Bull. Fish. Res. Stn., Ceylon. Vol. 21, No. 1, pp. 7–16 June, 1970.

Biology of the Exploited Stock of Mackerel Tuna *E. affinis* (Cantor) off the South-West Region of Ceylon

K. Sivasubramaniam *

INTRODUCTION

According to the statistical data published annually in the Administration Report of the Director of Fisheries, the bloodfish production in 1967–68 showed about 100% increase over a period of five years and the production figures for none of the other groups of fishes have exhibited a parallel to this. Furthermore, the bloodfish group ranks first in the order of production, having displaced the herring and sardine group which had been in the lead for over a decade. This indicates that increasing attention is being directed on the production of this group of fishes, in the coastal waters of Ceylon.

Observations over the last seven years show that the fishery along the South-West region of Ceylon has undergone and is contining to undergo drastic changes. A change occurred about a decade ago with the introduction of the mechanisation scheme. The present change due to the introduction and increasing popularity of Drift Nets (over 4″ mesh size), commenced about the middle of 1967. Pole and Line method which had been traditionally with the fishermen of the South for over forty years and Tuna longlining are declining due to the popularity of the Drift Nets on one hand and due to the bait problems on the other. The most widely applied method of trolling is also declining but relatively less rapidly due to the fact that it is still the most economical gear operated for bloodfish by Ceylonese fishermen. In the recent past, we have had a number of fishing disputes and most of them were due to the introduction of Drift Nets (over 4″ mesh) but today this method is being adopted at such a rapid rate that problems of improportionate distribution of effort, fishing intensity and interactive fishing have to be anticipated.

Major contributions to the bloodfish production are made by the four species ; yellow fin tuna (*T. albacares*) (Bonnaterre) skipjack tuna (*Katsuwonus pelamis*) (L.) mackerel tuna and narrow corseletted frigrate mackerel (*Auxis thazard*) (Lacepede) Minor contributions are made by Big eye tuna (*T. obesus*) (Lowe) broad corseletted frigate mackerel (*A. rochei*) (Risso) and oriental bonito (*Sarda orientalis*) (Temminck and Scheegel). The four main varieties are found in almost all the coastal regions of Ceylon. The south-west region has been selected for the present study because of the fact that there is a very heavy concentration of fishing effort on this group, and also because of the radical changes in the distribution of fishing effort in this region. However, mackerel tuna forms the least precentage composition of the four species exploited from this region of the coastal waters.

Source of material for analysis

In this region, about 1,100 mechanised boats of the 3½ ton class and about 20 mechanised vessels of the 11-T class and an unknown number of traditional crafts (outrigger canoes) are engaged in the coastal fishery with their effort directed mainly through gears suitable for bloodfish. The 3½ T boats operate drift nets (20–30 pieces 4″–6″ mesh) trolling lines (2 or 3 lines, 30 jigs on each sometimes one baited hook), pole and line (4–5 poles) and Tuna longline (60–100 hooks). The 11-T vessels in this region operate only drift nets (about 40 pieces 4″–5½″ mesh). Traditional crafts operate trolling lines and pole and line for bloodfish but they often carry out handling for other varieties or even prawn trawling. The data of these traditional craft have not been included in the present analysis.

* Fisheries Research Station, P. O. Box 531, Colombo, Ceylon.

The 3½-T boats conduct mixed operations even within a single season but off the west coast longlining is generally restricted to the period December to March/April. The traditional crafts and 3½-T mechanised boat fishermen unload their catches along the coastline, in close proximity to their residences, whereas the 11-T vessels operate from four stations in this region. The drift nets are operated at night, the trolling lines are operated often in the early hous of the morning and even in mid-daylight, longlining generally covers part night and part day. The landings by drift net boats are between 5 a.m.–10 a.m. troll line catches are landed between 11 a.m.–3 p.m. long line catches are unloaded between 12 noon–4 p.m.

Sampling Methods

Based on the differences in the composition of catches among the different areas observed during the preliminary studies by the author (1965, 1967, 1968) the South West region has been divided into four areas. The length of coast line, distribution of fishing boats and catch composition were taken into consideration in defining the four areas. The areas are " North West " between 8° 30′ and 7° 30′N; " West " between 7° 30′ and 6° 30′N; " South West " between 6° 30′N, and 80° 15′E and the " South " between 80° 15′E and 81° 15′E. Five landing points for the 3½-T boats and one landing point for the 11-T boat were selected within each area and six days of sampling carried out each month. Though there could be loss of precision because of probable correlation between landings on successive days, samplings were conducted successively for three days around the full moon period and the other three days around the new moon period. All samplings were further stratified by class of boats, gear and season. Nominal catch statistics were not used. In spite of several practical difficulties, sampling was carried out when the fishes were being unloaded from the boats. The system of handling and distribution of fish in Ceylon is such that bias is introduced at every stage and by the time the fish researches the market the bias introduced cannot be corrected.

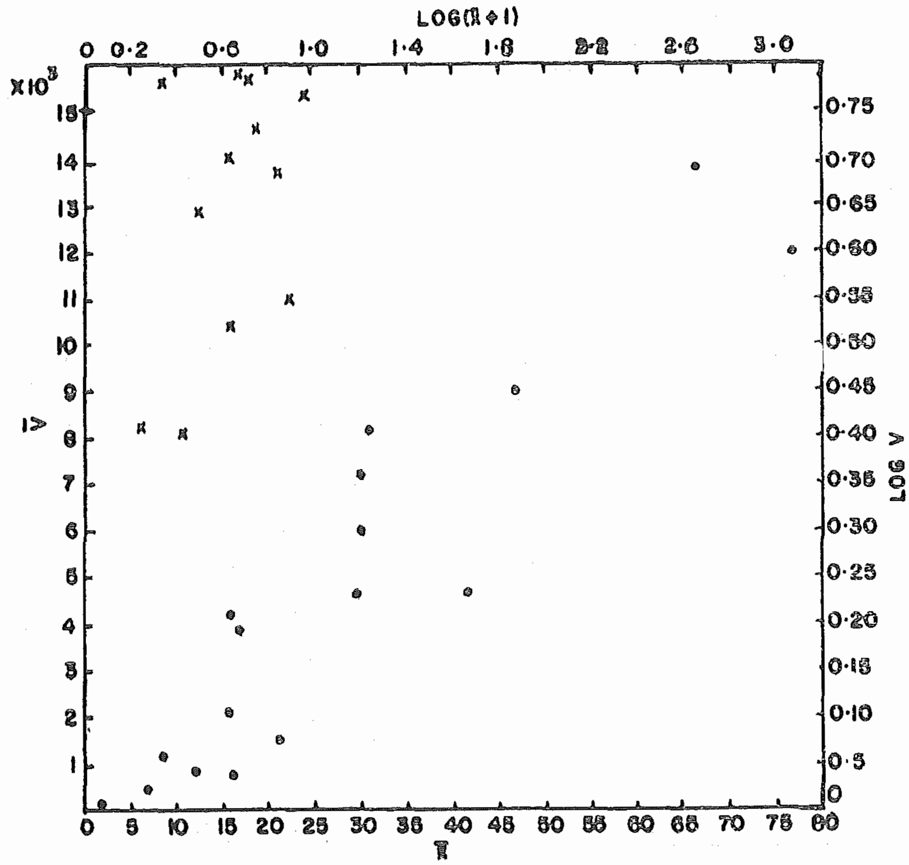

Fig. 1.—Mean—Variance correlation. X is for transformed data.

Statistical Analysis

The length frequency distribution was plotted for each month, to determine size composition of the catch, size at first entry and migratory pattern. The catch rates for all fishing gears and types of boats were determined as the catch in pounds per operation or per trip not exceeding 24 hours. The catch rates do not fit a normal distribution and correlation between mean and variance exists (Fig. 1). The logarithmic transformation $y=(\log(x+1))$ reduced this relationship (Fig. 1). The mean catch rates have been used as an index of abundance. The distribution of effort by gear and by area was estimated from the numbers of boats operating each type of gear, at the sampling stations, on the sampling days.

TABLE I

Percentage Composition for the Blood Fish Group of Fishes and effort (percentage by gear) in the South-West Region

Area	*Period*	*Species %*				*Gear %*			
		Yellow-Fin	*Skipjack*	*M. Tuna*	*F. Mackerel*	*Troll*	*Drift Net*	*Pole & Line*	*Long Line*
North-West	1963—1967	6.9	6.3	60.4	26.3	60.2	20.1	0	19.7
	1968—1970	55.2	39.8	3.2	1.8	15.6	82.4	0	2.0 (Madel)
West	1963—1967	23.4	33.8	37.5	5.3	68.4	11.3	0	20.3
	1968—1970	26.7	59.9	10.9	2.4	16.2	76.6	0	8.2
South-West	1963—1967	6.0	54.6	26.2	13.1	70.3	2.1	21.5	6.1
	1968—1970	18.8	68.6	4.9	7.6	35.0	45.9	9.1	10.0
South	1963—1967	32.1	34.3	7.3	26.2	61.5	0.5	29.7	8.3
	1968—1970	20.2	55.1	3.2	21.4	24.4	70.6	4.5	0.5
South-West Region	1963—1967	12.3	43.8	20.1	23.8	66.5	4.5	18.0	11.0
	1968—1970	30.6	55.3	6.6	7.5	22.1	67.2	3.3	7.3

The analysis of variance method was applied to evaluate the variability within areas, between areas and significant differences in mean values among strata (Appendix). The yield values were estimated according to Gulland (1966).

Co-occurrence and Mixed Fishery

In the coastal waters of Ceylon young yellow-fin, skipjacks, mackerel tuna and frigate mackerels co-occur and hence no attempt is made to direct fishing effort on any specific member of this group. The catches are almost always mixed and the number of varieties in a catch varies inversely as the average fork length of the whole school or aggregate. This aspect has been dealt at length elsewhere (Sivasubramaniam 1968).

Table 1 illustrates clearly the percentage composition of the four main species as occurring in the landings in the four areas. A heavy shift in the fishing effort into drift net fishing for blood fish has brought about drastic changes in the percentage species compositions as shown in the Table. The changes in the distribution of effort in all four areas are also given in the same table. Very interesting changes and new facts have become evident as a result of the changes in the distribution of fishing effort, especially in the cases of yellow-fin and skipjack tuna, which will be discussed in the paper to follow.

Size Composition and Selectivity of the Gears

Commercially exploited size range for the mackerel tuna from this region is 20 cm. to 65 cm. Occasionally 15–20 cm. and 65–68 cm. size group have also been exploited. The length frequency distribution with monthly stratifications for three areas are given in Figure 2. The " North West " is not shown because of the very poor catches and poor sampling from this area. No radical changes in the size range exploited was envisaged due to the changes in the distrubition of effort because trolling method which samples a very wide range of size, continues to be applied in this region.

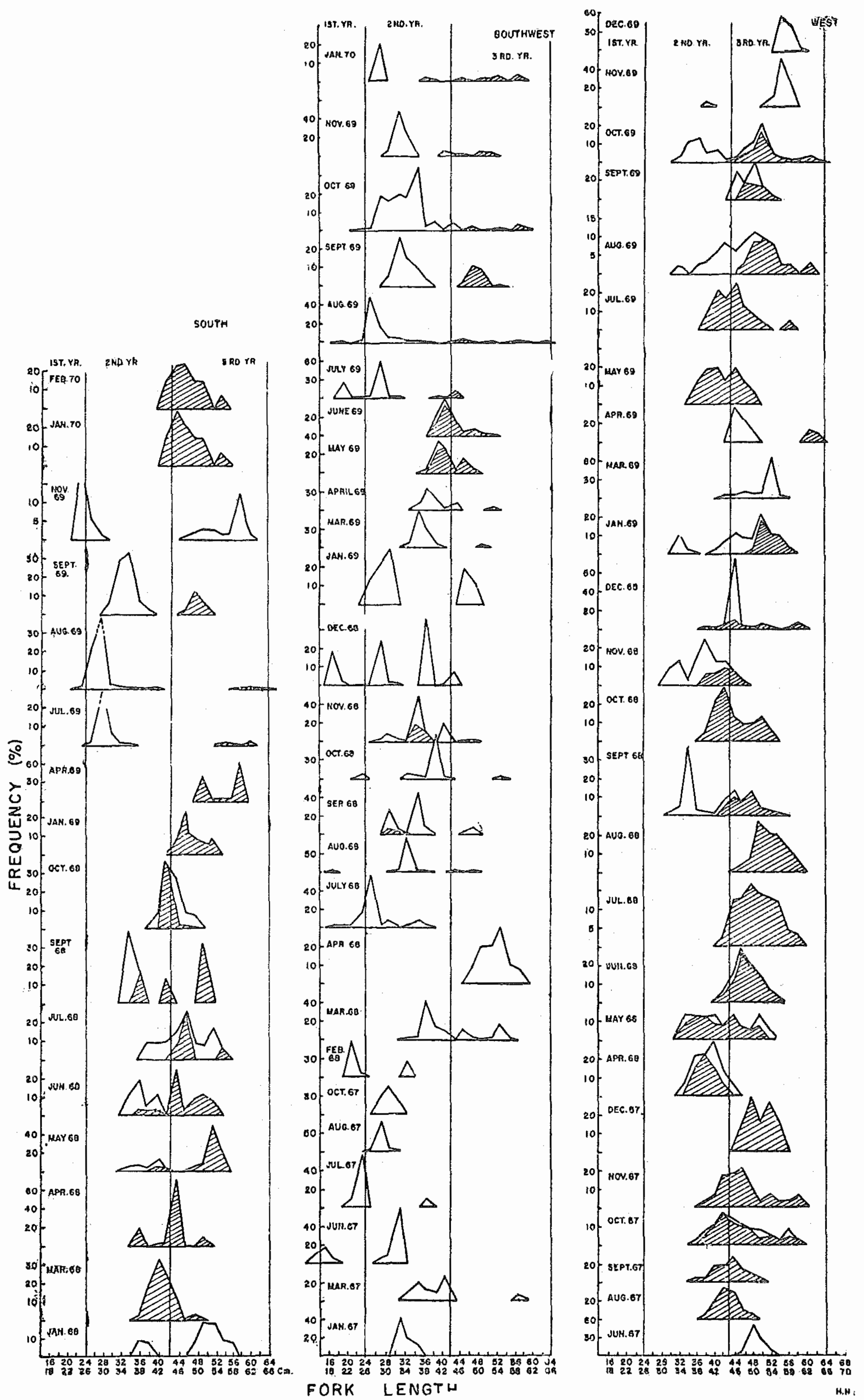

Fig. 2.—Monthly length-frequency distributions for mackerel tuna. (Striped area for drift nets and other for troll catches)

However, small sized mackerel tuna groups appear more frequently in surface schools than the older fish as evident from the troll and drift net catches. Hence the length frequency samplings with trolling lines during preliminary studies have contributed to an over-estimation of the proportion of smaller sizes of mackerel tuna in the stock (Fig. 3).

The pole and line method is very selective because of the highly limited seasons of operations and mainly due to the reason that this method is directed at the surface schools of skipjack. Hence mackerel tune of narrow size range associated with the skipjack (40–55 cm.) at or near the surface becomes vulnerable. The drift net is a highly selective gear but in Ceylon, a fairly wide range of mesh sizes (4″–6″) are used by mechanised boats probably so that the gear would be effective for the smaller frigate mackerels, mackerel tuna, skipjack and medium sized yellow-fin. This results in the exploitation of a fairly wide size range of mackerel tuna by this method (Fig. 3). The selective power of the tuna longline in relation to both size and behaviour eliminates mackerel tuna from the catches. " Nearly all marine sampling instruments are biased and sample representatively only a small proportion of the true population " (Gulland, 1966). As such trolling lines and drift nets may be considered suitable sampling gears and these two methods are applied in all four areas.

Age determination in the case of mackerel tuna has not been confirmed and for the present the age-size relationship suggested by Wheeler and Ommanney (1953) has been adopted and are indicated in Fig. 2. It could be said that juveniles, first year and early second year, groups are exploited almost

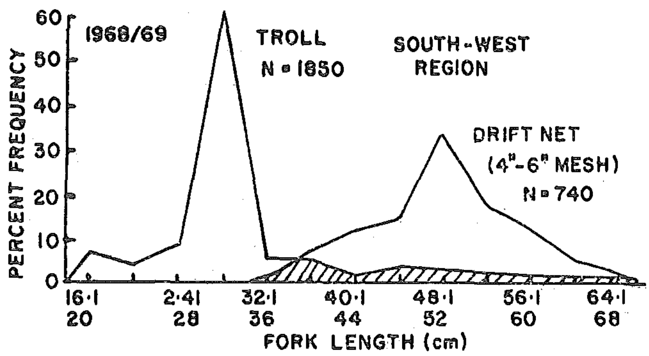

Fig. 3.—Length frequency distributions for mackerel tuna caught by drift nets and troll lines, in the South-west region.

entirely by the troll fishery and the advanced second year and third year groups are mainly exploited by the drift net fishery and partly by the troll fishery. Occasional catches of the fourth year group have been made by drift nets.

Size composition by area indicates that in the " South West " the catches consist of first year and very large percentage of second year fish ; in the West and even North-West, the catches show a fair amount of the advanced second year and a large percentage of third year fish and in the " South " it is almost equal quantities of the second year and third year fish with a very small percentage of the first year fish occurring occasionally.

Initial entry or the first entry is to the troll fishery and it occurs in the " South West " between June and July every year, and to a smaller degree during the period November to February. Other than these young fish may be entering irregularly and at insignificant levels, throughout the year. During certain years, first year group have been observed in the South too but considering the time of occurrence and the irregularity, it is conjectured that these recruits are also part of the normal recruitment to the " South West " but overcarried into the " South ".

Seasonal Occurrences and Migratory Trends

The monthly mean catch rates for the last two years estimated independently for the troll and Drift net fishery on an area basis, is given in Fig. 4. In any one of these four areas the pattern of seasonal variations in the mean catch rates derived for troll fishery and that for drift net fishery

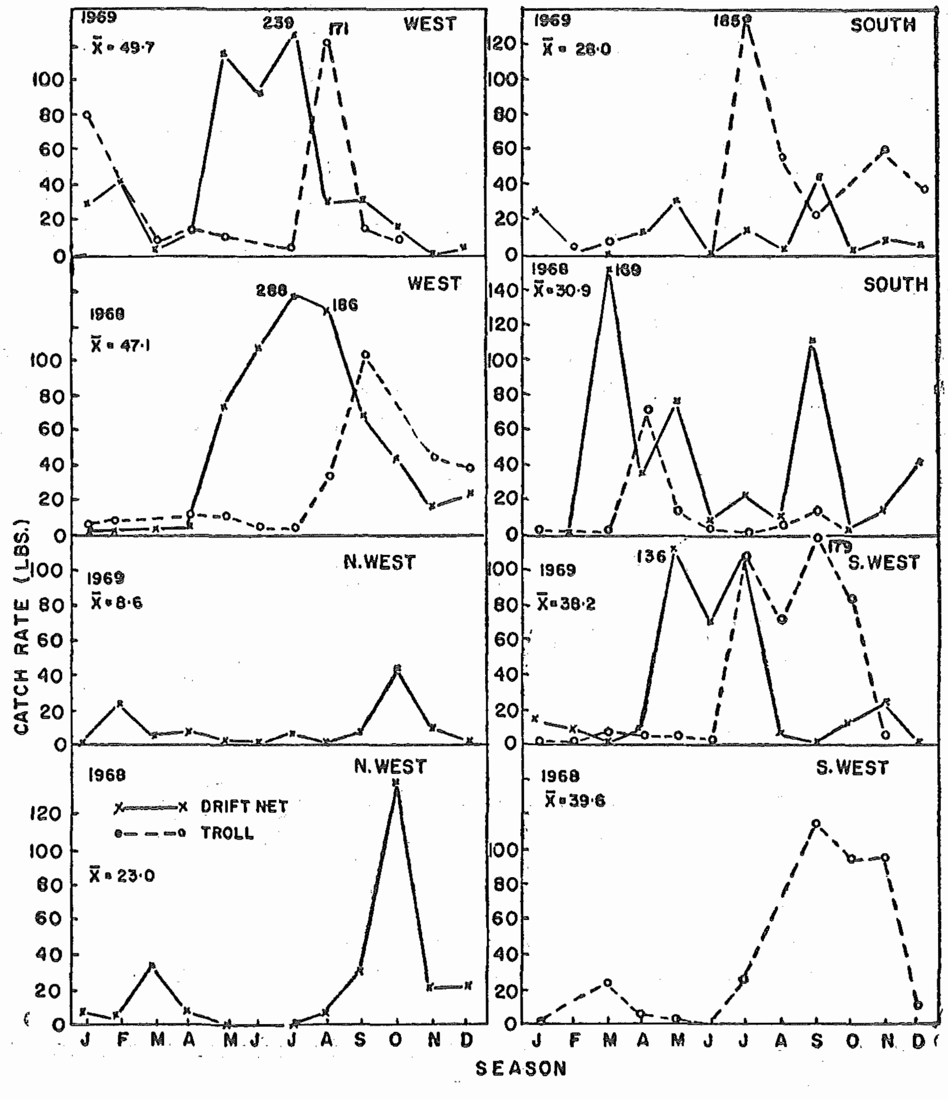

Fig. 4.—Seasonal variations in the occurrence of mackerel tuna (X is the mean of seasonal mean catch rates for the area).

cannot be super-imposed because of the obvious reason that their selective powers are higher for two different size ranges (Fig. 3). Study of figure 3 and 4 together will show that the peak catch rates for both types of fishing coincides with the entry of the vulnerable size groups into the area. In the " South West " troll catches will show two peak seasons, January to March and July to September, when the two recognisable entry of juveniles and young fish occurs. Drift net catch rate shows a peak season between May and July when second year group and a small quantity of the third year group occur in this area. In the " South " the pattern is not very clear but it seems that in the first quarter and latter part of the third quarters of the year advanced second year fish and third year fish occur respectively. Troll catch rates show peaks in the early part of the second, third quarters and even the fourth quarter. This probably is due to double entry produced by direct entry of juveniles and first years, as mentioned earlier and indirectly through the " South West " area. In the " West " drift net catch rates show high mean catch rates between April and July due to occurrence relatively of heavy concentration of advanced second year and even third year fish, This is followed by the successful troll catches in August/September when the second year fish enter this area, probably from the " South West ". In the " North West " catch rates are extremely poor during the greater part of the year, except two short drift net seasons—February to March and around October. The latter season shows a high mean catch rate comparable with those of other areas and is composed almost entirely of the second year fish and during the former season mostly third year or advanced second year occur. It has to be confirmed whether some of the second year entering " West " during August/September move into " North West " in October, and return in February or March to show up in the " West " during the peak season in April.

Thus the seasonal changes in the length frequencies (Fig. 2) and the seasonal changes in the occurrences (Fig. 4) for the four areas appear to indicate the migratory trends of the mackerel tuna in the South West region. Juveniles, 1st year and early second year fish enters the coastal fishing area in the " South West " Area. Sometimes these first entry group may be over-carried into the " South ". The second year fish probably moves northwards into the " West " and eastwards into the " South " areas. As mentioned earlier, mixing up of the direct and indirect recruits into the " South " reduces the clarity of the situation of length frequency distribution of the " South ". It also appears from the mean catch rates for each area, that entry of mackerel tuna into the " South ". may be of a lesser strength than that entering the " West ". Considering the continuity of the size group pattern between the " West " and " North West " and the fact that annual mean catch rate for " North West " is extremely poor compared to that of the " West " one is forced to consider whether the distribution of the mackerel tuna stock in the South West region does not extend very much beyond the " West ". Similar condition appearing at the easternmost boundary of the " South " also needs confirmation. Though detailed investigation of the gonad index has not been commenced yet, general observations indicate that this species matures around 45–50 cm. length sizes (end of second year). The point of spawning will have to be determined.

Length-Weight relationship studies on the species showed a statistically significant heterogeneity among the regression coefficients for the areas of this region (Sivasubramaniam 1968). As evident from the present studies, the mackerel tuna of this region probably belong to a single stock and the heterogeneity obtained must have been due to the anomaly caused by the differences in the size ranges sampled from the four areas, as suspected earlier.

Catch Variability and Index of Abundance

The catch rates of mackerel tuna from this region show a very high variability due to its schooling behaviour and seasonal changes in their occurrence, and also exhibit a definite correlation between the mean and the variance (Fig. 1). Hence analysis of variability was carried out on an area basis, further stratified by gear and boat types, using logarithmically transformed data (Fig. 1).

Attempt was made to reduce the variability within area by stratifying the samplings by gear, craft and season and at the same time the analysis of variance method was applied to determine any significance in the differences among the mean values between strata. The mean catch rates for drift net fishery by the 3-Ton class and the 11-Ton class showed no statistically significant differences. Though the value for 11-Ton class appeared to be slightly higher than that for the 3-Ton class, standardisation of the effort by the classes of boats would have shown a lower mean catch rate for the 11-Ton class because they generally use greater number of pieces of net than the 3½ Ton class This, however, could not be carried out because the number of pieces used for the 11-Ton class appeared to vary day to day as a result of damage or loss during operation and inconsistancy in the number pieces within the class itself. Relatively poor performance by the 11-Ton class in relation to the mackerele tuna catches may be attributed to the reasons that this class of boats operated rift nets throughout the year and show a very high frequency of zero mackerel tuna catch whereas the 3-Ton class alternate the operation of drift nets and trolling lines even within a season, to suit the fishing conditions prevailing and hence show lesser freauency of zero catch rate. Statistical analysis of the length frequencies of the mackerel tuna caught by both classes of boats operating drift nets show no differences, indicating that they are both sampling the same population. The fact that 11-Ton ted to fish in areas beyond those covered by the 3-Ton class may result in the

11-Ton class exploiting the mackerel tuna stock to a lesser degree. This is supported by the fact that comparatively much better results shown by the 11-Ton boats, in the cases of skipjack and yellow-fin catches during the same operations. The drift nets used by 11-Ton class of vessels appear to be constructed with a relatively greater emphasis on the exploitation of skipjack and yellow-fin.

The annual mean catch rates for trolling lines was found to be significantly higher than those for drift nets, within "South West" and "West". In the "South" the mean values did not show such a significant difference probably because of the relatively very low mean catch rates for all methods of operation (Fig. 5). Such an anaylsis could not be carried out for the "North West" area because of the poor number of samplings of troll catches.

Generally, drift net has been acclaimed a more effective gear than trolling lines, for blood fish. Though the annual mean catch rates tend to be low, seasonal mean catch rates show relatively much higher value for drift nets (Fig. 4). Unlike the drift net operation, trolling lines are operated as an active gear at or near the surface and its effort directed on schools that can be located. From the size frequencies exploited by trolling lines and drift nets, the variability of the mean catch rates and the frequency of occurrence of zero catches, it is evident that the young mackerel tuna form surface schools more often than the older fish.

Figure 3 shows that trolling method samples the widest size range of the mackerel tuna population in this region, than the drift nets in use. However, its selective power appears to be very high for the young ones under two years for the reason discussed just above. The mesh size of the drift nets in use have a higher selective power for the third year group which are also caught by the trolling lines, when they form surface schools. It means that the frequency of forming surface schools decline with increase of size or age and the older fish becoming less vulnerable to the troll fishery becomes vulnerable to the drift net fishery.

Differences in the mean catch rates between areas were determined separately for the Drift net and troll catches. These values for both types of fishing methods showed highly significant differences between areas, even when the values for the " North West " area which show the lowest mean catch rate, was eliminated from the analysis. The highest value was shown by the area " West " followed by " South West ", " South " and " North West " (See Fig. 5 for mean values). Perhaps this should have been anticipated because of the fact that there are differences in the size composition between areas and the bias in the two instruments of sampling will contribute to significant difference.

It was also noted from the drift net operations during 1968/69, 0·5% of that in the " West " and 0·2% of those in the " South " as well as " North West " showed catch rates of over one thousand pounds, whereas it was zero percent for the " South West."

The trolling lines as a sampling unit shows a higher annual mean catch rate and also exhibits a relatively lower selective power by sampling a wider size range (Fig. 3) as against the drift net which proves its efficiency in obtaining a very much higher seasonal mean catch rate than trolling lines (Fig. 4). Though such differences exist, the relative differences in the mean catch rates for the four areas are similar whether we consider the values derived from Drift net or trolling line operation (Fig. 5). The annual mean catch rates obtained from the total catch and total effort could serve as indices of relative densities of distribution in the four areas. But the occurrence of mackerel tuna in each area is highly seasonal and there is a tendency for the mean catch rates to approach an equally high value in each area during one season or another. Hence it is considered that a mean of seasonal mean catch rates for each area (Fig. 4).would be better indices of the relative densities of distribution in the four areas. In turn, a mean of these mean values for the four areas could be used as an index of apparent abundance for the mackerel tuna stock in this region (35.3 for 1968 and 31.1 for 1969). The mean value obtained for the " South West " area (Fig. 4) could serve to evaluate annual fluctuation in the strength of the first entry group. Considering the life span of the mackerel tuna in this region any changes in the stock due to the fishery will become evident within a short period of two years.

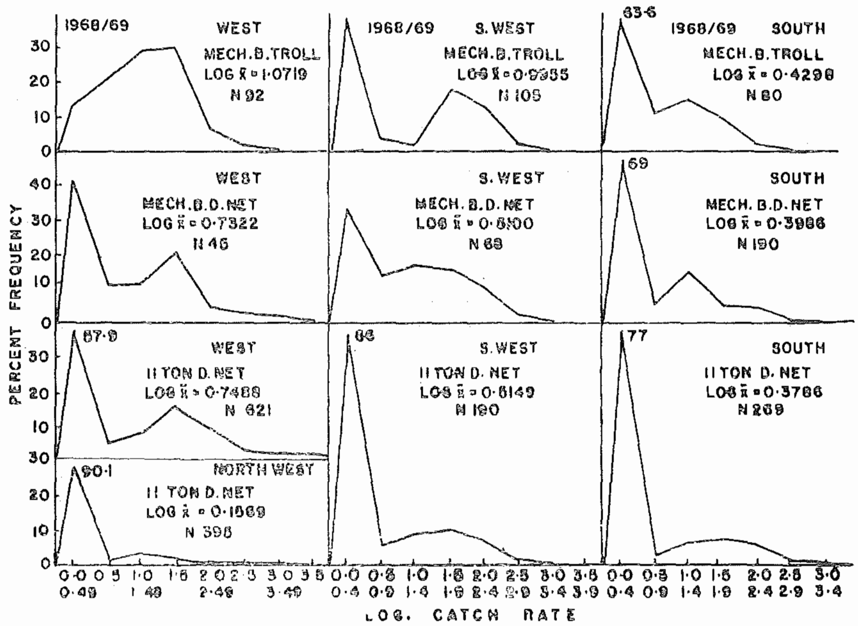

Fig. 5.—Frequency distributions of logarithmic catch rates, by area and by gear.

Yield Trends

It is estimated that approximately a little over 600 tons of mackerel tuna were produced from this region in 1969, by mechanised boats. The contribution by non-mechanised crafts could not be estimated.

It is expected that there would be large annual fluctuation in catch resulting directly from the variations in the extent of exploitation of first entry group. In the case of mackerel tuna evidence shows that there is some differential distribution by size categories and it may be possible to alter the size at first capture by avoiding the areas of small fish. If this were possible, then it might be expected that the total yield would increase considerably. In the present context, suspension of troll fishery in the " South West " at least between June and September would conriderably increase the annual yield through drift net fishery.

At present there is a tendency to reduce drift net mesh size range from 4″–6″ to 5″–6″, especially among the 11-Ton class of vessels. This clearly shows the preferential shifting in the fishery for the relatively larger members like skipjacks, yellow-fin and marlin and will result in the reduction of the catch rates for members like mackerel tuna and frigate mackerel. This trend will again cause changes in percentage composition of species and add to the problems of unbalanced exploitation of the coastal resources of the South West region and other regions as well.

REFERENCES

Bailey, N. T. J., 1959 Statistical Methods in Biology. English Univ. Press. Lond.

Francis, William, 1962 Synipsis of Biological data on little tuna E. Affinis Cantor. World Sc. Meeting on Biol Tuna and related sp. La jolla, Sp. Synop. 5.

Gulland, J. A. 1966 Manual of Sampling and Statistical Methods for Fisheries Biology. F. A. O. Manuals in Fish. Sci. No. 3.

Sivasubramaniam 1965 Exploitation of tuna in Ceylon Waters. Bull. Fish. Res. St. Vol. 18 No. 2.

1967 Distribution and length-weight relationship of tuna and tuna like fishes around Ceylon. Bull. Fish. Res. St. Vol. 19 No. 1 and 2.

1968 Co-occurrence and relative abundance of narrow and broad corseletted frigate mackerels (A. thazard and A. rochei) in Ceylon waters. Symp. Living Resources of Seas around India. Cochin Dec. 1968.

WheelerJ, F. G. and Ommanney F. D. 1953 Report on the Mauritius p Seychelles Fisheries Survey 1948–49. Fish. Publ. (3) 120–145

M. S. received June, 5, 1970

APPENDIX

Analysis of Variance

I WITHIN AREAS

(a) BETWEEN CLASSES OF VESSELS

(11–Ton and 3½–Ton Vessels)

(1) *West*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	1	.0107	.0107	
Residual	664	584.7406	0.8806	0.0012
Total	665	584.7299		

(2) *South West*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	1	.00036	.00036	
Residual	204	131.51742	0.6446	0.0005
Total	205	131.5178		

(3) *South*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	1	0.0448	0.0448	
Residual	457	231.1931	0.5058	0.088
Total	458	231.2379		

(b) BETWEEN GEARS

(Troll, Drift Nets—11–T and Drift Nets—3T)

(1) *West*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	2	8.5094	4.254	
Residual	755	629.8364	0.8342	5.10**
Total	757	638.3458		

(2) *South West*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	2	16.0954	8.0477	
Residual	308	126.4254	0.4104	19.6**
Total	310	142.5208		

(3) *South*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	2	0.1353	0.0676	
Residual	511	253.4759	0.4960	0.136
Total	513	253.6112		

II BETWEEN AREAS
(West, South West and South)

(1) *11–T Catch*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	2	28.0533	14.026	
Residual	1077	822.3078	0.7635	18.3**
Total	1079	850.3601		

(2) *Troll Catch*

	DF	*SS*	*MS*	*Var. Ratio*
Varieties	2	15.8344	7.9670	
Residual	249	148.2686	0.5954	13.38**
Total	251	164.1030		