skipjack from western Indian Ocean by different countries. The total catch in 1988 was 182271 tonnes whereas, it was only 28000 tonnes in 1975-79 period (FAO, 1990). This 6.5 fold increase in

Table 1. Catch of Skipjack from Western Indian Ocean (Unit MT)

Countries	1985	1986	1987	1988
Maldives (%)	42602	45445	42112	58546 (32.12)
Spain (%)	22854	24877	35399	52863 (29.00)
France (%)	33084	40363	41771	37442 (20.54)
Sri Lanka (%)	12118	13737	12896	13398 (7.35)
India (%)	3066	3151	5315	5855 (3.21)
Other countries (%)	11637	8821	11352	14167 (7.77)
Area Total (%)	125361	136394	148845	182271 (100.00)

(from FAO Yearbook)

the catch was the result of purse seining mainly by countries like Spain and France. These countries alongwith Maldives and Sri Lanka take the major portion of skipjack from the area. Still the species is considered as not fully exploited. We are exploiting the resource from a narrow area around Lakshadweep islands and the fishing success is dependant on the movement of skipjack shoals into this fishing area, their response towards bait offered, availability of forage fishes and weather conditions. Hence, our fishery is not of any significance at present to affect the skipjack stock. Though, Silas *et al.* (1985) observed that the present fishing for skipjack in India does not affect the stock, estimates presented by them do not show much scope for development. The exploitation rate to produce the MSY as per their estimate is about 0.8 when the present E is 0.71 according to which increasing the present exploitation rate to 0.8 can greately reduce the profitability of the fishing operations. The present Y/R studies show that the scope for further development of the fishery is much greater.

Skipjack is highly migratory and their availability in the fishing area is controlled by the factors already explained. As observed by Hunter *et al.* (1986) their seasonal movements may be more related to changes in forage availability than to an inherent migrational cycle. Some stocks of skipjack

Table 2. Estimates of the growth parameters (L∞ and K) in skipjack tuna with computed value of Ø' = (log K + 2 log L∞)

Area	L∞ (cm)	K (y^{-1})	Ø'
Hawaii	84.6	1.16	3.92
Hawaii	85.1	0.95	3.84
Eastern tropical Pacific	85.1	0.44	3.50
Hawaii	82.3	0.77	3.72
Pacific Ocean : 10° N 100° W	80.5	0.63	3.61
North of Madagascar	62.3	0.98	3.58
Central Pacific	102.0	0.55	3.76
Hawaii	92.4	0.47	3.60
Eastern Pacific	142.5	0.29	3.77
Eastern Pacific	72.9	0.83	3.64
Eastern Pacific	107.5	0.41	3.68
Eastern Pacific	88.1	0.43	3.52
Papua New Guinea	65.5	0.95	3.61
Papua New Guinea	74.8	0.52	3.46
Papua New Guinea	65.0	0.92	3.59
Philippines (Southern)	84.5	0.51	3.56
Philippines (Southern)	82.5	0.48	3.45
Hawaii	101.1	0.39	3.60
Taiwan	103.6	0.30	3.51
Taiwan	103.8	0.43	3.67
Eastern Pacific	79.1	0.64	3.60
Western Pacific	61.3	1.25	3.67
Eastern Pacific	75.5	0.77	3.64
East tropical Atlantic Ocean	80.0	0.60	3.58
Vanuatu, Western Pacific (1)	60.0	0.75	3.43
Vanuatu, Western Pacific (2)	62.0	1.10	3.63
Lakshadweep (India)	66.0	1.10	3.68 (Present study)

appear to be more nomadic than migratory (ICCAT, 1984). Hence, mortality rates estimated based on data collected from Minicoy will have its limitations. For better estimates of mortality data from more areas of its distribution will have to be collected. More data from some important northern islands in Lakshadweep may improve our estimates. Moreover, we do not know whether we are fishing on same stock on which Maldives, Spain, France and Sri Lanka fish on. Regional co-operation with these countries in studying the population dynamics and stocks of skipjack will be necessary while attempting any major development in its fishery.

Intensive collection of data on the fish of sizes below 30 cm and studying the progression of their modal values so that it can be extrapolated to length 0 with confidence will prove the period of peak spawning, the size at age and age at first maturity with accuracy.

Studies on the environment of tuna fishing grounds need more attention. Peak availability of skipjack normally coincides with peak availability of bait-fishes which might have been caused by abundance of zooplankton in the fishing area. The factors which cause this with variations in time during different years have to be studied in detail. Upwelling is reported in Minicoy waters during the month of November-December (Rao, *et al.*, 1966). Monitoring of the environment of the area of fishing for some years will throw more light on factors affecting the changes in abundance of skipjack.

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