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Wadge Bank Trawl Fishery Studies

Part V. Rational exploitation of the resident demersal stock

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INTRODUCTION

The general history of the trawl fishery of the Wadge Bank off Cape Commorin, South India (Fig. 1), the nature and composition of its demersal fish population, and the present state of its fishery has been given by various authors (Malpas 1926, Pearson and Malpas 1926, Sivalingam and Medcof 1957, Medcof 1963, Mendis 1965*a*, 1965*b*, Sivalingam 1966*a*, 1966*b*, 1969*a* and 1969*b*).

It has been shown earlier (Sivalingam and Medcof 1957, Sivalingam 1969*a*) that the Wadge Bank stock is made up of two groups. The resident stock which is present on the fishing grounds throughout the year and the migrant stock that appears on the fishing grounds only during the southwest monsoon months. The object of this paper is to discuss the effect of fishing on the resident stock between 1945 and 1962 and based on the information available, assess the maximum sustained yield of the resident stock.

The " Bigfish " of the resident stock is the mainstay of the Wadge Bank trawl fishery (Sivalingam 1969*a*) and it will be shown that this stock has been overexploited from 1953 to 1957. The first sign of recovery was evident in 1960 and continued till 1962. The data since 1962 are not available to the author for analysis. It has been reported by Mendis (1965*b*) that considerable expansion of the trawler fleet was anticipated in 1966, and if so, the history of the fishery from 1953 to 1957 may be repeated.

The assessment presented in this paper should form a rational basis for management programs.

ACKNOWLEDGEMENTS

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DATA

The 1945–1962 records of the Wadge Bank trawl fishery (Sivalingam and Medcof 1957, Sivalingam 1966*b*) are unusually detailed and afford many advantages for analysis. During this period practically all the trawlers that operated on the Bank were from one country (Ceylon). The operation of the main fishery was government-sponsored and hence there was no reluctance on any one's part to record accurate data. In addition to the above advantages, the trawlers were few, of more or less similar size and power and all used the same type of gear, thus reducing complications regarding standardization of effort. Further, unloading was always in one port which helped in the maintenance of proper records.

On the few occasions (1947, 1961 and 1962) when private trawlers did operate, they landed their catch in Colombo, where the Government trawlers were based. Of these private trawlers it has been possible to obtain information on total landings (i.e. all species) of " Aringa " which operated in 1947. The weight of the resident species landed by " Aringa " has been estimated on the assumption that the percentage of the resident species in the total landings was the same for both " Aringa "

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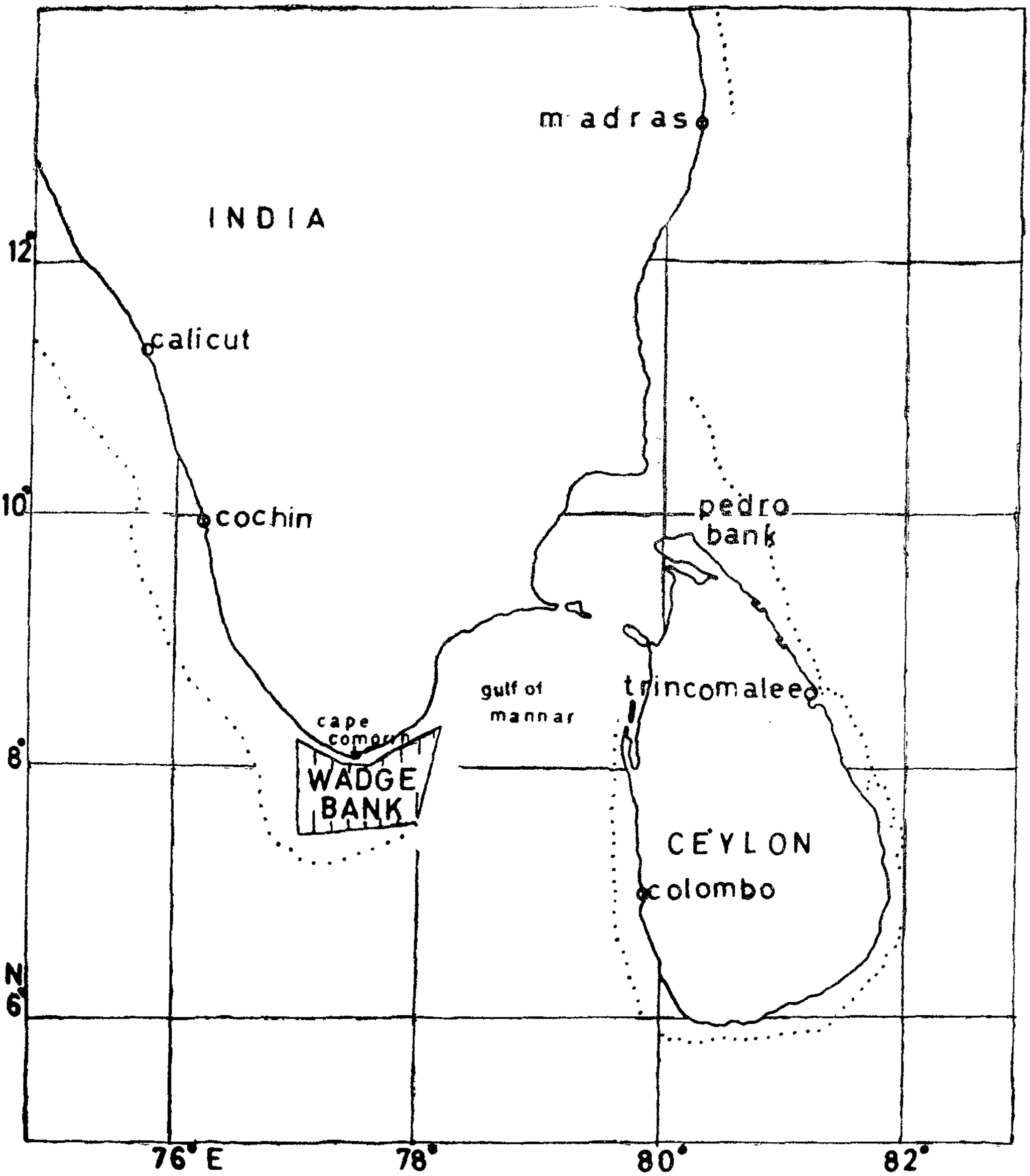

Fig. 1. Parts of the Indian Ocean to show relative position of Wadge Bank and adjoining areas. One hundred fathom contour indicated by dotted line. (Ex. British Admiralty Chart No. 70.)

and " Raglan Castle." The percentage for " Raglan Castle " is known. The total effort for " Aringa " on the " Braconglen " standard has been estimated by dividing the total catch landed by " Aringa " by her catch per unit effort (c. p. e.). It has already been shown that the c. p. e. of " Aringa " and " Raglan Castle " are the same (Sivalingam 1966*b*). It has not been possible to obtain information on the operations of " Daishi Maru " in 1961 and that of the " bull " trawlers (Mendis 1965*a*) that operated for a short period in 1962. The absence of these data do not seriously affect the analysis.

STANDARDIZATION OF FISHING EFFORT

The selection of " catch in pounds per hour of trawling " as the best available measure or index of abundance has been discussed earlier (Sivalingam 1966*b*). Comparison of efficiencies of the three trawlers that operated during the period under study was also discussed. According to this comparison " Reglan Castle " was only 0·8 times as efficient as " Braconglen " and " Braconglen " and " Maple Leaf " were equally efficient. This conclusion does not agree with the observation made by Mendis (1965*b*). The data given by Mendis in Figure 21 (1965*a*) and Fig. 3 (1965*b*) are not consistent. The relative efficiencies obtained earlier from the set of originals submitted by the skippers and shore staff (Sivalingam 1966*b*) are used in this analysis.

CHANGES IN FISHING EFFORT FROM 1945 TO 1962

From the beginning of the present fishery in 1945 up to July 1951 only one trawler " Raglan Castle " was in operation except for 1947 when an additional private trawler operated. In 1951 the aging " Raglan Castle " was replaced by the more efficient and newer " Braconglen ". Subsequently in 1953 a similar trawler " Maple Leaf " was added and both of them continued to operate till the end of 1962. As a result of these changes, the total annual fishing effort which remained fairly steady and at about 1,000 hours of trawling per year up to 1950, increased steadily to 5,590 hours in 1954, the highest on record (Table 1, Fig. 2). During this period both trawlers were comparatively new, required little maintenance and put in maximum fishing time. During the next three years 1955–1957, effort was lower than in 1954 but higher than the pre-1954 level. After 1957 the aging trawlers spent more time under repairs and the total annual trawling hours came down to 3,030 in 1961 and 3,546 in 1962.

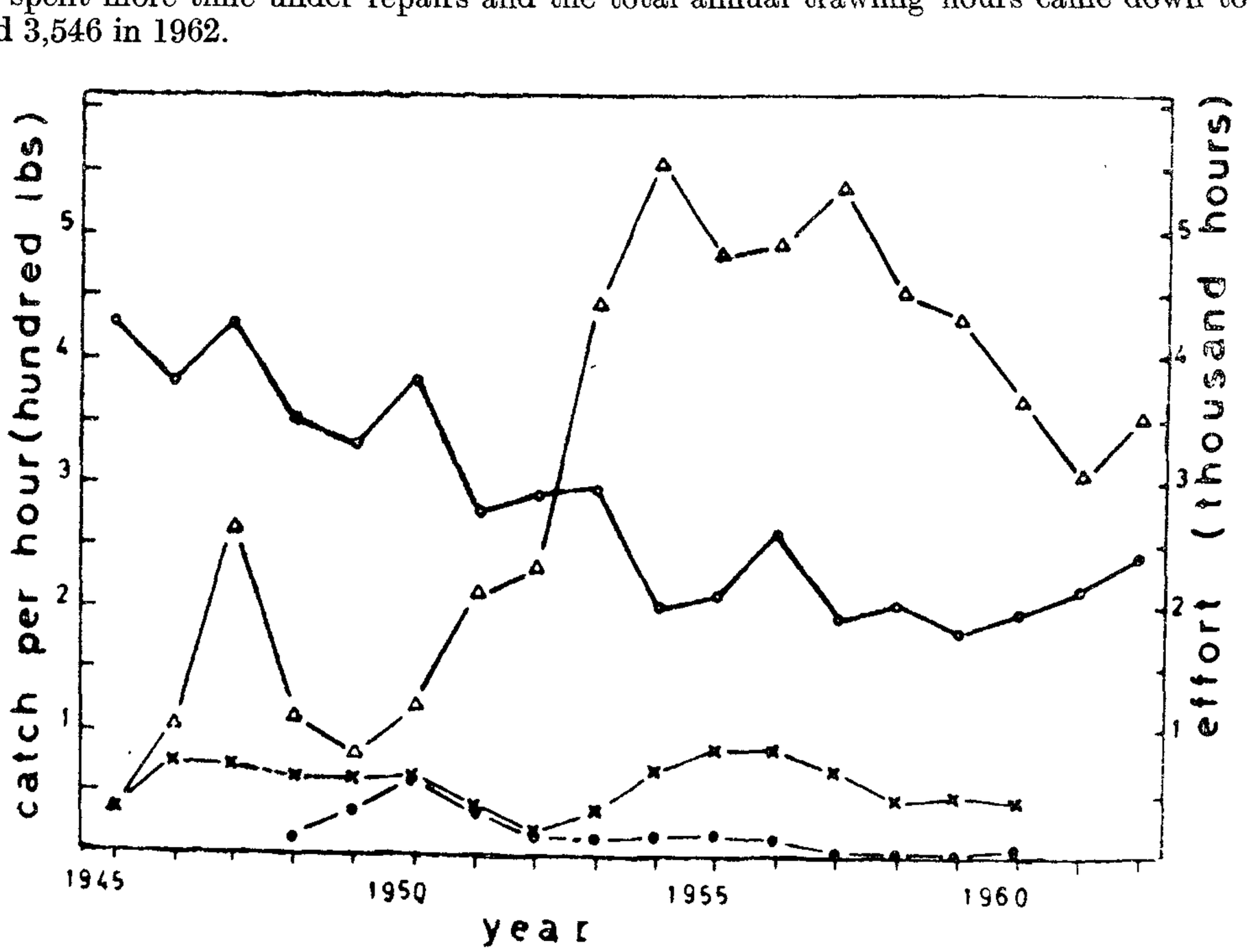

Fig. 2. Catch per unit effort (1945–1962) of " Bigfish " (circles), " Smallfish " (crosses) and " Leather jackets " (dots) with changes in fishing intensity (triangles).

CHANGES IN CATCH PER UNIT OF EFFORT AND TOTAL CATCH

" Bigfish "

The Wadge Bank fish stock was not exploited between 1935 and 1945. In 1945 when the present fishery commenced, the fish population is assured to have been stabilized and in a virgin state. In this state, theoretically, the catch per unit of effort should be the highest and then decline, the rate of decrease depending on the rate of exploitation. But in practice it is not necessarily so, since the crew will be new to the grounds and a period of exploration will have to be gone through. The c. p. e. will initially be low, but will increase rapidly at the rate at which the crew becomes familiar with the characteristics of the fishing grounds.

However, in the case of the Wadge Bank, with special reference in category "Bigfish" although the crew was new to the grounds, the c. p. e. was the highest during the initial stages (430 pounds) and later declined (Table I and Fig. 2). Possibly the area of initial exploitation coincided with the area of good fishing grounds. With the introduction of newer trawlers in 1951 and 1953, the c. p. e. steadied itself, but with still further increase in effort the c. p. e. did level off but at a lower level of about 200 pounds (Fig. 2). With a reduction in fishing effort there was an improvement in c. p. e. from 1960 onwards.

Figures 3 and 4 give the catch of category " Bigfish " landed for different values of fishing effort during the periods 1928 to 1935 and 1945 to 1962 respectively. It will be seen that during the first fishery (1928–1935) the catch continued to increase with increase in effort. No decline with increased effort is evident. The largest poundage landed was 700,000 pounds while the highest recorded fishing effort was 210 fishing days by trawlers " Bulbul " and " Tonkol " (Sivalingam 1966*a*). During the second fishery (1945–1962) the catch continued to increase with increase in effort till a total of 700,000 pounds was landed for 2,300 hours fishing in 1952. Up to this level the rate of increase appear to follow a pattern very similar to that of the first fishery. The sudden increase in fishing effort from 2,350 trawling hours in 1952 to 4,450 hours in 1953 increased the total catch to 1,350,000 pounds, (Table 1). In 1954 and 1955 the fishing effort was further increased to 5,590 and 4,813 hours of trawling, but there was no corresponding increase in the catch. After 1957 fishing effort continuously declined and catch declining with it (Table I).

TABLE I

EFFECT OF CHANGES IN FISHING EFFORT ON THE CATCH PER UNIT EFFORT (C.P.E.) AND TOTAL CATCH OF " BIGFISH ", " SMALLFISH " AND " LEATHERJACKETS " FROM 1945 TO 1962. AVERAGE EFFORT REFERS TO THE AVERAGE OF THE EFFORTS OF THE YEAR UNDER REFERENCE AND THAT OF THREE PRECEEDING YEARS

Year	*Effort*	*Average effort*	*" Bigfish "*		*" Smallfish "*		*" Leatherjackets "*	
			Total catch	*c.p.e.*	*Total catch*	*c.p.e.*	*Total catch*	*c.p.e.*
	hours	*hours*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
1945	346	87	149,361	431	10,989	32	—	—
1946	1,064	370	408,134	384	80,760	76	—	—
1947	2,665	1,019	1,146,419	430	72,229	76	—	—
1948	1,108	1,296	392,109	354	71,278	64	18,494	17
1949	808	1,411	268,368	332	53,289	66	32,011	40
1950	1,209	1,448	468,389	387	84,252	70	81,674	68
1951	2,124	1,312	597,421	281	104,830	49	80,480	38
1952	2,344	1,621	687,023	293	57,786	25	44,117	19
1953	4,446	2,531	1,331,827	300	187,318	42	74,102	17
1954	5,590	3,626	1,140,583	204	410,591	74	112,417	20
1955	4,814	4,298	1,033,526	215	440,067	91	87,636	18
1956	4,910	4,940	1,302,968	265	446,574	91	77,218	16
1957	5,388	5,176	1,064,019	198	408,734	76	29,784	6
1958	4,525	4,909	935,170	207	217,746	48	28,299	4
1959	4,327	4,788	795,731	184	234,720	54	20,804	5
1960	3,682	4,480	733,017	199	175,183	48	31,426	8
1961	3,030	3,891	664,227	219	289,230	95	?	?
1962	3,546	3,646	871,360	246	319,634	90	?	?

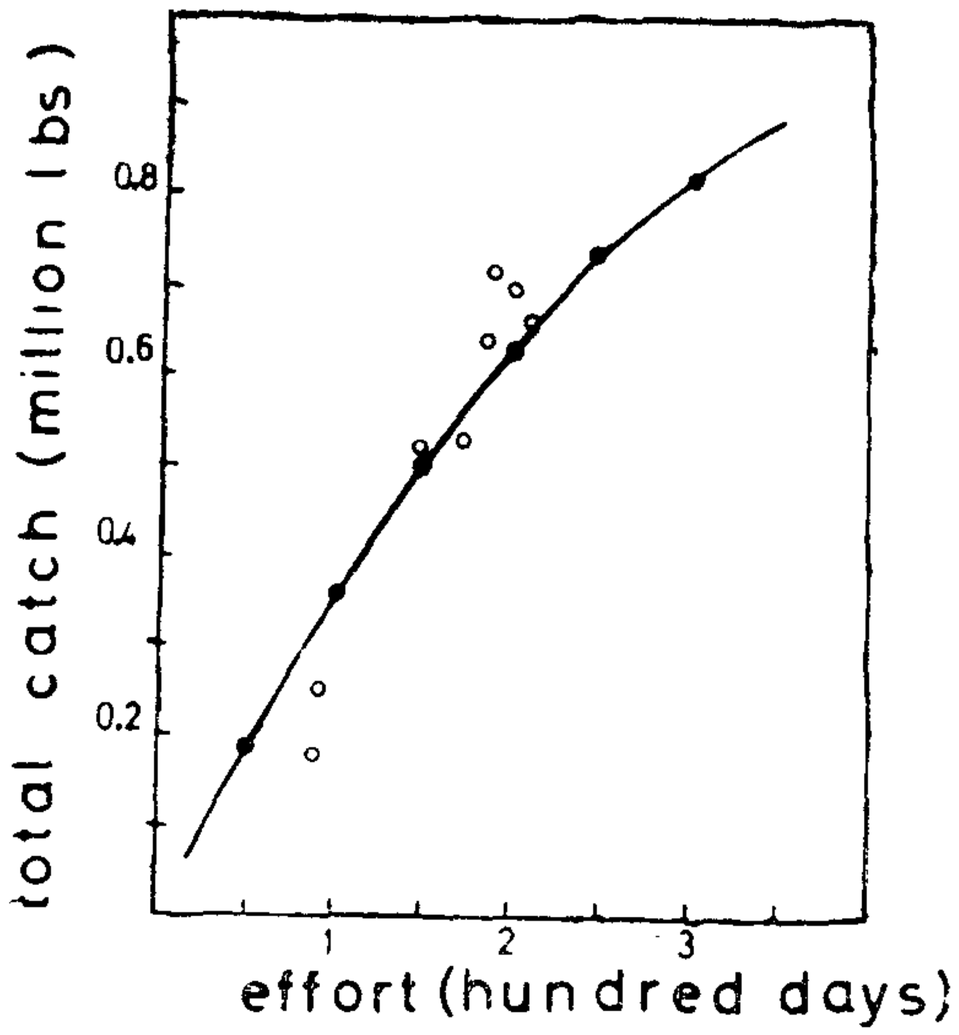

Fig. 3. Observed annual catches of " Bigfish " (circles) in relation to effort (total number of trawler-days fishing per year) in the period 1928 to 1935. Dots represent expected catch on the basis of 1945 to 1962 data (Fig. 4). One day's fishing (1928–1935) has been arbitrarily assumed to be equivalent to 10 hours of trawling on the trawler " Braconglen " standard.

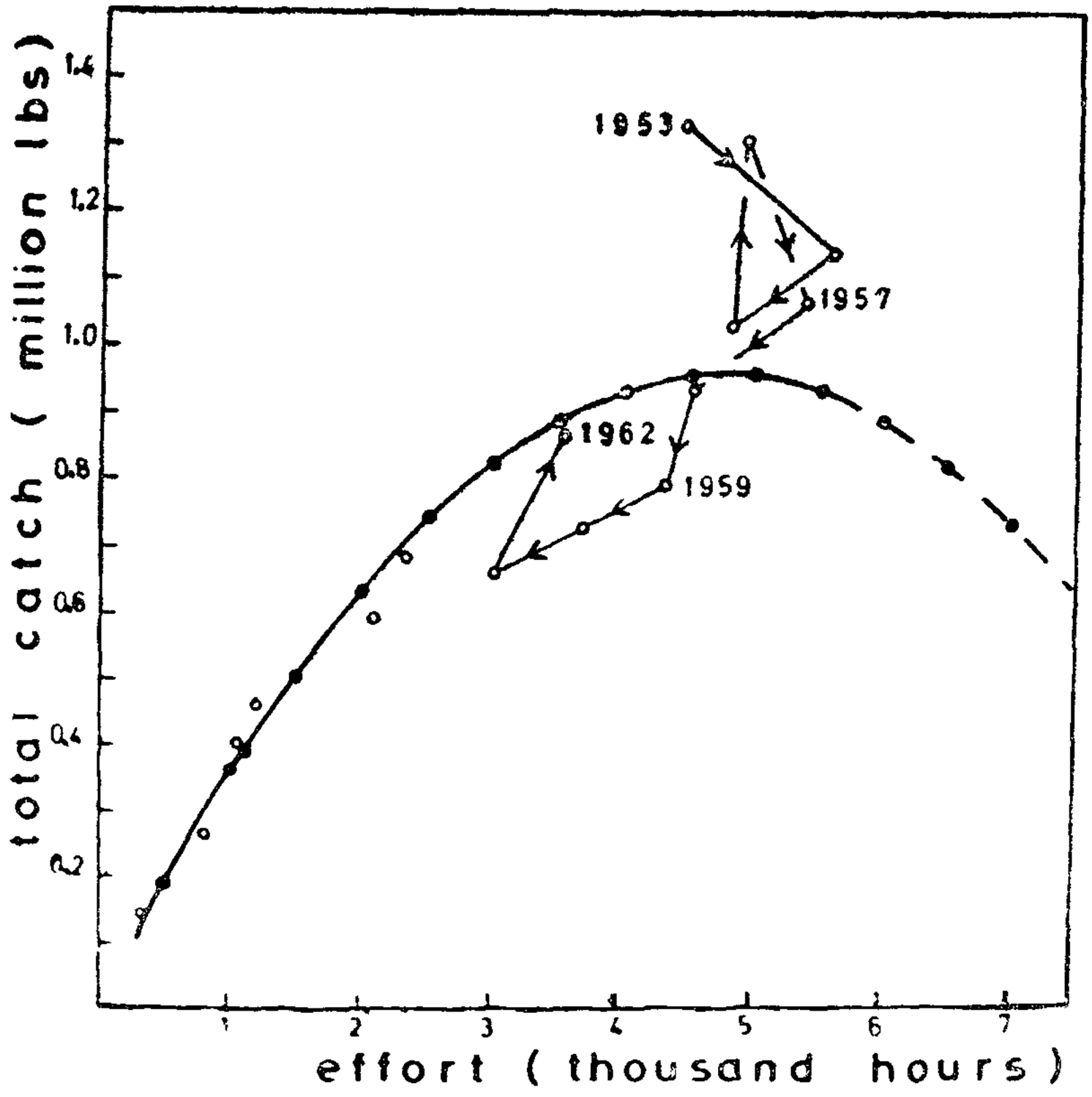

Fig. 4. Relationship between observed catch of " Bigfish " (circles) (1945 to 1962) and the expected catch (dots) for diffrent levels of fishing effort if operated in a steady state. The latter estimated from regression equation Fig. 6, page 61).

Beverton and Holt (1957) have shown that an increase in c. p. e. is to be expected with a decrease in fishing effort. But there was no sign of an increase in the c. p. e. in 1958 and 1959. The first upward trend was evident only in 1960 (Fig. 2).

" Smallfish "

The c. p. e. of " Smallfish " (Sivalingam 1969*a*) remained fairly steady throughout the period 1945 to 1960 (Table I). It did exhibit fluctuations but within narrow limits unlike that for " Bigfish ". Changes in fishing effort apparently had little adverse effect on " Smallfish " (Fig. 2).

" Leatherjackets "

" Leatherjackets " are classified as Grade III in the markets and are of minor commercial importance. They form a small percentage of the total catch (Sivalingam 1969*a*). Their c. p. e. declined throughout the period and does not appear to have recovered by 1960 (Fig. 2, Table I).

CAUSE OF DECLINE IN " BIGFISH " CATCHES

Assuming that there is no change in growth rate and natural mortality of all species concerned, decline in c. p. e. with increased fishing effort and subsequent failure to recover with reduced fishing effort could result from one or both of the following :—

1. Decline in rate of recruitment.
2. Excessive fishing mortality, i.e. overfishing.

It has already been shown that recruitment of sea bream (*Lethrinus nebulosus* (Forskal), was more or less steady from 1954 to 1957 (Sivalingam 1969*a* and 1969*b*). And Table II shows that average lengths of the commercially important species sea bream, red snappers (*Lutianus dodecanthus* Day, *L. malabaricus*, Day) " Laweya " (*Epinephelus undulosus* Quoy and Gaimard) and " Tholan " (*Plectorhynchus pictus*, Tanaka) declined continuously from 1953 to 1957. If recruitment had declined between 1953 and 1957, the percentage of smaller sizes would have decreased and the percentage of larger sizes increased, resulting in an increase in the average size of the catch. Actually the average size decreased continuously indicating that recruitment did not decline till 1957. On the basis that the species are available for exploitation on the fishing grounds for a period of 4 years (page 61), the year classes of these species that entered the fishery in 1957 would have contributed to the fishery till 1961. Under these circumstances, it is reasonable to assume that recruitment did not decline throughout the period.

With growth and natural mortality remaining constant and with no sign of decline in recruitment, the main cause of the initial reduction in c. p. e. with increased effort, and subsequent failure to recover with reduced effort is excessive fishing mortality, i.e. removal in excess of the maximum sustained yield of the resident stock.

MANAGEMENT AIMS

The principal objective of management of living resources of the sea is to obtain the maximum sustained yield. This was agreed to, by representatives of 45 nations that attended the 1955 United Nations International Conference on conservation of living resources of the sea held in Rome. This principle has been written into the various international treaties concerning fisheries resources (Schaefer and Revelle 1959).

Graham (1956) has pointed out that such other considerations as catch per unit effort, average size of fish and monetary return to fishermen may also be important. Economists like Gordon (1953) insist that a proper objective is maximum net economic yield, that is, the maximum of the difference between the cost of harvesting and the value of the harvest. Schaefer (1957) has shown that maximum economic yield must always occur at a lower level of fishing effort than that permitting maximum sustained yield and that these two objectives are mutually exclusive and the choice of objectives depends on the need.

TABLE II

AVERAGE CAUDAL FORK LENGTHS OF COMMERCIALLY IMPORTANT SPECIES OF "BIGFISH" IN 1949 AND FROM 1953 TO 1958. THE 1949 MEASUREMENTS WERE STANDARD LENGTHS AVAILABLE IN 5 CM. GROUPINGS AND THE NORTHEAST MONSOON AND SOUTHWEST MONSOON DATA WERE POOLED. THE CORRESPONDING CAUDAL FORK LENGTHS ARE GIVEN

Species	*Year*	*Northeast monsoon months*		*Southwest monsoon months*		*Annual Average*
		Number measured	*Average lentghs cm.*	*Number measured*	*Average lentghs cm.*	*cm.*
Lethrinus nebulosus	1949	(	299	)		50·8
	1953	316	45·5	—	—	45·6
	1954	1,409	44·8	1,198	42·1	43·5
	1955	1,134	42·6	1,145	42·0	42·2
	1956	730	40·7	1,822	42·6	42·1
	1957	863	41·9	1,610	40·5	41·0
	1958	—	—	627	45·6	—
Lutianus dodecanthus	1949	(	264	)		55·5
	1953	183	51·6	—	—	51·6
	1954	736	50·7	564	47·6	49·4
	1955	603	50·4	446	50·7	50·5
	1956	160	46·7	1,121	50·7	50·2
	1957	133	48·7	100	48·6	48·6
	1958	—	—	—	—	—
Lutianus malaboricus	1953	30	42·8	—	—	42·8
	1954	240	40·1	156	42·5	43·5
	1955	73	42·6	176	41·7	42·0
	1956	129	42·3	231	42·3	42·3
	1957	86	41·7	165	41·5	41·5
	1958	—	—	22	43·6	—
Epinephelus undulosus	1949	(	220	)	—	54·9
	1953	90	54·6	—	—	54·6
	1954	533	56·3	1,147	50·7	52·5
	1955	520	58·4	765	51·7	54·4
	1956	374	51·9	919	52·1	52·0
	1957	386	54·3	887	47·2	49·4
	1958	—	—	281	45·6	—
Plectorhynchus pictus	1949	(	252	)		52·0
	1953	87	54·1	—	—	54·1
	1954	554	49·6	521	48·6	49·1
	1955	650	51·1	496	48·0	49·8
	1956	382	47·8	687	50·9	49·8
	1957	458	48·8	356	46·8	47·9
	1958	—	—	90	45·6	—

In the case of the Wadge Bank trawl fishery, when the second trawler fishery commenced in 1945, the need and the objective was to exploit the Wadge Bank stock " to produce fish to relieve Ceylon's protein food shortage " (Amirthalingam and De Zylva, 1947). The fishery was Government sponsored and continues to be so. Originally the protein shortage was due to the second world war The shortage continues and appears to be more acute, mainly as a result of foreign exchange difficulties and a rapid population increase within Ceylon. The objective must therefore remain the same i.e. the maximum sustained yield in the form of edible protein supply. Profit should be of secondary importance to national health, as long as the whole operation pays its way.

But a strict definition of the term " protein supply " is required at this stage. Wadge Bank catches are made up of commercial Grades I, II, III and inedible varieties which are at present discarded (Sivalingam 1966*a*). Of these three, Grades I and II are all sold in the iced or frozen state without much loss to their protein value. But Grade III categories (sharks, skates, catfish and leatherjackets) due to their poor keeping qualities and unpopularity in the market when preserved on ice, are sold as dried fish.

There is considerable loss in its nutritive value as a result of poor standard of handling processing and storage. Few attempts were made to sell Grade III varieties in acceptable form (e.g. frozen fillets) and none are popular. As long as the practice of drying Grade III varieties continues, management program aimed at increasing catches of Grade III fish at the expense of Grades I and II will not serve management aims. Until such time as Grade III varieties can be used in the iced, frozen or other forms without loss of its protein value, the term " protein supply " should refer to Grades I and II only. In other words the main objective should be maximum sustained yield of Grades I and II only.

But a parallel increase in Grade III varieties is beneficial provided the storage capacity of trawlers permits such an increase without reducing storage space for Grades I and II thereby shortening the length of stay at sea.

It is necessary to explain this clearly because increase in c. p. e. of all varieties combined, including Grade III (Mendis 1965*a*, Sivalingam 1966*b*) has led to the wrong notion that fishing effort can be further increased without adverse effects on fish populations (Mendis 1965*a* and 1965*b*, and Medcof 1963). The authors have not considered that increases in c. p. e. of all grades combined was mainly due to increases in c. p. e. of Grade III varieties which by wet weight more than compensated for losses in catches of Grade II varieties.

ASSESSMENT OF MAXIMUM SUSTAINED YIELD

Previous Assessments

Assessments of the Wadge Bank's potential productivity dates back to 1926. They may be summarized as follows :—

Hornell (in Malpas 1926) recorded thus: " The Wadge Bank is so extensive an area as to offer good fishing for an indefinite period to a large fleet of steam trawlers of full power and size."

Malpas (1926) on the basis of an average catch of 195·3 pounds per hour and 18 hours of trawling per day expected a daily catch of 3,515 pounds.

Hickling (1951) indicated that the Wadge and Pedro Banks would not support more than ten trawlers, without showing diminishing returns.

Blegvad (1951) advocated progressive intensification of trawling but also expressed the opinion that the Wadge Bank could easily support 10 trawlers or perhaps 20.

John (1951) did not expect Wadge and Pedro Banks to support more than about 6 trawlers.

The National Planning Council (Anon 1959) expected an annual catch of 156,600 cwt. made up of all varieties.

Sivalingam (1961) advocated progressive intensification of fishing until returns indicated that no further expansion is possible.

Medcof (1963) commented that John's estimate (1951) seemed to be an underestimate, that Blegvad's more ambitious recommendations (1961) be followed, that the fleet of large trawlers be increased slowly and effects of the increase on fish stocks be monitored so that expansion could be halted before stocks were diminished to levels where exploitation becomes unprofitable.

Mendis (1965*a*) suggested that seven government-owned trawlers and the privately owned trawlers (seven or eight in all) operate on the Wadge Bank. He further recommended that the trawlers should put in more fishing time and expected total landings of 14·8 million pounds per year. He also recommended (1965*b*) that six trawlers operate on the Wadge Bank and that detailed studies be made to obtain information on standing crop and feasibility of introducing more trawlers.

Critique of Previous Estimates

It is understandable that in the absence of (1) any information on various parameters of commercially important species, and (2) records of catch and effort data over a long period and wide range of fishing effort, the earlier estimates had to be on the basis of guess work, based on comparison with other fishing grounds. But Kestevan (1951) has pointed out that such comparisons are not satisfactory specially because the fish stocks are quite different, and further that trawlable areas are smaller and recruitment and annual increment rates different.

The more recent estimates appear to have been made on the false assumption that since the annual average c. p. e. of all species combined is increasing the stock is not being overfished. In interpreting changes in c.p.e. and arriving at the above conclusion no consideration has been given to—

(1) Fluctuations in fishing effort. In fact the annual fishing effort declined from 1957 till 1961 (Fig. 2) and up to 1962 Wadge Bank was not fished any harder than previous to 1957 as stated by Mendis (1965*b*).

(2) Heterogeneous nature of the stock. This stock is composed of migrant and resident species (Sivalingam and Medcof 1957). During the good fishing season the migrant forms appear on the Bank in addition to the resident forms. During the off season, only the resident forms are present. The average annual c. p. e. of the total landings of both resident and migrant forms does not give a true picture of the strength of the fish stock, unless the percentage of the annual effort for the good fishing season and that for the off season remained the same for all the years.

Under these circumstances annual average c. p. e. for all species combined are not directly comparable and cannot give information on the state of the stock.

Present Assessment

When complete knowledge of parameters for different species are known, it may be possible to work out the theoretical maximum sustained yield for fish stocks of more than one species. But tropical trawl fisheries are handicapped by the excessive number of species and the lack of information on practically all species. In the case of Wadge Bank, the problem is further complicated by the presence of two distinct populations, resident and migrant. Ricker (1953) has shown that such groups require different methods of analysis and have to be treated separately.

Among the residents " Bigfish " are of primary importance. Of the other two, category " Leatherjackets " though it showed a decline in c. p. e. is of minor commercial importance. " Smallfish " have not showed signs of diminishing up to 1960.

To assess maximum sustained yield of " Bigfish " two approaches have been made. In the first, the principle applied by Thompson and Bell (1934) for Northeast Pacific halibut has been used. In the second the standard stock assessment method (Gulland 1965) using effort and c. p. e. data has been used.

Both these methods are based on the assumption that growth and natural mortality rates, and rate of recruitment are more or less constant. Both methods are applicable to a fishery exploiting a single species. But with " Bigfish " of the resident stock of Wadge Bank there are 9 species, which are important (Sivalingam 1969*a*). All these species are equally priced and it has been shown that the increase in fishing effect has affected all in a similar manner (Sivalingam 1969*b*). To obtain the best results from data available, commercially important " Bigfish " or is treated as a single " unit ".

Thompson and Bell (1934) were among the first to develop a basis for rational exploitation of a fish stock. Their principle was applied successfully to the Northeast Pacific halibut fishery (Van Cleve & Johnson 1963). Thompson (1950) discussing the principle used to assess " normal yield " (i.e. maximum sustained yield) of the Northeast Pacific halibut fishery showed that it could be assessed by averaging the catches of a series of years, where—

(1) the stock was at the same level at the beginning and the end of the series ; and

(2) within the period, catches in certain years were too large followed by a period when the catch was too small.

The first Wadge Bank trawl fishery (1928–1935) does not offer any possibilities of assessment on the above basis (Sivalingam 1966*a*). But during the present fishery, i.e. from 1945 onwards, the statistics available permit estimation of maximum sustained yield on the above basis.

It will be seen that from 1953 to 1962 (Fig. 5), there is a series of early years where total catch of " Bigfish " was too large and a later series where the catch was low. It will also be seen (Fig. 2) that from 1951 to 1953 the c. p. e. was more or less steady and later declined. With reduction in fishing effort and consequent reduction in catch, by 1960 the c. p. e. showed signs of improvement of the stock. By 1962 the c. p. e. had improved but had not come up to the 1953 level. Since data for 1963 is not available the average is calculated up to 1962.

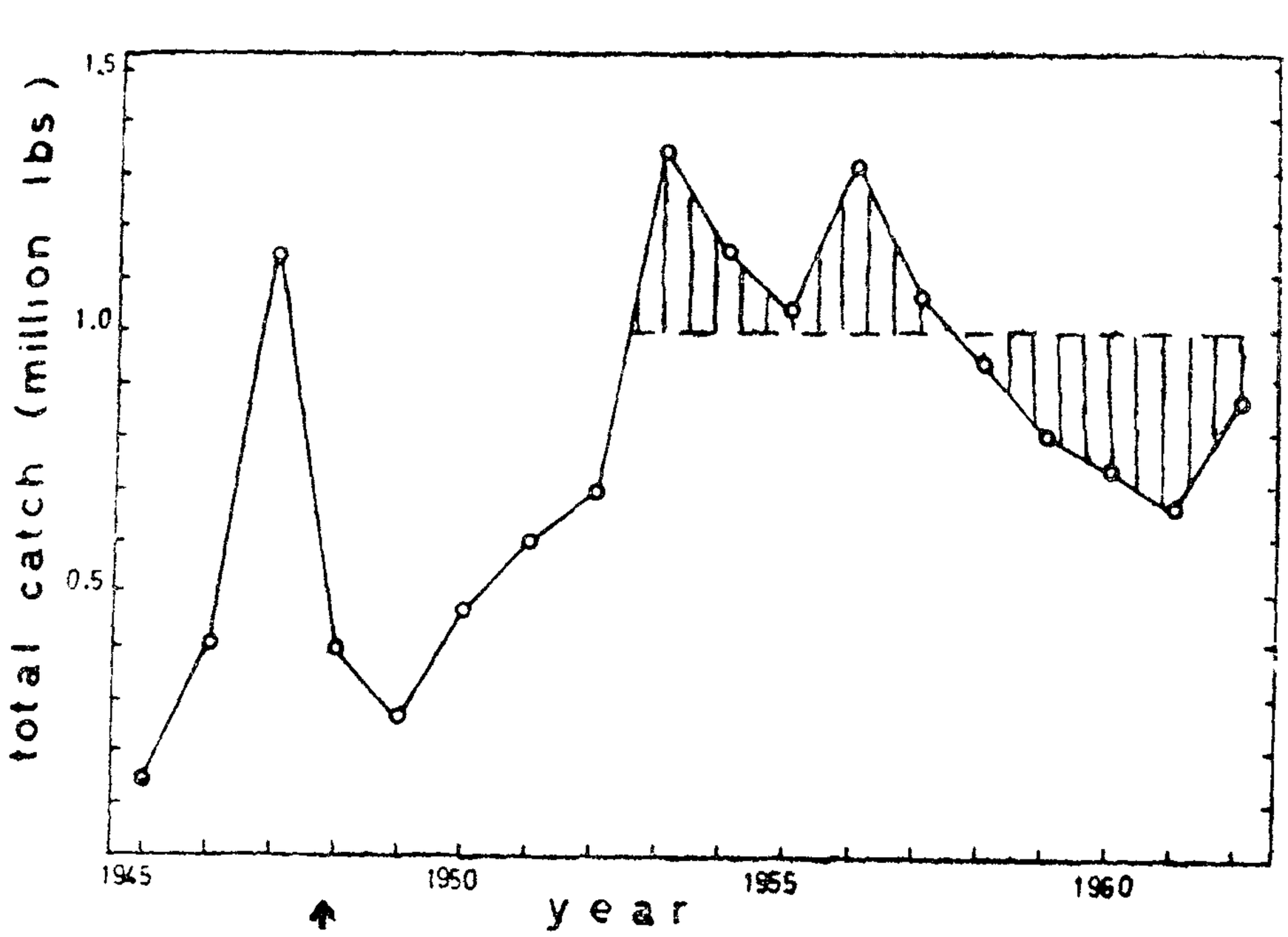

Fig. 5. Catch of " Bigfish " from 1945 to 1962. The horizontal broken line represents the maximum sustained yield estimated on the basis indicated by Thompson and Bell

On the basis indicated by Thompson (1950) the maximum sustained yield of " Bigfish " is the average of total catch for the period 1953 to 1962 which is 987,000 pounds (Fig. 5).

In the case of the standard stock assessment method, Gulland (1965) has shown that if statistics are available for a number of periods during which effort was steady, the estimation of the maximum sustained yield would be simple. In the case of the Wadge Bank fishery effort was continuously changing and a different approach has to be made. As indicated by Gulland (1965) in the absence of effort statistics at different steady levels, the average of the fishing effort over the mean duration of life in the exploited phase of the species may be used.

In treating all species as a " unit " the problem of deciding on the " duration of life in the exploited phase " of the " unit " arises. It has been shown for sea bream (Sivalingam 1969*b*) that the duration of life on the fishing grounds (exploited phase) is 3–4 years. The author's study of length-frequencies of other important species of " Bigfish " over the same period as for sea bream, indicates that the mean duration of life is probably 4 years. The duration of life of the exploited phase of the entire " unit " is therefore assumed as 4 years.

Table I gives the average effort and c. p. e. for the years under study. The relationship of c. p. e. to average effort is given in Figure 6. From this regression the expected c. p. e. for different values of effort was estimated. The expected total catch of " Bigfish " for the different values of fishing effort, if operated in a steady state, was then determined by multiplying the estimated c. p. e. by the corresponding values of effort. The estimated values and observed values are given in Figure 4. This figure shows that total catch of " Bigfish " will continue to increase with increase in fishing effort up to a maximum of about 4,700 fishing hours on the trawler " Braconglen " standard. Total catches of 964,000 pounds may be expected under these conditions, but with further increases in effort the annual catches will fall.

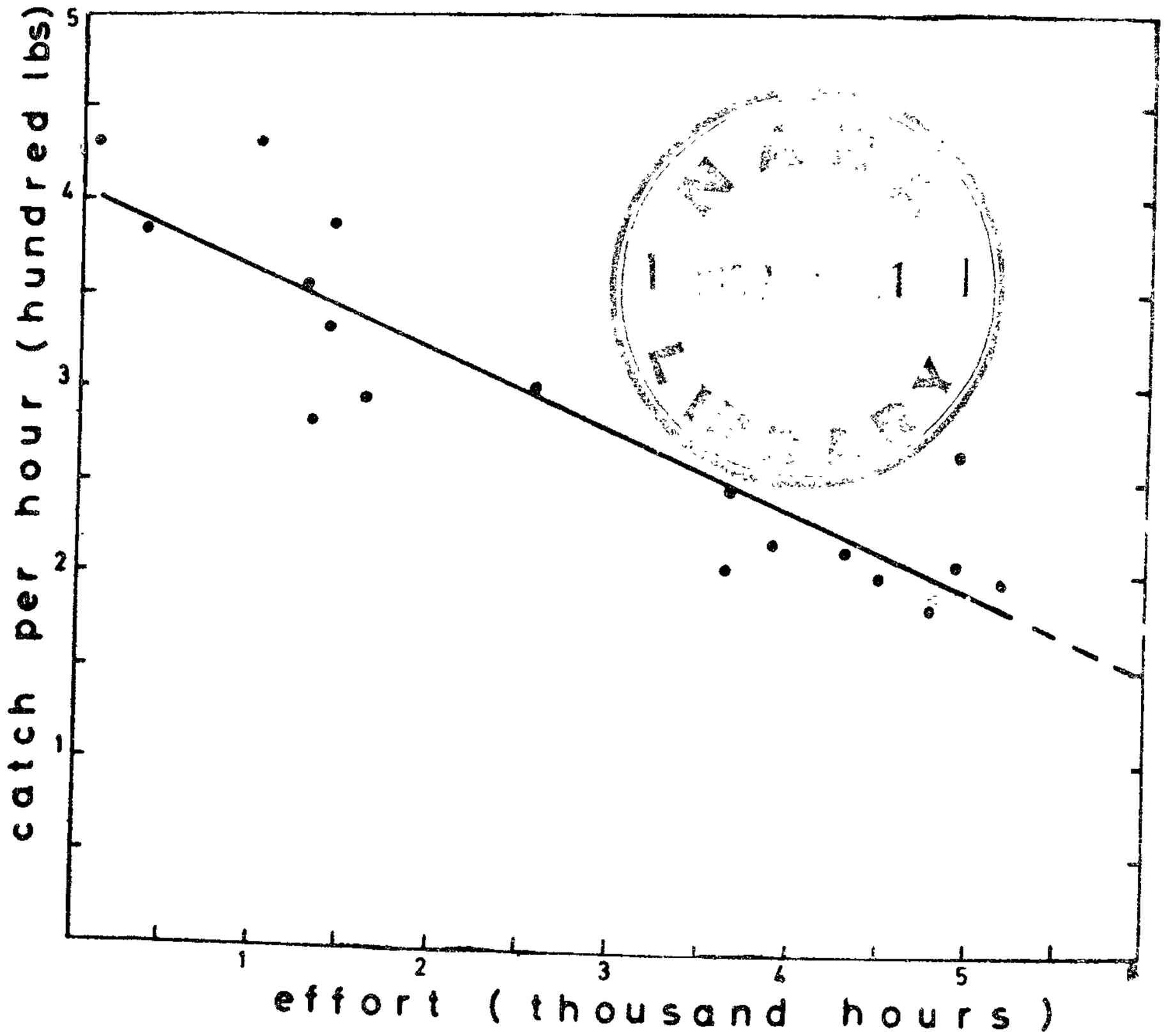

Fig. 6. Effect of increase in fishing effort (average for four consecutive years) on the catch per unit effort.
Y=406+(—0·04285) X.

Expected values on the above basis have been plotted against total catch for the first fishery (Fig. 3). The close fit of the two sets of values indicates the soundness of this concept.

The two estimates are the best available from present data, considering the nature and composition of the stock. The closeness of the two estimates adds a high degree of reliability for the values.

The average of the two estimates is 972,750 pounds, i.e. approximately 973,000 pounds. This of course refers to the grounds that have been regularly fished, which are 1,250 square miles in extent (Sivalingam and Medcof 1957). The portion of the continental shelf outside this area has been explored but results have not been encouraging (Medcof 1963). If due to excess number of trawlers it is necessary to expand the fishing area to cover grounds to the northeast and northwest, the value of the maximum sustained yield will naturally be higher but not in direct proportion to the increase in area, since the new area is not equally " rich ".

To begin with, it may be safe to work on the basis of half the value obtained from the regular area, i.e. $\frac{1}{2}$ of 973,000 pounds for 1,250 square miles or approximately 39,000 pounds per 100 square miles of additional area.

Future Possibilities

The maximum sustained yield estimated in the preceding section is that which can be obtained with the mesh sizes of the nets in use between 1945 and 1962. Beverton and Holt (1957) have shown that it is generally true, that greater maximum sustained yields can be obtained by increasing size at first capture (i.e. mesh size) and increasing fishing effort. This may be possible in the case of Wadge Bank demersal stock and its possibilities should be investigated.

This investigation requires a series of trials with nets of different mesh sizes. In working out the program of fishing trials it should be noted that, practically all species of " Bigfish " do not appear on the fishing grounds till they are in the " exploitable phase " as defined by Beverton and Holt (1957). Table III shows that except for sea bream, most " Bigfish " are all larger than 30 cm. The percentage smaller than 30 cm. is less than 1%.

TABLE III

WEIGHT OF COMMERCIALLY IMPORTANT " SMALLFISH " SPECIES (LESS THAN 31 CM. CANDAL FORK LENGTH) EXPRESSED AS A PERCENTAGE OF ALL " SMALLFISH " AND OF TOTAL LANDINGS OF ALL CATEGORIES

Species	*Percentage within category " Smallfish "*		*Percentage of total landings*	
	1957	*1958*	*1957*	*1958*
Lethrinus nebulosus ..	26	19	3·4	1·5
Lutianus dodecanthus ..	<1	<1	<1	<1
Lutianus malabaricus ..	<1	<1	<1	<1
Epinephelus undulosus ..	<1	<1	<1	<1
Plectorhynchus pictus ..	<1	<1	<1	<1
Lutianus rivulatus ..	Nil	Nil	Nil	Nil

Increase in mesh size will affect all species of " Smallfish " and " Leatherjackets ". These categories are of little commercial importance and reductions in their catch would not seriously affect the value of total landings. Of all the important species of " Smallfish " only the sea bream grows into " Bigfish ", i.e. larger than 30 cm. Others have not been recorded in appreciable numbers in sizes larger than 30 cm. In all probability the benefits of increase in mesh size derived from sea bream alone would offset reductions in catch of " Smallfish " and " Leatherjackets ".

RECOMMENDATIONS TO ACHIEVE MANAGEMENT AIMS

The heterogeneous character of the Wadge Bank demersal fish population has been pointed out. It is made up of both resident and migrant stocks. From the data available it has been possible to assess the maximum sustained yield of " Bigfish " which is the mainstay of the resident stock. With the specifications of the net in use from 1945 to 1962, this is about 973,000 pounds. The management objective will be to obtain a catch of 973,000 pounds of " Bigfish " annually without in anyway altering the status quo of the migrant stock.

The effect of fishing from 1945 to present, on the migrant stock is not yet known and selective fishing exclusively for either migrant or resident stock may not be possible when both are present on the fishing grounds together. Fortunately, the migrant stocks are present on the fishing grounds only for certain months of the year, while the resident stocks are present throughout the year and this permits selective management of the resident stock. Even during the years when the largest quantity of " Bigfish " was caught (*1953*, 1,331,800 pounds and *1956*, 1,303,000 pounds), the catch of " Bigfish " during the months of abundance of the Grade I migrant forms did not exceed the estimated maximum sustained yield of 973,000 pounds. The plan of action would therefore be as follows :—

(1) Consider the " fishery year " as from May of one year to April of next year.

(2) Carry on the normal fishery as before between May and October when the Grade I migrant forms appear on the Bank.

(3) The total landings of " Bigfish " from May to October deducted from the annual quota of 973,000 pounds would give the balance that can be harvested. between November and April of the following year.

(4) Increase or decrease fishing effort between November and April to obtain the balance quota for the " fishing year ".

(5) Investigate possibility of obtaining higher yield with larger mesh sizes.

The program for the first few years immediately after initiating the management proposal will depend on the effect of fishing on the " Bigfish " stock since 1962 up to the year when the above proposals are put into force, specially the last four years, which is considered the mean of the duration of life in the exploited phase. If the stock was under-exploited during these years, the annual catch could be proportionally increased for the next four years. But if on the other hand the catch was in excess of the maximum sustained yield, it will be necessary to reduce the annual quota proportionally over the next four years and then when the level of the stock as indicated by c. p. e. is re-established, the normal quota could be fished yearly by following the program given in the preceeding paragraph.

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