Reports on surveys with the R/V Dr Fridtjof Nansen.

A survey of the Coastal Fish Resouces of Sri Lanka, report no. III Jan. - Feb. 1980

1980

Fisheries Research Station, Colombo
Institute of Marine Research, Bergen

DR. FRIDTJOF NANSEN

The fishery research vessel «Dr. Fridtjof Nansen» belongs to the Norwegian Agency for Development Cooperation (NORAD). It was designed and built for scientific and exploratory investigations of fishery resources of developing countries, under a joint plan with the Fisheries Department of FAO.

The first four years of operation from 1975 to 1978 include a survey of the pelagic fish resources in the NW Arabian Sea organized with FAO's Fisheries Department (1975-76), a survey off Pakistan under a bilateral agreement with this country, a survey of Mozambique waters organized bilaterally with the government of Mozambique (1977/78); a brief assignment off the Seychelles in July 1978 and finally surveys around Sri Lanka, off Burma and Bangladesh. All of these programmes formed part of and were sponsored by FAO's Indian Ocean Fisheries Development Programme. The Institute of Marine Research, Bergen is under a sub-contract with NORAD responsible for the operation of the vessel, and the various research programmes were planned and conducted jointly with the relevant fisheries research organizations in the countries concerned.

Results of the previous surveys have been reported on in a number of cruise- and progress reports under each programme.

REPORTS ON SURVEYS WITH THE R.V. "DR. FRIDTJOF NANSEN"

A SURVEY OF THE COASTAL FISH RESOURCES OF SRI LANKA, REPORT NO. III JAN. - FEB. 1980

BY

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Institute of Marine Research,

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Bergen/Colombo, August 1980.

CONTENTS

(Contents continued)

1. INTRODUCTION

After the first survey of the waters around Sri Lanka with the fishery research vessel "Dr. Fridtjof Nansen" it was recommended to repeat the survey in other seasons. The vessel has now undertaken three surveys of the fish resources in the waters around the Sri Lanka. The two first surveys (Referred to as Survey I and Survey II in the present report) were carried out in August - September 1978 and April - June 1979 respectively. Reports on the two first surveys (Referred to as Report I and II in the present report) were issued in March 1979 (Sætersdal and de Bruin 1979) and December 1979 (Blindheim, de Bruin and Sætersdal 1979). The third survey which is reported on here, was carried out in January - February 1980, and its main intention was to give information on the distribution and abundance of the fish resources in the north-east monsoon season. Since no further surveys are planned, a summing up of the findings from all three surveys is also included in the present report.

The following scientific personnel participated in the cruise:

Institute of Marine Research, Bergen	Fisheries Research Station, Colombo
J. Blindheim	A. de Alwis
L. Føyn	G.H.P. de Bruin
H. Kismul	P. Dalpadado
J.P. Maude	P.G. Pereira
A. Roald	

The personnel from the Fisheries Research Station, Colombo, mentioned above, joined on 18 January and participated for the rest of the cruise while A. Jayasuriya and Y.J. Raphael participated from 5 to 18 January.

The above staff took part in the observational work and carried out the analysis and processing of observations and data which was done on board.

A. de Alwis and P. Dalpadado have also assisted in the preparation of the present report during a visit to the Institute of Marine Research and the University of Bergen with NORAD fellowships. The figures are drawn by H. Kismul.

2. WORK SYSTEMS, EQUIPMENT AND OBSERVATIONS

2.1 Work systems

In order to retain comparability with previous findings, survey methods and observational procedures were mainly the same as during the two previous surveys. Observations and data were acquired, processed, analysed and interpreted through a set of work systems which are described in detail in Report I. Fish resources were observed acoustically and fishing experiments were made for biological sampling and identification of acoustic recordings. In addition intensive trawling was carried out on the Pedro Bank for assessing the demersal fish stock on basis of catch rates. Also on the deep lobster ground in the Gulf of Mannar, trawling was undertaken to obtain indications of its abundance.

The cruise lasted from 5 January to 15 February 1980, and the survey work started near the Little Basses Reef in the Hambantota area (Sub-area III). The south and west coasts were covered before 27 January while the rest of the time was spent on the east coast.

Fishing experiments were made on a total of 133 fishing stations. The number of stations operated with different types of gear used were: Bottom trawl 92, pelagic trawl 19, bottom long line 18 and oysters dredge 4.

Environmental factors were observed on 54 hydrographic stations.

Cruise tracks and stations from the cruise are shown in Fig. 1.

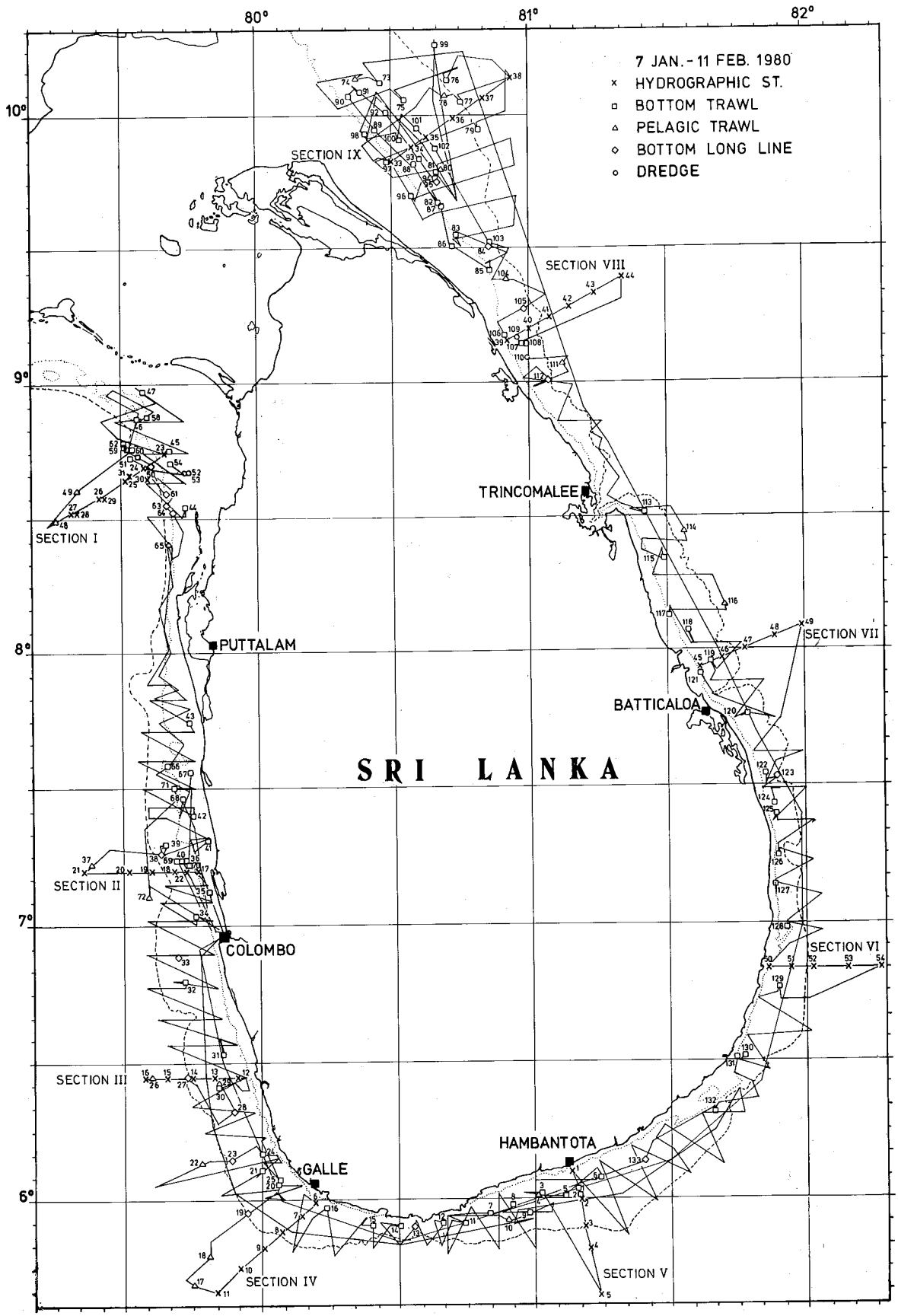

Fig. 1. Survey lines and stations worked.

2.2 Fishing gear

The trawl gear used was of the same type and design as during Survey I and II. The bottom trawl is a shrimp trawl type which is adapted also to demersal fish trawling. Its head line is 96 feet and the 63 foot ground rope is equipped with 0.5 m rubber bobbins. During all three cruises the trawl was operated with 40 m bridles. The design of the net of this trawl is appended to Report II.

The pelagic trawl was the same gear as used in the previous surveys. It has 1600 meshes around the trawl mouth which is 16 by 16 fathoms. The length of the bridles on this gear was 120 m, and it was always operated with a net sonde.

The bottom long lines used were of the same type as those used during Surveys I and II: Line of monofilament no 120, snood of monofilament no 80 and hooks no 80 with long leg.

2.3 Oceanographic instruments

Nansen bottles were used for the oceanographic work. Temperature, salinity, dissolved oxygen and nutrients were observed at standard depths to maximum 500 m. The salinity samples were analysed by means of an inductive salinometer on board the vessel. Dissolved oxygen was determined on board according to the Winkler method. Samples for nutrients were immediately deep-frozen and stored for determinations by means of an auto-analyzer in Bergen.

2.4 Acoustic instruments

The acoustic survey equipment consisted of two echo sounders, one operating at 38 kHz and one at 120 kHz. An analog echo integrator was connected to each of these echo sounders. Performance and settings of the echo sounders are given in Appendix I. The vessel is further equipped with a searchlight sonar (18 kHz) and a net sonde (50 kHz). The sonar was operated periodically at basic range 1250 m, sweeping 60 degrees to each side or fixed 90 degrees to one side as appropriate. The net sonde was operated routinely on pelagic trawl stations.

Generally the processing and interpretation of the acoustic data followed the standard acoustic work system as described in Report I. The echo integrator values were recorded for each nautical mile sailed and averages over 5 nautical miles were worked out and logged. In order to retain comparability with Surveys I and II the acoustic assessment was based on the data from the 38 kHz echo sounder. The echo integrator readings (unit: mm/nautical mile) are relative measures proportional to fish density, i.e. one unit of 1 mm/nautical mile represents a certain number of individual fish per square nautical mile. For conversion from these relative measures to total fish biomass, a conversion factor (density coefficient) has to be applied. Such coefficients for the present cruise are given in Appendix I together with data on the settings of the echo sounders.

3. BOTTOM CONDITIONS

During the two previous surveys the echo recordings were analysed with respect to the character of the bottom. This routine was followed also during the present survey and the same scale of classification was applied: (i) Even flat bottom, (ii) uneven bottom, (iii) very rough bottom, (iv) steep slope. The observations were combined with the observations of bottom conditions from Survey I and II, and the resulting chart with indications of the character of the bottom is shown in Fig. 2. The shelf was fairly densely covered during the two first surveys and the data from the present cruise could only contribute to the general picture with regard to details in some few areas.

An abrupt transition from a shallow shelf to an extremely steep slope is a characteristic feature along most of the shelf edge. Only in the Gulf of Mannar and on the Pedro Bank there are exceptions. Predominance of rough and uneven bottom on the outer shelf is also a general feature.

In the Gulf of Mannar most of the inner part of the shelf area is too shallow to allow navigation with the "Dr. Fridtjof Nansen". A great part of the navigable shelf is, however, smooth enough for trawling.

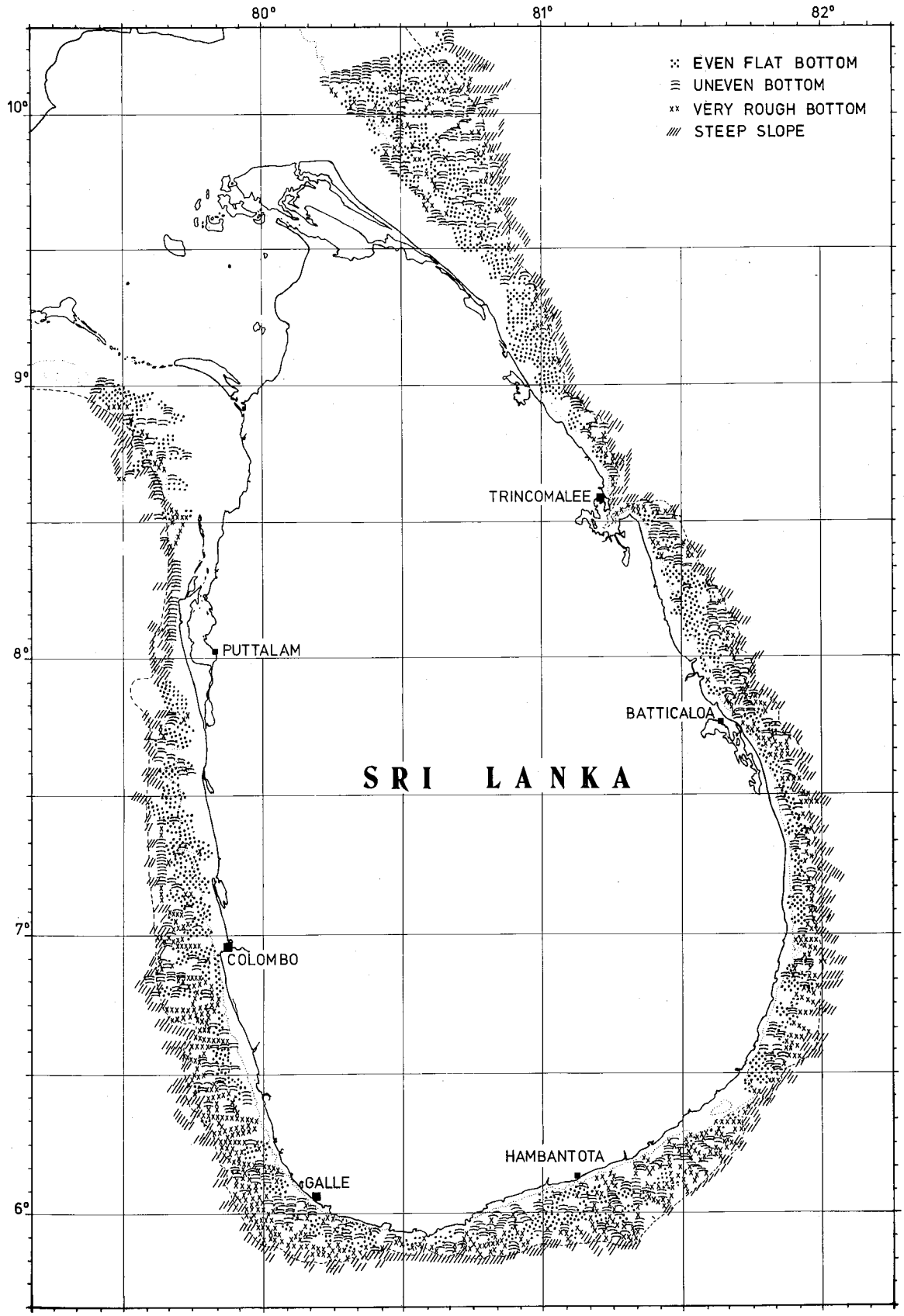

Fig. 2. Observations of the character of the bottom on the continental shelf.

An area with fairly gently sloping bottom at depths between about 250 and 400 m forms a deep water trawling ground. During Survey I this area was mapped in some detail as described in Report I.

South of the very narrow shelf off Puttalam the shelf widens gradually southwards to the latitude of Colombo, and particularly on the nearshore half of the shelf there are fairly extensive areas with trawling ground. The outer part of the shelf is rough and at places there are corals.

On the south-west coast the relatively wide shelf is characterized by rough and uneven bottom. On nearshore parts of the shelf there are areas with flat bottom, but in some cases the bottom in these areas is too soft for trawling. The outer part of the shelf has quite rough bottom and conventional bottom trawling is practically impossible.

The Hambantota Banks, the shelf off the south coast, offers limited areas for trawling. The outer shelf is rough and uneven, but on mid-shelf there are relatively wide areas with fairly smooth bottom, notably off Hambantota.

On the east coast to the south of Trincomalee, the shelf is generally somewhat narrower than the west coast shelf. The rough character of the outer shelf is typical also here, but there are smooth areas from mid-shelf towards the shore. Between Trincomalee and Sangama Kanda Pt (7^{o}N) there are, however, sponges and corals in some areas with flat bottom.

The shelf north of Trincomalee and the Pedro Bank generally has the smoothest bottom within the survey area. Bottom conditions are here more or less suitable for trawling over rather extended areas. Some areas with soft mud where the trawl will get stuck occur in shallow parts. In the northern part of the bank the transition to the continental slope is more gradual than elsewhere on the coast. The slope is here rather gentle and there is fairly smooth bottom to at least 300 m depth.

4. HYDROGRAPHY

Temperature, salinity and dissolved oxygen were observed in the same sections as during the two previous cruises. Some of the sections were now slightly extended seawards. Observations were made to maximum 500 m.

4.1 Water masses

The dominant water masses in the survey area are illustrated in Fig. 3 which shows T-S relations in the sections on the west and east coast respectively. The waters of the mixed upper layer, above the thermocline, are seen as an isothermal water mass covering a wide range in salinity. The temperature of this water mass was mainly between 27 and 28°C, slightly lower in the northern part of the survey area than around the south coast. On the east coast the salinities were lower than on the west coast, ranging between 32.5 and 35.0°/oo and 33.7 and 35.4°/oo respectively. These properties are characteristic for the Bay of Bengal surface water. Its distribution on the west coast is typical for the north-east monsoon season.

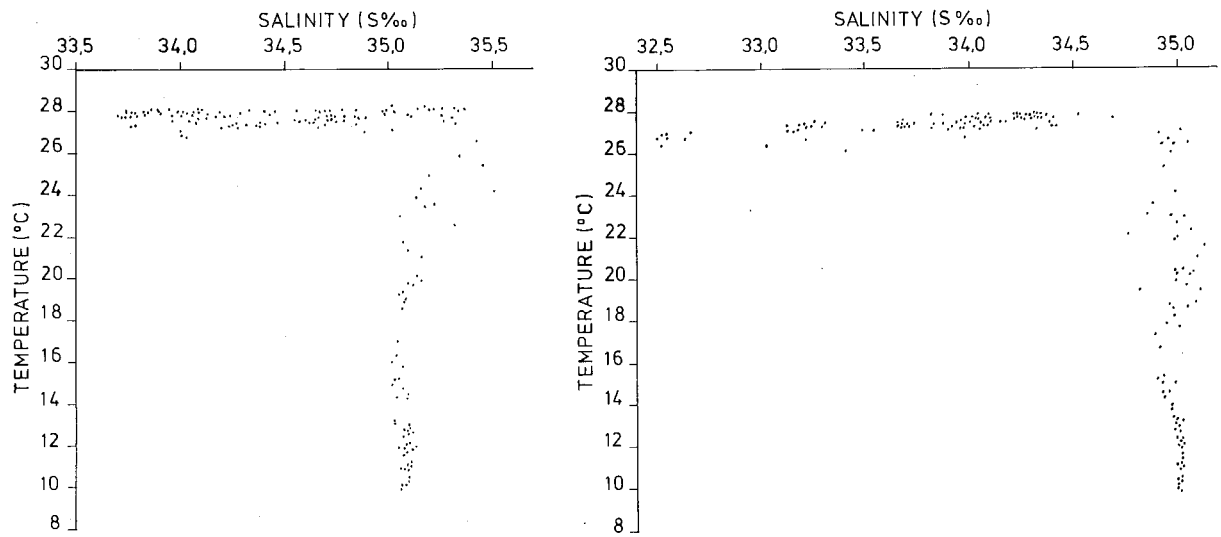

Fig. 3. T-S diagrams for the sections on the west coast (left) and the east coast (right).

High salinity Arabian Sea water of temperature between 22 and 26°C and salinities above 35.0°/oo (Wyrtki 1973) was observed in the upper portions of the thermocline. In the sections on the west coast its salinities were ranging between 35.1 and 35.5°/oo. During survey III this water mass was also present in the sections on the east coast. Its salinity was here in most cases below 35.05°/oo. The slight maximum in salintiy at temperatures around 12°C is seen in both T-S relations in Fig. 3, indicating that the Arabian Sea intermediate water (Wyrtki 1973) was observed in all sections.

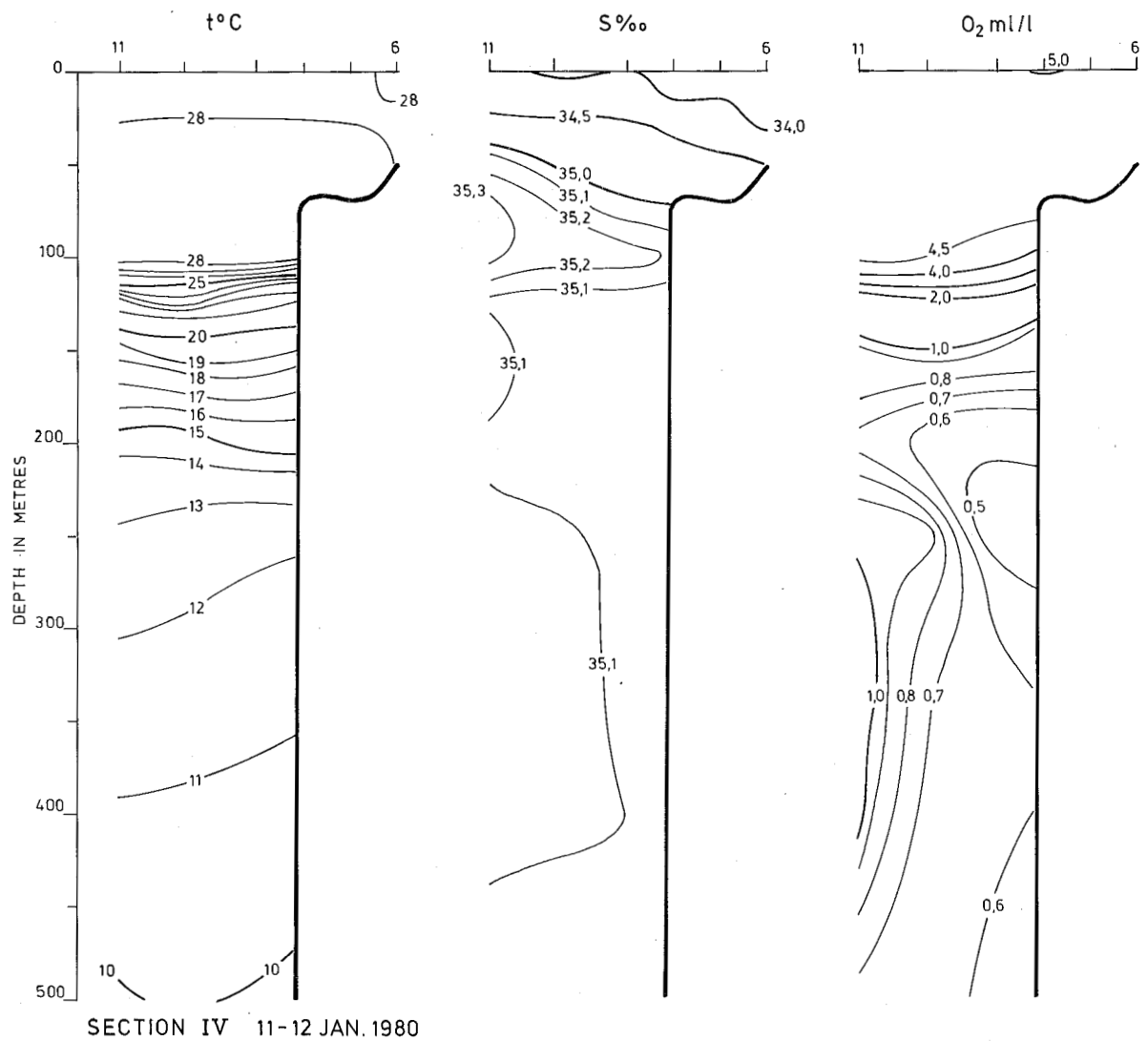

Fig. 4. Temperature, salinity and dissolved oxygen in section IV on the south-west coast.

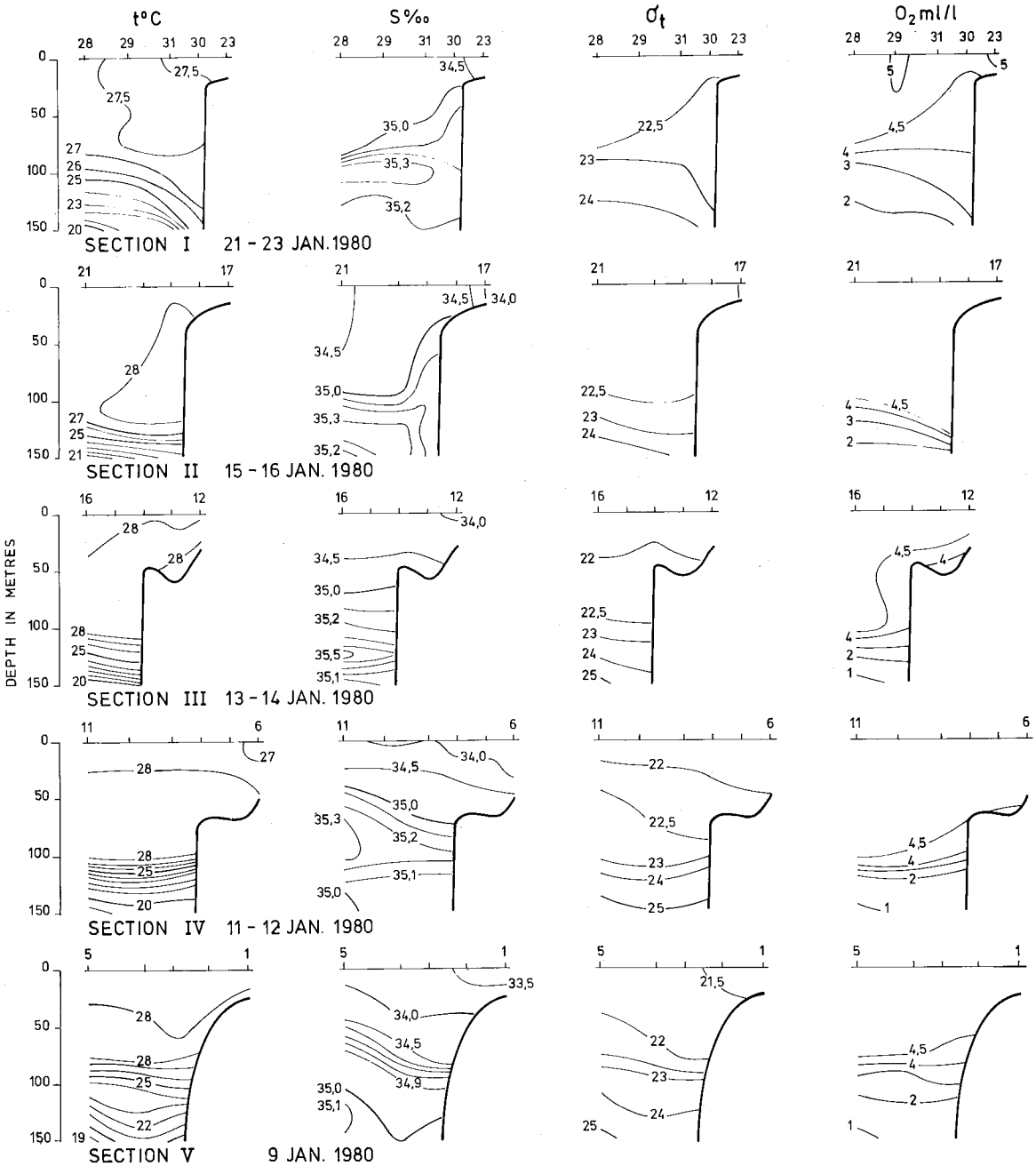

Fig. 5. Temperature, salinity, density (σ_t) and dissolved oxygen in the upper 150 m of sections I-V.

4.2 Hydrographic structure

Section IV of the south-west coast, is chosen to show the hydrographic conditions to 500 m depth (Fig. 4). Below the main thermocline the temperature decreased rather slowly with depth, from about 13 to 10°C between about 250 and 500 m depth. The salinity varied little below 150 m depth and was mainly close to 35.1°/oo. The slight salinity maximum between about 250 and 450 m depth with salinities in excess of 35.1°/oo indicates the Arabian Sea intermediate water. Such a salinity maximum was observed in this depth layer in all the sections, indicating that the Arabian Sea intermediate water was distributed off the entire stretch of continental slope around Sri Lanka. In general the hydrographic conditions below the thermocline were rather uniform in all sections. As regards the layers below the thermocline, Section IV is therefore representative for the whole coastal stretch around Sri Lanka.

The conditions above 150 m depth are illustrated in Figs. 5 and 6.

In section II off Negombo, the main thermocline was observed at about 130 to 160 m depth and was deeper and sharper than elsewhere along the coast. Also in sections III and IV the thermocline was situated below 100 m depth while it was observed somewhat shallower in the Gulf of Mannar (Section I). On the south coast and particularly on the east coast, the thermocline was somewhat less developed and the mixed layer was shallower than off the west coast, decreasing from about 70 m on the Pedro Bank to about 50 m on the south-east coast (Section VI). On the south coast the depth of the mixed layer was about 80 m.

The mixed layer was characterized by homogeneous temperature conditions. In the Gulf of Mannar the temperatures in the mixed layer were between 27.5 and 28.0°C. Southwards along the west coast the temperatures increased slightly and were mainly above 28.0°C off the south-west coast in Section IV.

divergence the current was flowing north along the coast with velocities mainly less than ½ knot.

4.4 Dissolved oxygen

As shown in Figs. 4, 5 and 6 the waters above the thermocline were rich in oxygen and the mixed layer contained generally more than 4 ml/l.

$T\text{-}O_2$ relationships for the west and east coasts are shown in Fig. 7. The figure indicates that also at the time of Survey III there was a well defined relationship between temperature and oxygen content. The oxygcline coincided with the thermocline and there was no difference between the east and west coasts with regard to this coincidence. Below the thermocline the oxygen content was mainly below 1 ml/l.

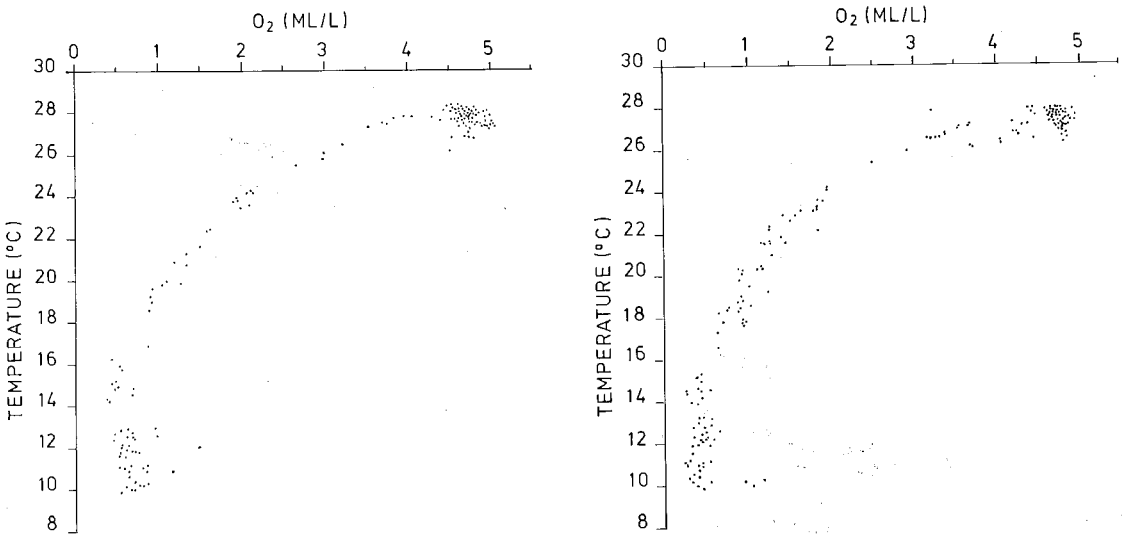

Fig. 7. $T\text{-}O_2$ diagrams for the sections on the west coast (left) and on the east coast (right).

4.5 Nutrients

The water samples for nutrients determinations were dispatched as frozen cargo from Colombo to Bergen. In Bergen the samples were received in a non-frozen condition.

Although the history of the samples from leaving Colombo till arrival in Bergen was not known, the nutrient values were in good agreement with duplicated samples and throughout the various sections.

There was also a fairly good agreement between these data and the data from the Indian Ocean Expedition (Wyrtki 1971). It is therefore considered justified to neglect possible effects due to the storage of the samples.

The distribution of nutrients follows, in general, the pattern of the salinity and temperature distribution, but will give a more complicated picture as the nutrients are influenced both by the hydrographic conditions and the biological processes taking place in the particular water mass.

Figs. 8, 9 and 10 show the distribution of phosphate, nitrate and silicate along sections I, IV and IX respectively. The distribution of phosphate shows a clear difference between the west and east coast (sections I and IX). While there is some phosphate above the thermocline on the west coast, there is complete depletion to about 75 m on the east coast. The amounts of phosphate below the thermocline is somewhat higher on the east coast.

Section IV representing the south-west coast, demonstrates a more complicated distribution of phosphate. Above the thermocline there are values well over 0.2 µM phosphate which are given as mean values by the Indian Ocean Expedition for the upper water masses of the whole area around Sri Lanka. Below the thermocline the phosphate distribution may indicate an upwelling process. This is also demonstrated by the nitrate distribution. Both the phosphate and nitrate distribution indicate that nutrient rich water has reached through the thermocline and up to the surface close to the shore. Such an upwelling is, however, not indicated by the temperature distribution (Fig. 4).

The nitrate distribution follows in general the phosphate distribution, but the depletion in the upper layers is more pronounced.

Silicate is in contrary to phosphate and nitrate influenced by runoff from land or/and contribution from the shallow waters with sand bottom along the coast, as is shown by the nearshore distribution.

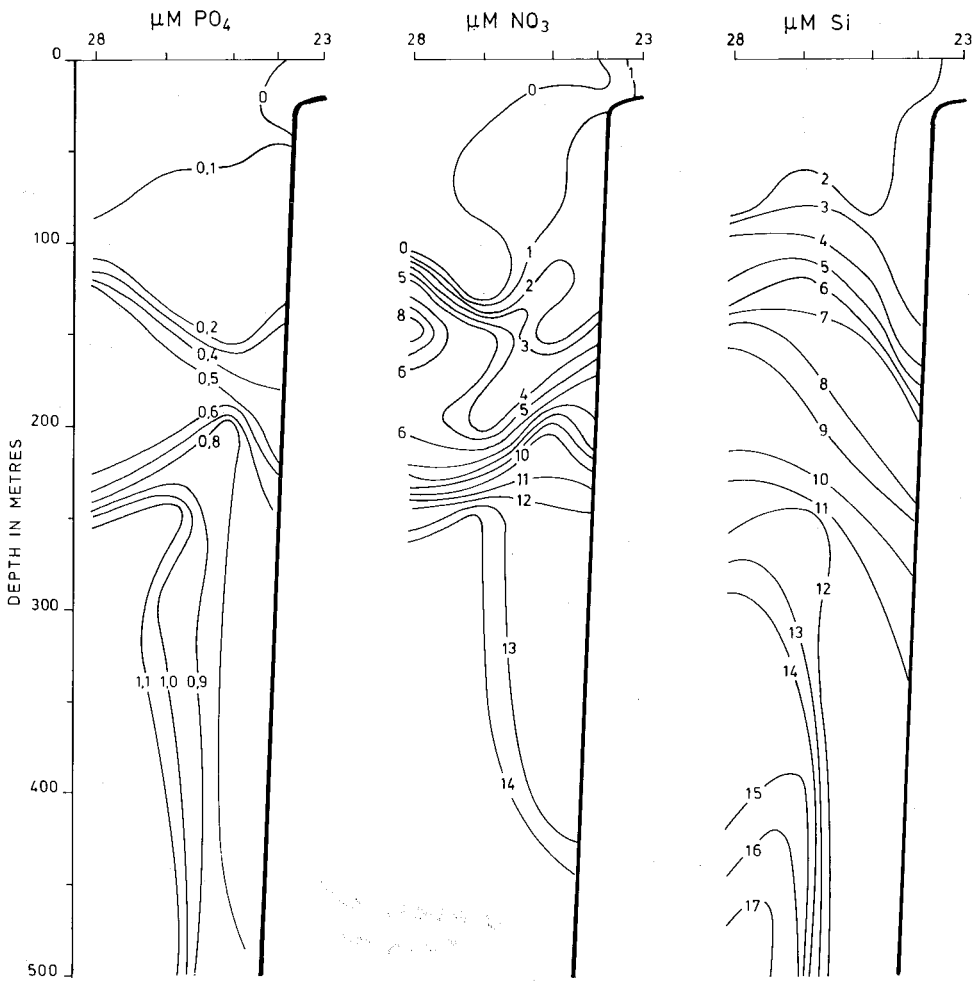

Fig. 8. Phosphate, nitrate and silicate in section I.

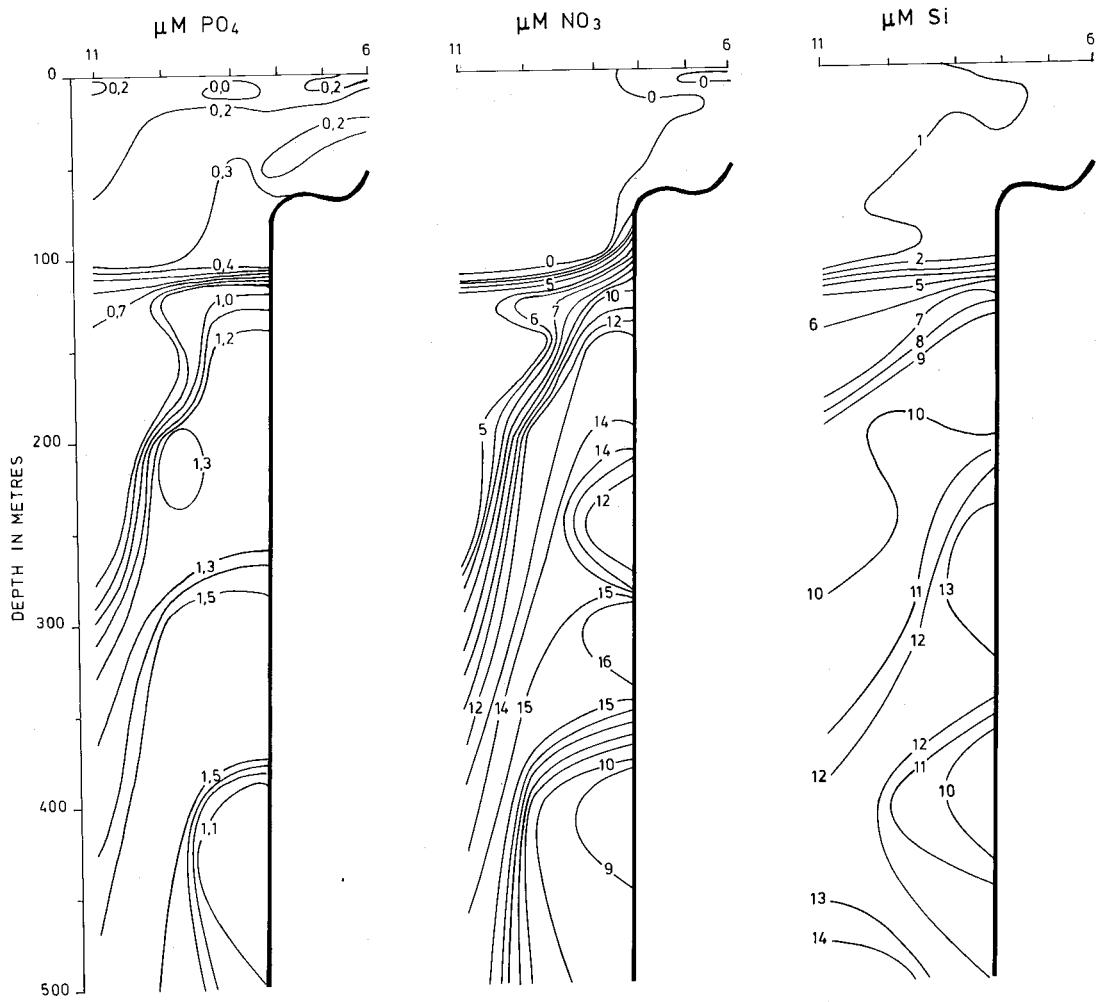

Fig. 9. Phosphate, nitrate and silicate in section IV on the south-west coast.

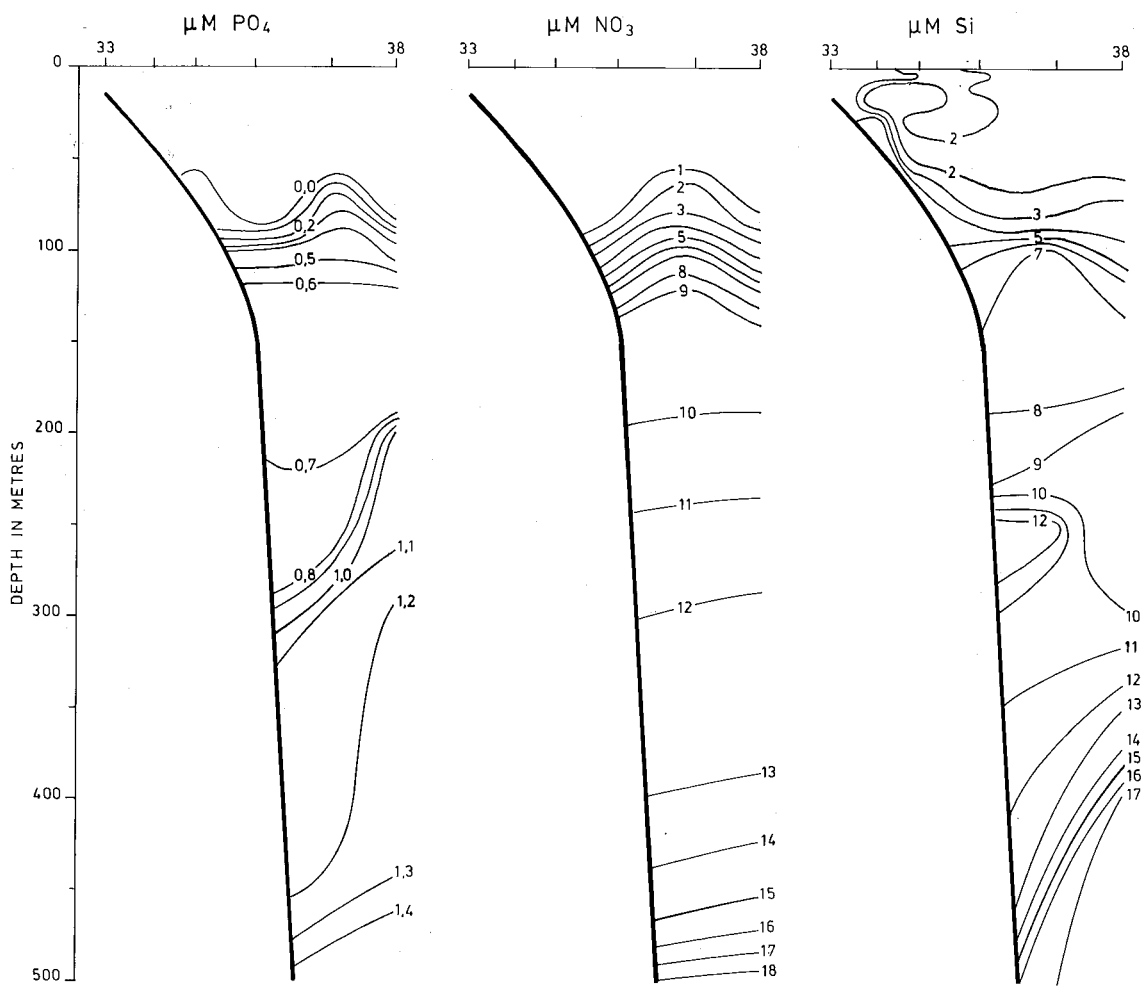

Fig. 10. Phosphate, nitrate and silicate in section IX on the Pedro Bank.

4.6 Seasonal variations

Comparison of the hydrographic observations made during the three surveys give some information on the conditions in three different seasons, i.e. in the beginning of the SW-monsoon, the end of the SW-monsoon and in the NE-monsoon. The most conspicuous feature is the seasonal reversal of the current with the monsoon. Both during Survey II in April - June, and Survey I in August - September, the current was governed by the SW-monsoon and the general oceanic circulation in the region was from west to east.

Off the south-west and south coasts of Sri Lanka there was strong current towards south-east and east with current velocities between 2 and 3 knots near the shelf break. On the east coast current velocities were more moderate. In May - June the current along the north-east coast, north of Trincomalee was directed towards north with maximum velocities between 1 and 2 knots. The more moderate current further south was mainly southerly. In August - September the current directions were generally from west and north, also then with fairly high velocities reaching 2-3 knots off the south and south-west coast.

During the north-east monsoon the circulation is reversed and the oceanic drift is generally from east to west. In this season the current velocities are generally weaker than in the south-west monsoon, and during Survey III the strongest current near the shelf edge on the south and south-west coast was assessed to be between 1 and 2 knots, now running towards west and north-west. North of 7 to 8^{o}N the current directions were now mainly northerly and velocities were moderate.

The depth of the thermocline varied somewhat with the seasons. Generally it was observed at greatest depths during Survey III, i.e. in the north-east monsoon season.

On the west coast the upper portion of the thermocline was observed at 100 to 125 m depth during Survey III. During the two other cruises, early and late in the south-west monsoon, it

was observed between 40 and 60 m depth and there was no marked difference in the depth of the thermocline between these cruises.

On the south coast the depth of the thermocline was also the same during Survey I and II. During Survey III it was 20 to 30 m deeper, between 70 and 100 m.

On the east coast, south of the Pedro Bank, the depth of the thermocline was about the same during Survey II and III, its upper portion mainly being found at 50 to 70 m depth. During Survey I (September) it was about 20 to 40 m shallower.

On the Pedro Bank the depth of the thermocline tilted up towards the shore during Survey I and II. During Survey I its depth ranged between 30 and 50 m while it was slightly deeper during Survey II. During Survey III the thermocline was mainly below 80 m depth.

The salinity maximum in the upper portion of the thermocline due to Arabian Sea water was on the west coast most pronounced during Survey II when its salinities exceeded 35.5°/oo in Section IV. Its widest distribution was, however, observed during Survey III. In contrast to the findings of the two other cruises, it was then observed in the sections on the east coast. During the north-east monsoon season the general current circulation is directed towards west. Along the east coast this resulted in a northward drift north of 7 to 8°N by the time of Survey III, and the Arabian Sea water is probably transported with the north-east monsoon circulation from areas south-east of Sri Lanka.

Below the thermocline there were no significant differences between the three surveys. The same water masses were observed and there were no marked fluctuations in their distribution or properties.

5. SURVEY RESULTS

5.1 Coverage, interpretation and classification of the echo recordings

The shelf area was, as indicated in Fig. 1, quite densely covered. In the locations of the hydrographic sections acoustic observations and fishing experiments were also made to sample the more oceanic conditions at some distance beyond the shelf. The type of gear used on the different fishing stations is indicated in Fig. 1.

For the matter of comparability, care was taken to follow the same procedures and routines as during the two previous surveys. The reservations previously connected to the survey method therefore applies equally for all three surveys. Assessment of the abundance of fish resouces on the basis of acoustic observations combined with experimental fishing is a method which is most suitable for fish observed in midwater. Such a behaviour characterizes a considerable number of the fish species found around Sri Lanka. There are, however, also notable exceptions, e.g. bottom dwelling fish which due to the limitation of the echo sounder in observing fish close to the bottom (within ½ - 1 m) may avoid detection. The echo sounder also have limitations in detecting fish close to the surface such as surface schooling tunas and tuna-like species. For navigational safety reasons survey work with the "Dr. Fridtjof Nansen" is limited to waters deeper than about 10 m. The extreme inshore waters and the extensive shallow areas stretching from the Gulf of Mannar to the Palk Strait could concequently not be covered. At some distance beyond the shelf edge observations were only made in the locations of the hydrographic sections. Resources of tuna and tuna-like species may occur in these offshore waters, but they are not primary target species for the present type of surveys although they are to some extent recorded by the acoustic system.

According to the types of echo traces the acoustic recordings were classified in different categories. Interpretation of the echo recordings was done as during Survey I and II and fish recordings were classified in three main categories:

a) Schools and aggregations of apparently larger fish near the bottom and in mid-water. These are ascribed to demersal or semi-demersal fish such as snappers, breams, groupers, jack mackerel etc. As during the two first cruises this was by far the most common type of recordings also during the present cruise. Fig. 11 shows typical recordings of this type from the south-west coast.

b) Single fish traces or small schools of bigger fish closer to the surface waters (Fig. 12). These recordings are thought to derive from tunas and tuna-like fish. They were less common and were mainly observed on the south coast. Probably such registrations were often "lost" in dense plankton recordings near the surface.

c) Recordings of true larger schools or dense layers mostly in upper water layers. These will most often derive from pelagic schooling fish, usually of smaller size, e.g. clupeoids, scads. Fig. 13 shows recordings from the largest concentrations of small pelagic fish observed during the present cruise. These consisted of Decapterus sp. on the eastern Pedro Bank. It is possible that dense plankton recordings in some places may have obscured also recordings of small pelagic fish.

Besides the three groups of fish a fourth group of organisms, actually the most abundant one, was interpreted to derive from plankton organisms. The abundance of plankton was at about the same level during the three surveys, possibly somewhat lower in the period of the present cruise than during the two previous surveys. The distribution pattern was also about the same as in the previous surveys with densest concentrations near the shelf edge.

Also during the present cruise mesopelagic fish was recorded beyond the shelf, mainly on the west coast. The concentrations were densest in the vicinty of the continental slope, but quantities were generally small and of no commercial importance.

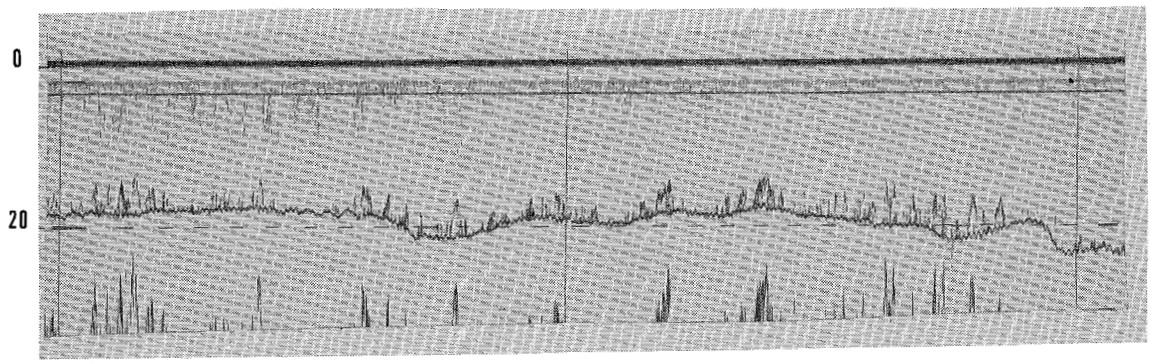

Fig. 11. Echo recordings of demersal and semi-demersal fish, "Type A", in Sub-area II.

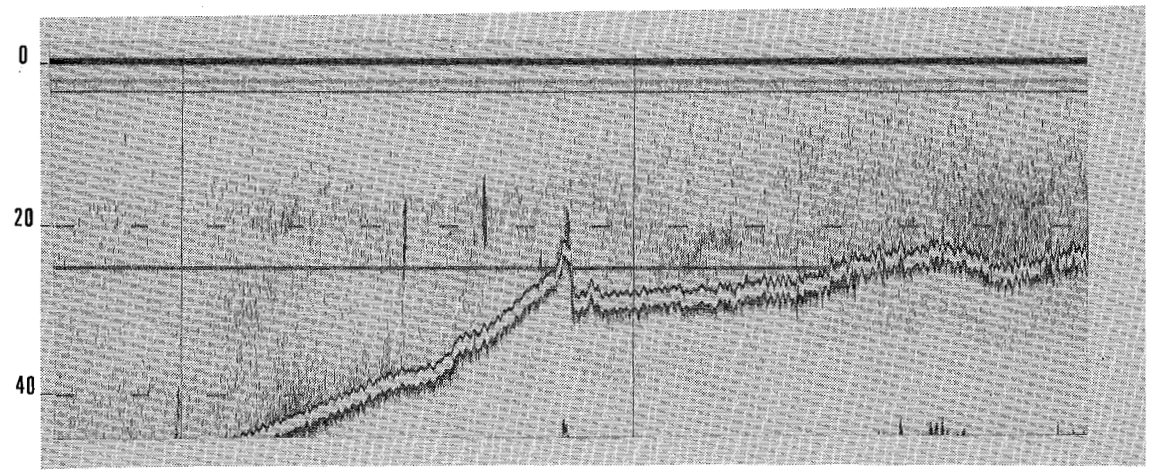

Fig. 12. Echo recordings of dispersed pelagic fish, Type B.

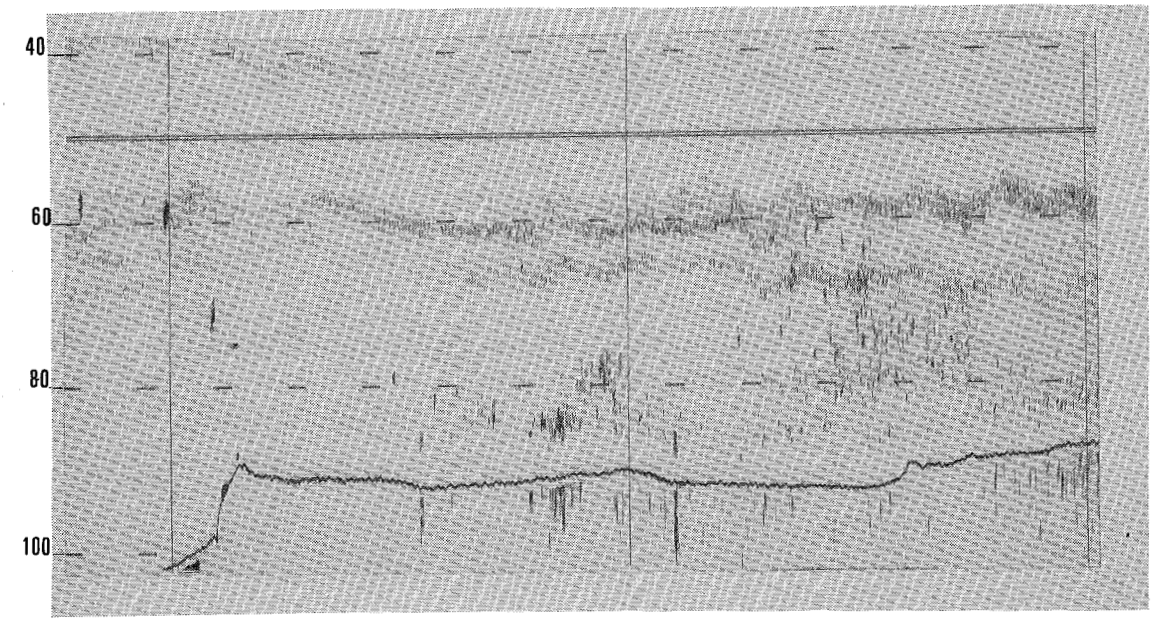

Fig. 13. Echo recordings of small pelagic fish, Type C, on the Pedro Bank.

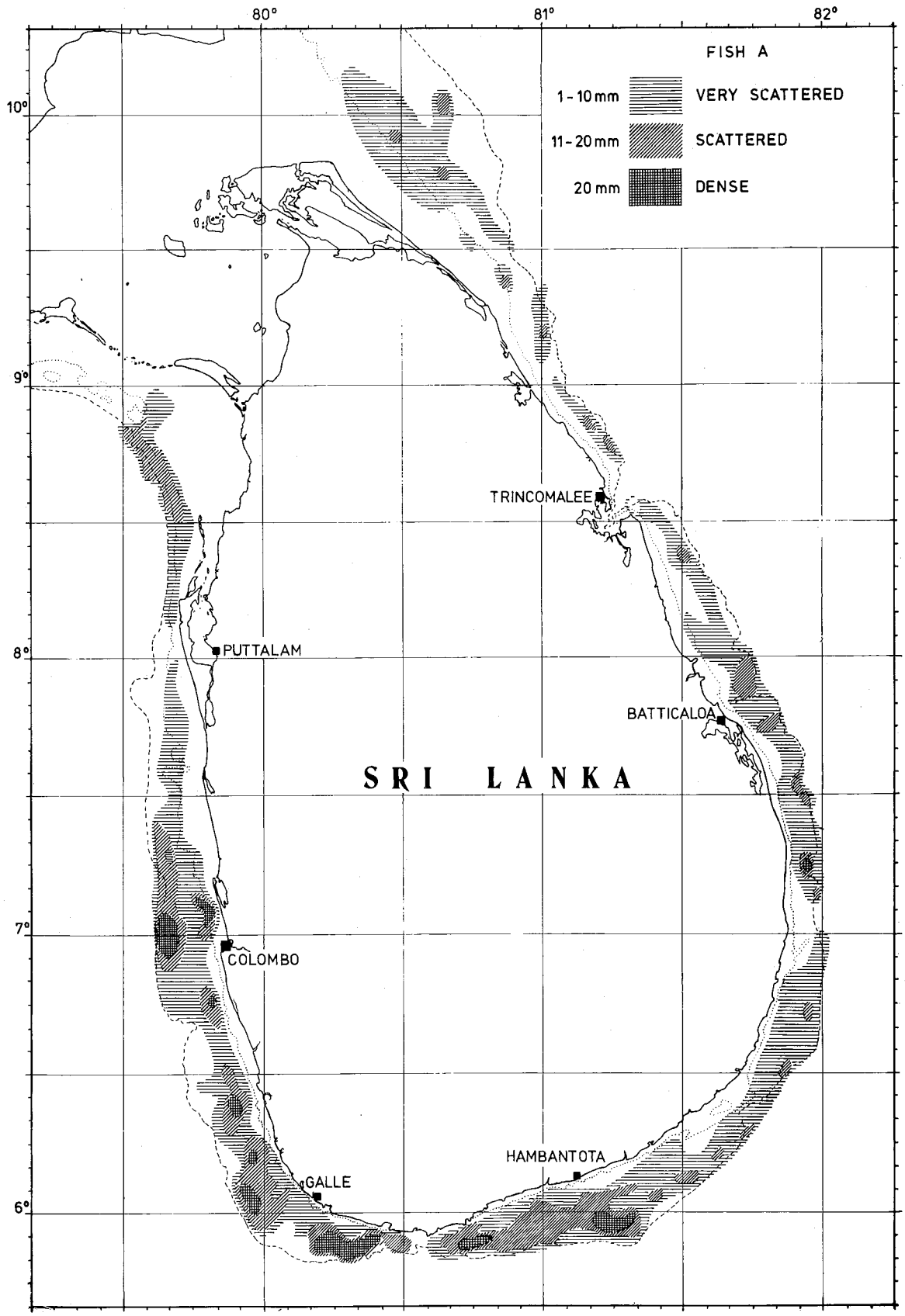

Fig. 14. Distribution of echo intensity of recordings classified as demersal and semi-demersal fish (Type A). Indices of abundance by levels of integrator deflection (mm per nautical mile).

In the Gulf of Mannar and east of the Pedro Bank, bottom trawling was possible at greater depths than elsewhere in the survey area. These areas yielded large catches of deep-water fish.

5.2 Fish distribution and abundance

In the processing of the acoustic data the echo integrator readings interpreted to derive from fish resources were ascribed to the three categories of fish mentioned above. Distribution charts were prepared for each category by plotting the integrator readings ascribed to the category along the course lines. As during surveys I and II, Type A was again the most abundant. Its distribution is shown in Fig. 14 together with indices of abundance. Type B was during the present cruise the least significant category. The distribution of Type B is illustrated in Fig. 15. Fig. 16 shows the distribution of Type C. The abundance of this category which was at a very low level during survey II, had again increased, and it was now assessed to be more abundant than Type B.

Also during the present cruise it was on some occasions not possible to identify the echo recordings by fishing. In some cases the interpretation of fish recordings was therefore doubtful. In such cases pelagic species were more likely to be classified as Type A than opposite.

For the analysis of the fish data, the shelf area is devided into 6 sub-areas as described in Report I:

I The north-west coast north of Negombo ($07^{o}15'N$), including the Sri Lankan part of the Gulf of Marmar.

II The south-west coast south of $07^{o}15'N$ and west of $80^{o}30'E$.

III The Hambantota Banks, the south coast east of $80^{o}30'E$ and south of $06^{o}20'N$.

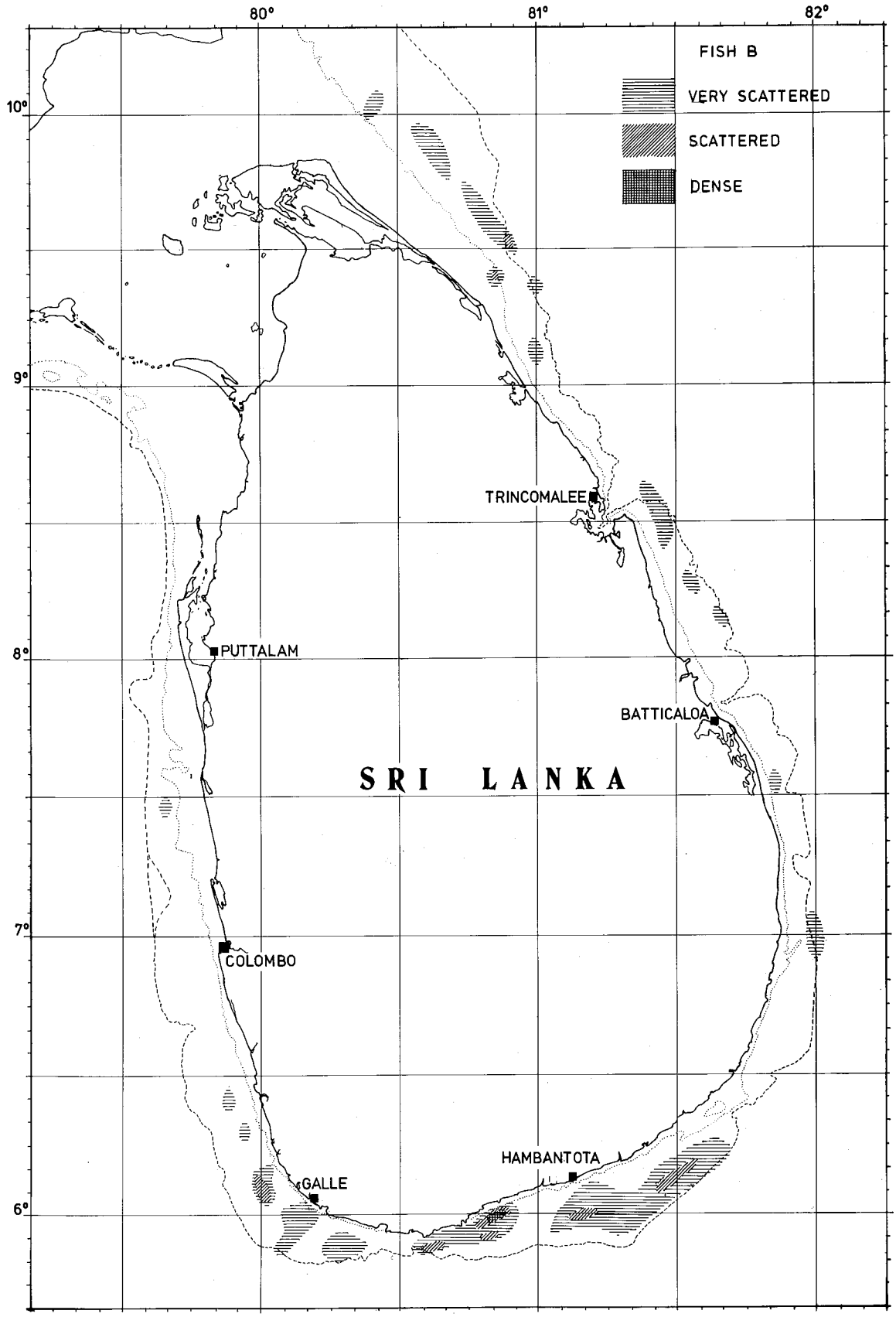

Fig. 15. Distribution of echo intensity of recordings classified as larger pelagic fish (Type B). Indices of abundance by levels of integrator deflection (mm per nautical mile).

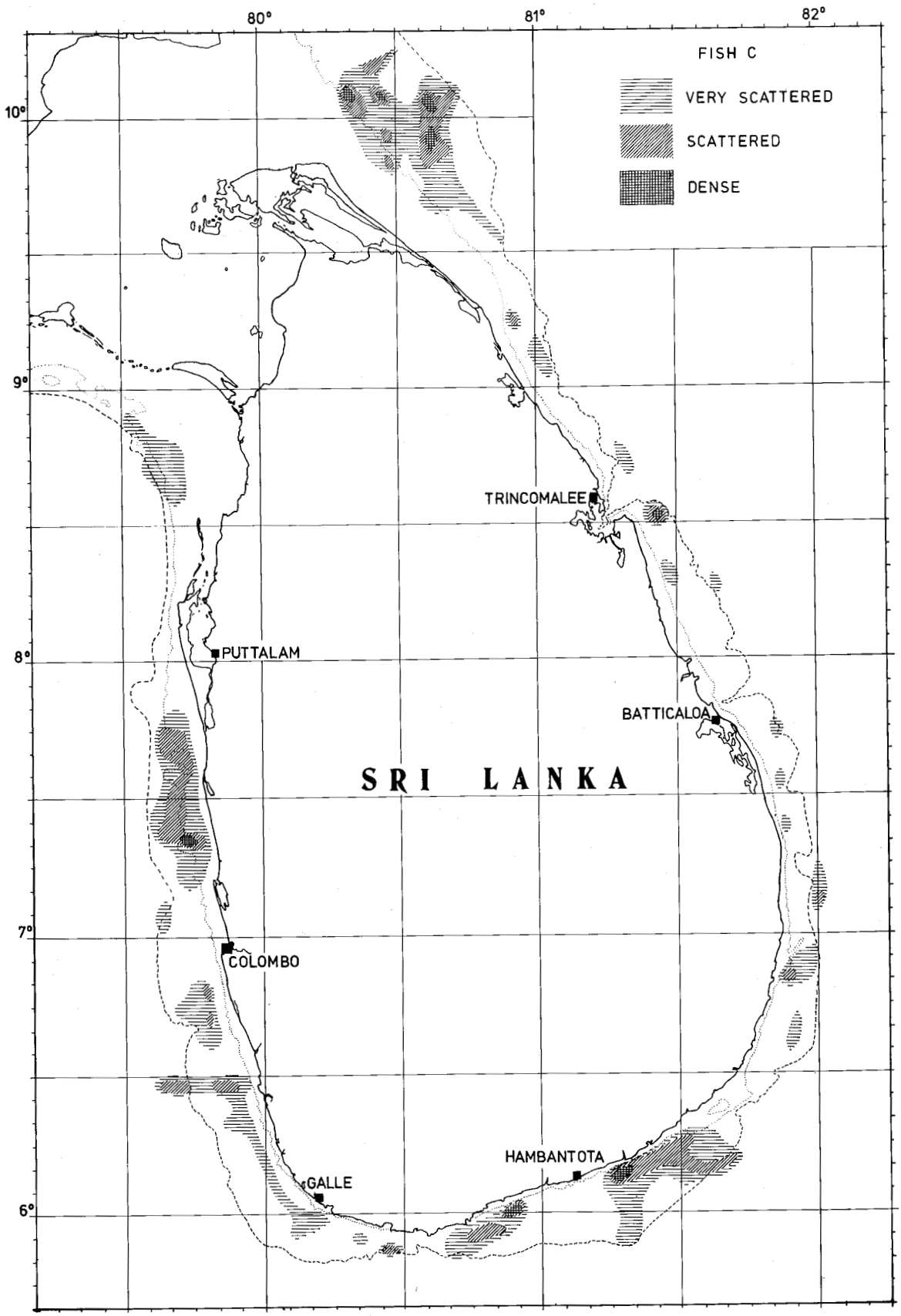

Fig. 16. Distribution of echo intensity of recordings classified as small pelagic fish (Type C). Indices of abundance by levels of integrator deflection (mm per nautical mile).

Table 1. Summary of length measurements by species or species groups - fork length.

cm	Breams	Groupers	Snap-pers	Sweet lips	Surgeon fish	Caranx	Bara-cuda	Scombro-idae	Indian macker.	Sar-dines	Misc.
5- 9			6			25				1	214
10-14	68		82			433	17		30	1	406
15-19	215		121		2	198	2		7	45	397
20-24	133		72		1	173	89		4		188
25-29	93	1	41	1		84	67				40
30-34	88	8	21	9	4	39	77	2			39
35-39	78	6	26	16	6	13	13				46
40-44	90	2	24	20	26	20	13				40
45-49	128	4	52	21	35	10	9	1			18
50-54	144	17	31	14	4	12	3	2			6
55-59	74	45	18	25		4	6	21			21
60-64	13	27	24	18		4	1	9			26
65-69	2	10	10	4		7	1	1			21
70-74	4	4	9	1		9	2				14
75-79	6		2			4	1	5			9
80-84	1	3				1	1	4			12
85-89		2				2	6	2			5
>90		3					13	1			2
N	1137	132	538	129	78	1038	321	48	41	47	1504

5.3.2 Area I, the North-west Coast

This area was surveyed in the period 16-25 January. Fishing experiments on the deep-water trawling ground and trials with oysters dredge on the pearl banks in the area were also carried out in this period. The survey tracks and positions of fishing experiments are shown in Fig. 1.

The total fish biomass in the area was estimated to be 55 000 tonnes. Out of this 35 000 tonnes were classified as demersal and semi-demersal fish, the abundance of small pelagic fish was assessed at 20 000 tonnes while the assessment from recordings interpreted as Type B was practically zero. Here the shortcoming of the acoustic method to observe fish very close to the surface should be kept in mind. In several cases surface schooling tuna was observed visually in the Gulf of Mannar, but were not recorded by the echo sounders. Local fishing boats were fishing on the schools with live bait. The assessment of pelagic species is therefore definitely an underestimate.

Table 2. Indices of integrated echo abundance and assessment of standing biomass.

Area	Demersal Type A		Pelagic Type B		Small pelagic Type C		Total
	Index of echo abundance	Estimated biomass 1000 tonnes	Index of echo abundance	Estimated biomass 1000 tonnes	Index of echo abundance	Estimated biomass 1000 tonnes	
I. NW coast	2350	35	20	-	3110	20	55
II. SW coast	7570	105	690	10	1660	10	125
III. Hambantota Banks	4060	55	3210	40	2590	15	110
IV. E coast	2010	30	165	-	320	-	30
V. Trincomalee-Mullaittivu	620	10	220	5	632	5	10
VI. Pedro Bank	1600	15	420	5	4260	25	45

With regard to small pelagic fish, Type C, the assessment of 20 000 tonnes represented an increase from the last survey. As indicated in Appendix table II these resources consisted mainly of small scads, indian mackerel and small trevallies.

The assessment of demersal resources represented a considerable decrease to only about a fifth of the assessment during Survey II.

The results of the fishing experiments are summarized in Table 3, and more details on each fishing station are given in Appendix table I.

Data on 6 trawl hauls on the deep-water trawling ground in the Gulf of Mannar is given in Table 4. As shown in the table relatively high catch rates of lobster, prawns and deep-water fish were obtained also now. The average catch per hour was 260, 70 and 3500 kg of lobster, prawns and deep-water fish respectively. Provided that the trawl net catches all the lobster in its path, this indicates a density of 13 tonnes of lobster per square nautical mile. This is a definite lower limit since the catch efficiency of the trawl is certainly not that high. Although the ground seems rich, the availability of the lobster is still limited since the extention of the trawlable

ground is only some few square nautical miles. The catches also indicate high abundance of deep-water fish, assuming a catch efficiency of 100°/oo the lower limit being about 175 tonnes per square nautical mile.

Table 3. Summary of fishing stations in Area I, NW coast north of Negombo.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers etc.	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other commercial	Other non-commercial
39	25	24					1
41	341	201				140	
42	317	237				80	
43	57	4	6	44		3	
44	19		16			1	20
45	141		40	82		19	
46	76	60				13	3
47	9	4	5				
54	452	77	200			175	
58	14	11	3				
66	51		48			3	
67	52		16			35	
68	72		31			41	
71	16			8		8	

Pelagic trawl (Catch per hour, kg)

Station no	Total catch	
48	20	Myctophidae (10), deep-water fish (10)
49	20	Myctophidae (15), small squid (4), decapterus sp. (1)

Bottom long line (Catch kg)

Station no	No hooks	Total catch	Snappers breams groupers etc.	Trevally mackerel etc.	Sharks rays	
38	100	4	4			
50	200	181	175	2	4	
56	100	76	76			
61	120	53	47		6	
63	200	34			34	
64	200	5	2		3	

Table 4. Summary of fishing stations in Area I, Gulf of Mannar, deep sea trawling ground. (Station no 51, 55, 57, 59, 60, 62 22 - 24 January 1980). Total catch composition.

Bottom trawl (Catch per hour, kg)

Station no	Fish	Shrimp	Lobster
51	6400	11	136
55	2000	7	98
57	5600	24	566
59	1520	60	231
60	2182	146	236
62	2560	3	320

Lobster	(Puerulus sewcelli)	810 kg	7%
Shrimp	(Aristacus semidentatus) (Heterocaypus gibbosus) (Parapandalus spinipes) (Metapenacopsis andamancnsis)	210 kg	2%
Deep-water fish		10500 kg	91%
	(Chloropthalmus agassizi) 80% (Epinnula orientalis) 12% (Centrolophus sp.) 1% (Myctophids) 7% Other varieties in small quantities		

5.3.3 Area II, the South-west Coast from Negombo to Galle

The Survey work in this area was carried out during the period 11-16 January. The estimated abundance of the total fish biomass in the area amounted to 125 000 tonnes. As in the two previous surveys, Area II was again the sub-area with the highest assessment of total fish biomass, but the assessment was less than in the two previous surveys. The decrease since Survey II was mainly due to a lower estimate of the abundance of demersal and semi-demersal fish. The resources of pelagic fish, Type B, were assessed to 10 000 tonnes which is half the assessment from Survey II. The resources of small pelagic fish had, however, increased and the total quantity of pelagic fish was about the same as during Survey II. Compared with Survey I the decrease in total resources was almost 100 000 tonnes, mainly due to a

considerable lower estimate of pelagic resources.

The densest concentrations in sub-area II were during Survey III observed in the very southern part of the area, south-east of Galle. Relatively dense concentrations were also observed on the outer part of the shelf north-west of Colombo. The resources on the nearshore part of the shelf north of Colombo were in contrast to the previous surveys rather moderate.

Table 5 summarizes the results of the fishing trials. The catch rates of the bottom trawl are rather low, but it should be noted that they are not representative for the densest concentrations of fish which always occurred on rough, untrawlable bottom. Also the average catch on bottom long line was lower than previously. The trials with long line were, however, too few for any definite conclusions to be drawn.

5.3.4 Area III, the Hambantota Banks

This area, the relatively broad shelf between Dondra Head and Little Basses Reef, was surveyed from 9 to 11 January. Some fishing experiments were also carried out in the eastern part of the area on 9 February. The recordings were relatively abundant during the present survey and the resulting assessment amounted to 110 000 tonnes which is higher than the assessments of the two previous surveys, slightly higher than the one from Survey I and about trice the assessment from Survey II. The Type A resources were assessed at 55 000 tonnes while pelagic fish of Type B and C were estimated to be 40 000 and 15 000 tonnes respectively.

The densest recordings of demersal and semi-demersal fish were recorded on the outer shelf from somewhat east of Hambantota to Dondra Head. The pelagic resources were mainly distributed in the eastern part of the sub-area. The resources of Type B in this area actually accounted for two thirds of the Type B resources of the whole survey area.

The results of the fishing experiments are given in Table 6 and details of the separate stations are entered in Appendix table I.

Table 5. Summary of fishing stations in Area II, SW coast, Negombo to Galle.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other commercial	Other non commercial
15	36	2	25		6		3
16	152	116	6		9	18	3
20	115	14	37	2	38	19	5
21	249	61	19		116	27	26
24	624	106	167	16	220	109	6
25	133	90			5	15	23
30	35	14	2		3	1	15
31	44	17				2	25
32	28	8					20
34	198	132	5			61	
35	288	236	1			51	15
36	529	465	49				
40	290	51	147			77	15
69	0						
70	328	258	43			27	
71	16					16	

Pelagic trawl (Catch per hour, kg)

Station no	Total catch	Other commercial	Other non commercial
17	6		6
18	14		14
22	1		1
26	6	2	4
29	2		2
37	0		
72	109	4	105

Bottom long line (Catch kg)

Station no	No hooks	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Sharks rays
19	200	42	32	5	5
23	200	12		3	9
27	200	25	7	18	
28	200	33	25	8	
33	20	2	2	180 hooks lost	

Table 6. Summary of fishing stations in Area III, Hambantota Banks.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other commercial	Other non commercial
1	0						
2	106	96			6	4	
3	14	1			7	1	5
5	131	120	1			8	2
6	32	1	1			4	26
7	13	9					4
8	126	119				7	
9	28				19		9
11	179	144	2			12	21
12	116	64	13	1	5	6	27
14	134	26	46		18	28	16
132	584	570				14	

Pelagic trawl (Catch per hour, kg)

Station no	Total catch	Small pelagic	Other commercial
4	7	6	1
10	2	1	1

Bottom long line (Catch kg)

Station no	No hooks	Total catch	Trevally mackerel sphyraena etc.	Sharks rays	Other commercial
13	0	Complete line lost			
133	200	14	14		

5.3.5 Area IV, East Coast and Batticaloa Banks

This area was surveyed in the period 7-9 February. Almost all the resources in this area were classified as demersal fish which were assessed to account for 30 000 tonnes. Pelagic resources were quite sparse in this area and neither of the two categories was assessed to exceed 3000 tonnes. Put together, Type B and Type C were assessed at hardly 5000 tonnes. The assessment of total fish resources represents a decrease since Survey II and it is less than one third of the assessment from Survey I, the assessments of these surveys being 55 000 and 120 000 tonnes respectively.

The demersal resources were fairly evenly distributed on the shelf which in this area is rather narrow. Type B was observed only in a few isolated areas near the edge. Also Type C only occurred southward from Batticaloa in some areas of limited extention (Figs. 15, 16 and 17). Table 7 shows in summary the results of the fishing operations in the area. The catch rates were generally low, the best catches being taken in shallow waters also during this cruise.

5.3.6 Area V, Trincomalee - Mullaittivu

This area was surveyed in the period 5-7 February. The total fish resources in this area were assessed to be hardly 20 000 tonnes. Demersal and semi-demersal resources accounted for about 10 000 tonnes while hardly 10 000 tonnes of pelagic resources were equally devided on Type B and Type C. This assessment of Type A represents a reduction to the half in relation to Survey II. The assessed resources of pelagic fish represents on the other hand an increase of approximately 5000 tonnes, mainly due to increasing quantities of Type C.

The densest registrations in Area V were observed just south of Trincomalee. Between Trincomalee and Mullaittivu the registrations were very scattered. As shown in Table 8, the catch rates were low, particularly with regard to the most common demersal species.

Table 7. Summary of fishing stations in Area IV, east coast and Batticoloa Banks.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other commercial	Other non commercial
117	731	267	285	16	22	191	
118	4		4				
119	0						
120	78	68	6		4		
121	0						
122	4		1			3	
124	48	48					
125	66	66					
126	18		4			14	
127	100	74				26	
128	32	26				6	
129	5					5	
130	13	6	1			6	
131	372		46	26	300		

Pelagic trawl (Catch per hour)

Station no	Total catch
116	0

Bottom long line (Catch kg)

Station no	No hooks	Total catch	Snappers breams groupers etc.
123	100	12	12

Table 8. Summary of fishing stations in Area V, Trincomalee to Hullai Hivu.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers etc.	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other com-mercial	Other non com-mercial
106	31	6	5			20	
107	322	70	136	46		71	
108	231		25	160		46	
113	0						
115	11					11	

Pelagic trawl (Catch per hour, kg)

Station no	Total catch	
104	192	Mackerels, various pelagic fish, small scads
111	0	
114	2	Fish larvae, Myctophids

Long line (Catch kg)

Station no	No hooks	Total catch	Snappers breams groupers etc.	Trevally mackerel sphyraena etc.	Sharks rays	Other com-mercial
105	200	28			7	21
112	200	13	4	5		4

5.3.7 Area VI, the Pedro Bank

The vessel worked on the Pedro Bank from 31 January to 5 February. After the acoustic survey work was done, a grid of trawl hauls were operated to get sufficient data for an assessment of demersal resources based on the catch rates.

The total fish biomass was assessed at 45 000 tonnes. This is a considerable increase since Survey II and is also about 15 000 tonnes in excess of the assessment from Survey I. The increase is mainly due to the increased stock of small pelagic fish which during Survey III was assessed at 25 000 tonnes. The Type C recordings consisted mainly of small scad which were distributed on the outer part of the bank, mainly beyond 50-60 m bottom depth. The concentrations were generally observed deeper than 50 to 60 m.

The demersal and semi-demersal resources were assessed at 15 000 tonnes and were evenly distributed over the shallower parts of the bank. This assessment is about 5000 tonnes higher than the assessment from Survey II. The average catch rates obtained with the bottom trawl were, however, lower than during Survey II and were suggestive of lower abundance.

A deep-water haul at 225 m depth in the relatively gentle slope of the bank towards greater depths, yielded a catch of deep water fish which exceeded 5 tonnes per hours tow. The catch contained small quantities of deepwater prawns and crabs, but no lobster. Deep water fish accounted for more than 95% of the catch. As in the Gulf of Mannar Chlorophthalmus agassisi and Epinnula orientalis, were also here the most important species. In two hauls at about 150 m Nemipterus spp and crabs were most abundant, and the deep-water species above were of little importance.

Catch rates and details on the fishing experiments on the Pedro Bank are given in Table 9 and Appendix table I.

Table 9. Summary of fishing stations in Area VI, Pedro Banks.

Bottom trawl (Catch per hour, kg)

Station no	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Small pelagic	Sharks rays	Other commercial	Other non commercial
73	88	4	1	65	5	13	
75	3					3	
76	5					4	1
77	342	Deep-water spp				342	
79	285	Deep-water spp				285	
81	22	11	6			5	
82	371	36	23		302	10	
83	60		48			12	
85	425		204	33		188	
86	0						
87	19		15			4	
88	133	99	34				
89	159	17	17		120	5	
90	43		9		4	30	
91	356	270	16		63	7	
92	249	179	40			30	
93	90	87	3				
94	86	57	4		15	10	
96	0						
97	256	161	12		80	3	
98	373	29	13	5	277	49	
99	5380	Deep-water spp					
100	0						
101	232	23	78	32	78	21	
102	27	15				12	
103	201	192				9	

Pelagic trawl (Catch per hour, kg)

Station no	Total catch	
74	54	Fish fry, juvenile squid
78	104	Decapterus sp (100), spanish mackerel (4)
80	7	Fish fry (7)

Bottom long line (Catch kg)

Station no	No hooks	Total catch	Snappers breams groupers sweet lips	Trevally mackerel sphyraena etc.	Sharks rays	Other commercial
84	200	20		10	3	7
95	200	12	12			

5.3.8 Estimate from trawl survey

Data from the trawl operations made on the Pedro Bank during Survey II were applied for an assessment of the demersal resources in the bank area. The result agreed reasonably well with the acoustic assessment.

Also during the present survey the number of trawl hauls worked on the Pedro Bank was sufficient for an assessment of the demersal resources.

The method for assessment of demersal resources on the basis of trawl catches is described in detail in Report II. The fish biomass per square nautical mile is calculated from the catch and the area swept by the trawl net during the tow. The same type of trawl net was used during the present survey as during Survey II. The distance between the wing ends was about 15 m and with a net sonde its vertical opening was found to be about 5 m.

An estimate of fish resources from catch rates in a trawl survey, is dependent on the efficiency of the trawl applied. Reliable data on trawl gear efficiency are scanty. As a first approximation the assumption of a catch efficiency of 100%, i.e. the efficiency coefficient, F, is 1.0, will give a minimum assessment (Saville 1977). Practical efficiency coefficients will be considerably lower (Harden Jones et al. 1977, Dickson, 1974). In Report II an efficiency coefficient of 0.5 was applied for the trawl net used. This means that the trawl catches 50% of the fish which is in the path of the trawl net during the tow.

Catch per square nautical mile for the bottom trawl stations on the Pedro Bank are given in Table 10 together with other relevant trawl data. The catch per square nautical mile for the trawl stations were plotted in a chart and additional values were determined by interpolation between trawl stations. This resulted in the distribution chart shown in Fig. 17. The main difference

Table 10. Data on fish density on bottom trawl stations. Catch per square nautical mile calculated from catch and area swept by the trawl net.

Stn No	Depth m	Dist. towed nm	Area swept	Catch kg	Catch/nm^2 kg
73	73	1.4	0.011	43.7	3973
75	74	1.3	0.011	1.5	136
81	47	1.3	0.011	11.3	1027
82	22	1.5	0.012	185.3	15442
83	16	1.8	0.015	39.7	2647
85	24	1.2	0.010	213.5	21350
86	16	1.3	0.011	no catch	
87	25	1.1	0.009	18.2	2022
88	22	1.5	0.012	66.8	5567
89	17	1.2	0.009	60.0	6667
90	20	1.4	0.011	20.6	1873
91	32	1.4	0.011	30.0	2727
92	36	1.4	0.011	124.2	11291
93	28	1.3	0.011	48.2	4382
94	27	0.9	0.007	34.4	4914
96	14	1.4	0.011	no catch	
97	15	1.5	0.012	128.7	10725
98	15	0.7	0.006	80.8	13467
100	36	1.3	0.011	no catch	
101	54	1.5	0.012	115.3	9608
102	46	1.6	0.013	14.0	1078
103	52	1.2	0.009	80.2	8911

on the north-west coast were observed on the outer part of the shelf, stretching northwards from a rich area west of Colombo. This indicates that a part of the demersal stock may have migrated towards greater depths. The possibility for such a migration is supported by the hydrographic observations. The thermocline was during Survey III, in the north-east monsoon, situated deeper than during the two previous surveys. On the west coast the demersal species now found waters with acceptable oxygen contents to about 125-150 m depth. It is therefore possible that a portion of demersal resources during the north-east monsoon were concentrated at relatively great depths near the edge. In these areas where the bottom at places is very rough and steep, the echo sounders may have considerable limitations in observing fish close to the bottom. The accuracy of the acoustic survey method may therefore in such a case be reduced and a considerable underestimate may occur.

On the east coast the demersal resources occurred rather evenly scattered along the coast and no considerable dense concentrations were observed. The assessment of 55 000 tonnes of demersal and semi-demersal fish agree fairly well with previous findings. The slight decrease since Survey II is within reasonable limits for the accuracy of the method, and there are no indications of any major migrations of the demersal stock within this area.

On the Pedro Bank there is some disagreement between the acoustic assessment and the assessment from the trawl survey which were 15 000 and 8000 tonnes respectively. The main reason for this seems to be that only a portion of the demersal and semi-demersal stock was distributed close enough to the bottom to be within reach of the bottom trawl. Further, a considerable part was distributed on non trawlable bottom. Some change in the species composition of the stock may also have influenced the rate of avoidance. The average catch rate decreased considerably in comparison with Survey II. Lack of the dense concentrations in shallow waters which yielded large catches during Survey II, was evidently the main reason, but it may partly also have been due to increased avoidance.

As a total for the whole survey area the demersal biomass was assessed to be 250 000 tonnes, 80 000 to 100 000 tonnes less than in the two previous surveys. Since this biomass mainly consists of long-lived species and is not heavily exploited, it is likely that this decrease is due to seasonal fluctuations in distribution and behaviour. The yield from the demersal and semi-demersal biomass may therefore be based on the level of the stock found during Survey I and II. The sustained annual yield is therefore assessed at about 70 000 tonnes.

A part of the fish biomass occurs near the bottom and the limitation of the echo sounder in detecting fish very close to the bottom will bring about an under-estimate. Some species normally occur closer to the bottom by day than night, and there will consequently be diel fluctuations in the avoidance of detection. As described in Report II, some replicate surveying was done during Survey II in an attempt to quantify the difference in echo abundance from the same area by day and by night. Also during the present survey replicate surveying was done over 75 nautical miles on the Pedro Bank. The average ratio between night and day recordings, classified as Type A, was 1.2. This result supports the ratio of 1.3 from Survey II and indicates that an under-estimate occurred. The effect of this under-estimation was about the same during Surveys II and III since the ratio between day and night surveying was practically equal during the two cruises.

The resources of big pelagic fish were generally at a very low level. Practically no observations of this category were made along the west coast and recordings classified as Type B were quite limited also along the east coast. The total assessment of Type B resources amounted to 60 000 tonnes of which 50 000 were observed off the south coast. The Hambantota area alone accounted for 40 000 tonnes and about 10 000 tonnes were observed off Galle (Fig. 15).

Off the north-west coast surface schooling tuna was observed visually and surface schools of tuna-like fish were observed both off the west coast and the east coast. These schools were

not detected by the echo-sounders and therefore not included in the assessment. The Type B resources were therefore definitely underestimated.

As mentioned in Report I, the present annual catch of tunas, bill fishes and sharks at and beyond the shelf edge amounts to about 20 000 tonnes. A decline of catch rates indicate that these stocks may already be affected by exploitation.

The largest concentrations of small pelagic fish were observed in Area VI, on the slopes of the Pedro Bank. This was small scad occurring in fairly dense aggregations in mid water, mainly at depths between 50 and 100 m. The mean weight was 0.03 kg and the length distribution is given in Appendix Table II. This resource will increase in weight as the fish grows.

7. DISCUSSION OF FINDINGS, SURVEYS I, II AND III

7.1 Distribution and abundance versus season

The survey area have now been covered in three different seasons, Survey I and Survey II covered the area after and before the south-west monsoon respectively while Survey III was undertaken in the season of the north-east monsoon.

The total assessments in the various sub-areas from the three surveys are given in Table 11. It should be emphasized that these assessments do not include the resources in waters shallower than 10-15 metres, the near-shore waters and the extensive shallow areas stretching from the Pedro shoals and Channel through Palk Strait to the Sri Lankan part of the Gulf of Mannar. The acoustic survey method also fails to record fish in the very surface layer and fish very close to the bottom, the distance from the bottom varying with depth and roughness of the bottom. Typical distance in the present survey is 0.5 to 1 m.

Table 11. Assessment of total fish biomass by sub-area for Surveys I-III, thousands of tonnes.

Total biomass	Survey I	Survey II	Survey III
Area I	40	120	55
II	220	150	125
III	100	35	110
IV	120	55	30
V	50	25	20
VI	30	15	45

As seen in Table 11 there were rather large fluctuations in abundance between the three surveys. The difference between the assessments from Survey I and III was 175 000 tonnes. The total assessment from Survey II was not much different from Survey III, but the differences were larger when the three categories of fish were considered separately. Since short-lived species account for a considerable portion of the fish stock around Sri Lanka, seasonal fluctuations in stock size may be expected. Further, seasonal migrations and changes in behaviour may also create fluctuations in the distribution and availability of the stock. Off the south-west coast of India (ANON 1976) a maximum in abundance has been observed after the south-west monsoon and a lean period in the north-east monsoon. To observe a similar trend also around Sri Lanka would therefore not be unreasonable. The data from the present surveys suggest that the Type A and Type B resources show such a pattern, but the seasonal trend of the Type C resources is different.

The demersal and semi-demersal group, Type A, was found to be slightly more abundant during Survey I than during Survey II, i.e. a slight maximum was observed after the south-west monsoon. In the north-east monsoon, Survey III, the abundance was at a considerably lower level.

The demersal biomass consists mainly of long-lived species, and seasonal fluctuations observed in the various sub-areas must

therefore be due to migrations. Indications of such migrations were observed. In Survey II the demersal resources in Sub-area I were assessed at 100 000 tonnes while the observations in Survey III indicated a decrease to about a third. A simultaneous increase was observed in Sub-area III, and also in Sub-area II most of the demersal resources were observed in its southern part. This suggests that the demersal fish on the west coast has a northerly distribution around the south-west monsoon while the Hambantota area, Sub-area III, has its highest abundance in the north-east monsoon. The increase in Sub-area III is, however, not large enough to explain the far bigger decrease in Sub-area I. Consequently there must also be other reasons for the fluctuation in Sub-area I. This may be migration out of the survey area or a behaviour by which the fish avoids detection. During Survey III the observations were suggestive of a deeper distribution of the demersal fish. The hydrographic structure on the west coast is during the north-east monsoon such that the transition layer for temperature and oxygen is situated at 120-150 m depth. In Sub-areas I and II the fish may therefore migrate to depths well beyond 100 m in this season. At these depths the bottom is generally sloping very steeply, and fish near the bottom may be impossible to detect with the echo sounders.

On the east coast the demersal resources were at a lower level. The fish occurred rather scattered and evenly distributed on the shelf. The difference in assessment between the surveys was small, and there was no indication of major north-south migrations. There was, however, clear indications of some seasonal migrations on the Pedro Bank. The composition of the catches indicated, as described below, that several of the most common demersal species had left the Pedro Bank in the season of Survey I.

Also the Type B resources, consisting of bigger pelagic fish, are mainly long-lived species, and seasonal fluctuations will mainly depend on their migratory habits.

Many species of this category are scattered over wide areas, often occurring as single fish or in small aggregations. It may

often be difficult to distinguish the echo recordings of such scattered fish from dense plankton recordings. A considerable portion of this biomass may occur in the surface layer and avoid detection by the echo sounders. Because of their high avoidance these species are also difficult to sample representatively with trawl. Consequently the assessments of Type B resources have a lower level of reliability than the assessment of Type A and C. In consideration of this, the three assessments made were at about the same level, 70 000 and 60 000 tonnes in Surveys II and III respectively and probably somewhat more in Survey I.

The category of small pelagic fish, Type C, shows more complex fluctuations. The total assessment of pelagic fish in Survey I was in excess of 200 000 tonnes and the greater portion of this was assessed to be small pelagic fish. During Survey II the abundance of Type C species was assessed to be at a negligible level while the assessment of Survey III was 75 000 tonnes. It seems likely that both migratory fluctuations and year-to-year fluctuations in abundance may occur, but the data available are not sufficient for definite conclusions in this regard.

7.2 Composition of the catches

The most important species in the demersal and semi-demersal fauna belong to the families Lethrinidae, Lutjanidae, Pomadasyidae Serranidae, Acanthuridae and Carangidae.

Lethrinus nebulosus was the most common species in the bottom trawl catches on all three cruises. Its contribution to the catches varied in the different sub-areas, and in some of the sub-areas its abundance varied considerably between the three surveys. This is suggestive of seasonal migrations. L. nebulosus was most common on the west coast where its average contribution to the bottom trawl catches was above 20% (by weight) in Sub-areas I and II. During Survey III L. nebulosus accounted for more than 10% of the bottom trawl catches in Sub-area III, but during the two other surveys it was quite scarse in this sub-area, its contribution to the catches being only 1 to 2%.

These fluctuations indicate seasonal variations in its abundance on the south coast. This is in agreement with the north-south migrations indicated by the acoustic survey. In Sub-areas IV and V on the east coast, between 5 and 10% of the weight of the trawl catches were L. nebulosus. On the Pedro Bank it accounted for 12 to 15% in the catches during Surveys II and III, but during Survey I it was not caught on the Pedro Bank.

Lethrinus miniatus was the most common species in the catches taken with bottom long line. In the bottom trawl catches the percentage of this species was generally low. Bottom long lines seem therefore to be a highly selective gear with different catch rates of closely related species.

Several species of Lutjanidae were caught as well in the bottom trawl as on bottom long line. L. argentimaculatus, L. sangvineus and L. rivulatus were most common and occurred frequently in the catches. These species contributed most to the catches on the south coast and were also somewhat more frequent on the east coast than on the west coast. Lutjanidae were not caught on the Pedro Bank during Survey I.

One species of the Pomadasyidae family, Plectorhyncus pictus, accounted for a considerable part of the catches. The average portion of Plectorhyncus pictus in the bottom trawl catches was about 10% of the total weight. This species was fairly evenly distributed around the coast, but nor did this species occur in the catches on the Pedro Bank during Survey I.

Several species of Seranidae occurred in the bottom trawl catches, mainly of the genus Epinephelus. These species were fairly evenly distributed along the coast. Although they were not particularly numerous in the catches, they contributed often considerably in weight due to their size.

Acanthurus strigosus was common in the catches on the south and south-east coasts during all three surveys. It was not caught on the west coast and its frequency in the catches on the east coast was varying. On the Pedro Bank it accounted for 12% of

the weight of the total bottom trawl catch during Survey II. During Surveys I and III, however, this species was not caught on the Pedro Bank.

Many species of Carangidae contributed to the bottom trawl catches. These species were scarse on the south coast, their contribution to the catches in Sub-area III ranged between 0 and 3% in the three surveys. Elsewhere on the shelf they accounted for considerable percentages in the catches.

From the composition of the bottom trawl catches it seems evident that most of the large demersal species had migrated from the Pedro Bank in September. The reason for this is probably the hydrographic conditions. As observed in Survey I, the thermo- and oxycline were in this season tilting up towards the shore. Beyond 20-30 m depth there was oxygen deficiency for species not particularly adapted for low oxygen contents.

7.3 Length distributions and length-weight relations

Length distributions for some species are appended to the reports (Appendix Table II). These measurements are too few to give much conclusive information. For some of the bigger demersal species there are, however, marked survey-to-survey differences in length distributions in some sub-areas. These differences may indicate fast growth of these assumably long-lived species. Systematic length measurements of commercial catches and studies of growth zones in otoliths may give more information on this.

Length and weight were measured on a fairly large number of single fish. Based on these measurements a length-weight relation has been calculated for some species. This relation was worked out with a logaritmic curve fit to the equation

$$y = a\, x^{b}$$

The length-weight (x - y) relations for the species considered are given in Table 12. Calculated values of the regression

coefficients a and b are given together with the coefficient of determination, r^2. The resulting length-weight relation for Lethrinus nebulosus and Lutjanus sangvineus are also shown graphically in Fig. 19.

Table 12. Length-weight relation for some species commonly caught on the shelf correlated to the equation $y = a\ x^b$. In this equation x and y represent length and weight respectively. The coefficient of determination is given by r^2.

	Lethrinus nebulosus	Lethrinus miniatus	Plecto-rhyncus pictus	Gnatha-nodon speciosus	Lutjanus argenti-maculatus	Lutjanus sangvi-neus	Lutjanus rivula-tus	Epinephe-lus endulosus	Acanthu-rus stri-gosus
Number measured	304	30	52	14	35	13	38	45	54
$a \cdot 10^5$	4.5	2.9	5.3	4.4	2.7	0.5	1.2	2.9	2.9
b	2.76	2.76	2.70	2.81	2.92	3.26	3.15	2.29	2.91
r^2	0.98	0.98	0.93	0.98	0.69	0.73	0.85	0.70	0.90
Weight, kg, calculated from a length of: 10 cm	0.03	0.02	0.03	0.03	0.02	0.01	0.02	0.06	0.02
20 "	0.18	0.11	0.17	0.20	0.16	0.09	0.15	0.28	0.18
30 "	0.54	0.35	0.51	0.63	0.54	0.34	0.52	0.46	0.58
40 "	1.19	0.77	1.12	1.42	1.24	0.87	1.29	1.35	1.33
50 "	2.20	1.42	2.05	2.65	2.37	1.80	2.61	2.25	2.55
60 "	3.64	2.34	3.35	4.43	4.03	3.26	4.64	3.42	4.33
70 "	5.57	3.59	5.08	6.83	6.32	5.39	7.54	4.87	6.79

Table 12 shows that the correlation (r^2) between length and weight is very high for most of the species, ranging from 0.85 to 0.98. Only for Lutjanus argentimaculatus, Lutjanus sangvineus and Epinephelus undulosus r^2 was calculated to be about 0.70.

For Epinephelus undulosus the exponential factor, b, was 2.29 while it ranged between 2.70 and 3.26 for the other species considered, i.e. approximately 3. This shows that the weight of these species is about proportional to the cube of their length.

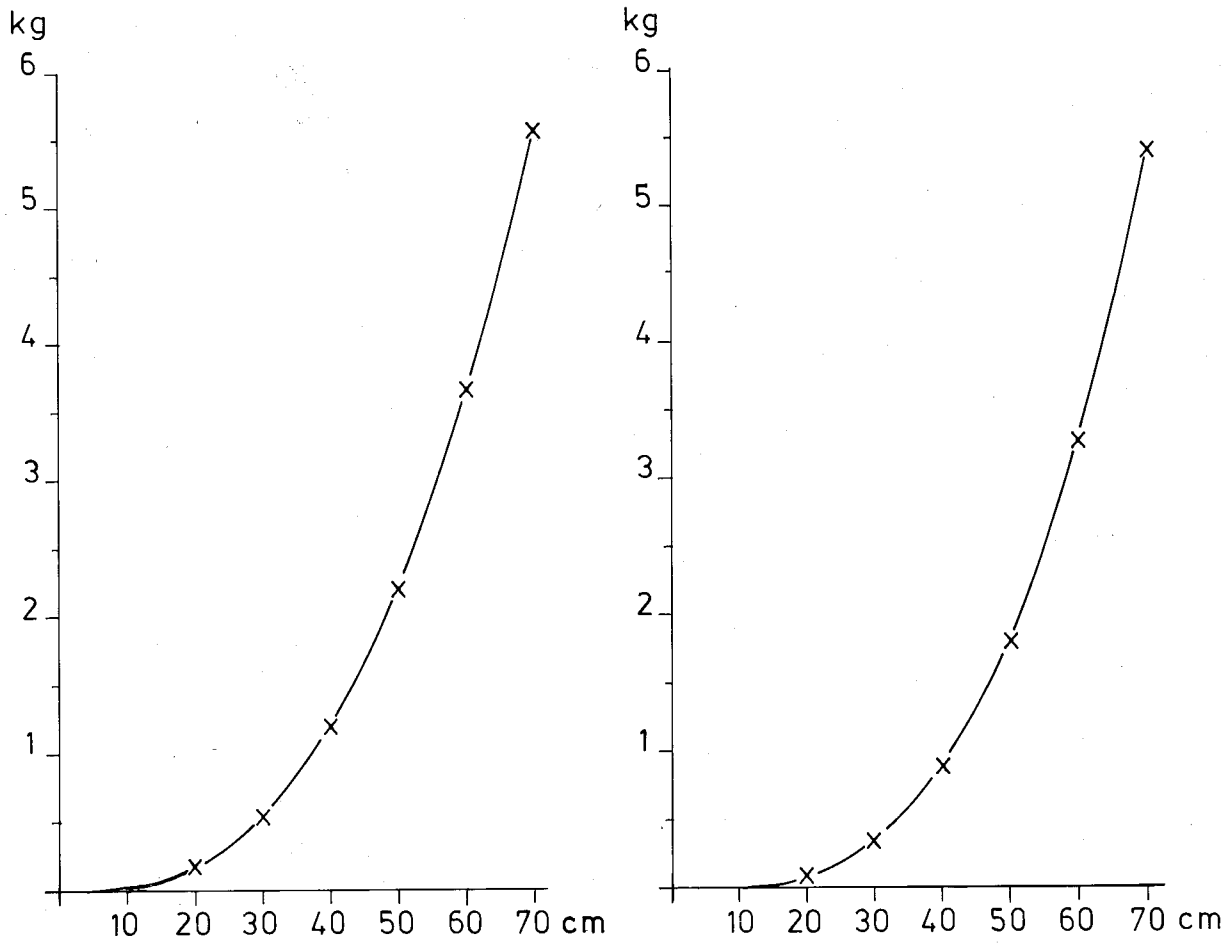

Fig. 19. Length-weight relation for Lethrinus nebulosus (left) and Lutjanus sangvineus.

7.4 Crustaceans and deep-water fish

The deep-water trawling ground in the Gulf of Mannar stretches from about 08°42' to 08°48'N and 79°30' to 79°34'E. As described in Report I this area was mapped in some detail during Survey I. During the three surveys respectively 7, 2 and 6 trawl hauls were made on this ground (Table 3 in Report I, Table 3 in Report II and Table 4).

Average catch per hour of lobster were 55, 165 and 260 kg in Survey I, II and III respectively. Similarly average catch rates of prawns were 170, 180 and 70 kg per hour, and of deep-water fish the average catches per hour were 520, 1900 and 3500 kg in the three surveys.

These fishing experiments indicate fairly high abundance of deep-water biomass. The extent of the trawling ground is, however, only some few square nautical miles, and its potential within a short time period is therefore limited. Its total potential is, on the other hand, likely to be higher than the production of its area since biomass may be added from adjacent areas with untrawlable bottom.

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Appendix Table I.
Record of fishing operations.
BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
09.01	0700	1	BTR	53	53	06°03'	81°10'	No catch			
09.01	0826	2	BTR	55	55	06°00'	81°95'	73	104.4	Lutjanidae (21.70)	3.61
										Serranidae (37.90)	2.22
										Acanthuridae (1.2)	0.60
										Plectorhynchus pictus (6.0)	3.00
										Sharks (4.4)	1.46
										Small fish (0.20)	-
										Big squid (0.50)	0.50
09.01	1700	3	BTR	54	54	01°5'	81°02'	7	13.95	Sharks (3.33)	1.66
										Pseudobalistes fuscus (2.6)	1.30
										Fistularia villosa (0.05)	0.05
										Small fish + squids (0.03)	-
09.01	1814	4	PTR	35	35	06°02'	80°57,5'	6	6.91	Sardinella sirm (0.2)	0.07
										Rastrelliger kanagurta (0.2)	0.20
										Decapterus lajang (0.05)	0.05
										Mixed small fish + squids (6.0)	-
09.01	2011	5	BTR	55	55	06°01'	81°07,5'	65	130.6	Lutjanidae (7.00)	1.40
										Lethrinidae (44.40)	1.64
										Pseudobalistes fuscus (7.0)	1.00
										Plectorhynchus pictus (7.0)	3.50
										Sphyraenidae (0.20)	0.20
										Misc. fish (5.70)	0.81
09.01	2252	6	BTR	48	48	06°05'	81°15'	16	31.6	Decapterus lajang (0.2)	0.10
										Lutjanidae (0.6)	0.30
										Small fish (13.0)	-
										Squid and prawn (2.0)	-
10.01	0807	7	BTR	47	47	05°57'	80°50'	7	13.6	Epinephelus undulosus (4.1)	4.10
										Alutera monoceros (1.9)	0.95
										Lutjanidae (0.5)	0.25
10.01	1030	8	BTR	55	55	05°58'	80°55'	127	126.6	Serranidae - epinephelus sp. (57.4)	2.50
										Lutjanidae (34.8)	
										Lethrinidae (11.3)	1.26
										Plectorhynchus pictus (16.3)	1.63
										Parrot fish (4.0)	4.00
										Pseudupeneus indicus (2.8)	0.40
										Red bait (0.04)	-
10.01	1327	9	BTR	60	60	05°57'	80°58'	17	28.3	Shark (11.4)	2.28
										Pseudobalistes fuscus (4.3)	1.43
										Pentraprion longimanus (1.3)	0.04
10.01	1535	10	PTR	61	40	05°55'	80°54'	2	1.63	Small squid (0.5)	-
										Small fish (1)	-

Appendix Table I, continued.
Record of fishing operations.
BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
10.01	1854	11	BTR	63	63	05°54.5'	80°44.5'	39	178.5	Serranidae - epinephelus sp. (18.2)	9.10
										Plectorhynchus pictus (5.5)	5.50
										Lethrinus nebulosus (2.3)	0.80
										Pseudupeneus indicus (0.7)	0.35
										Sphyraenidae (0.4)	0.40
										Lutjanidae (5.2)	0.58
										Squid (1.9)	0.95
										Small fish (4.5)	-
10.01	2128	12	BTR	60	60	05°54'	80°39.5'	57	117.2	Lutjanidae (16.3)	0.24
										Clupeidae (0.21)	0.01
										Sphyraenidae (6.4)	0.08
										Lethrinidae (11.1)	0.18
										Epinephelus tauvina (5.7)	5.70
										Shark (2.4)	2.40
										Small fish and squid (17.0)	-
11.01	0530	13	LL	80	80	05°54'	80°33'	-	-	Complete line lost	-
11.01	1019	14	BTR	57	57	05°54'	80°30'	60	133.3	Argyrops spinifer (10.3)	1.14
										Carangidae (18.9)	0.99
										Acanthuridae (4.6)	1.53
										Shark (7.9)	2.63
										Lethrinidae (1.2)	1.20
										Cybium commerson (1.7)	1.70
										Small fish and squid (15.4)	-
11.01	1227	15	BTR	63	63	05°54'	80°24'	13	34.6	Lethrinus nebulosus (0.7)	0.70
										Shark (2.1)	2.10
										Carangoides chrysophrys (1.0)	1.00
										Alectis indica (8.0)	4.00
										Small fish (0.9)	0.90
11.01	1533	16	BTR	67	67	05°58'	80°14'	107	152.9	Lethrinidae (9.9)	3.30
										Serranidae - Epinephelus sp. (43.9)	4.88
										Shark (6.6)	3.30
										Pseudobalistes fuscus (2.2)	1.10
										Argyrops spinifer (2.6)	1.30
										Carangidae (3.9)	0.98
										Lutjanidae (24.8)	4.13
										Small fish and squid (13.1)	-
12.01	0150	17	PTR			05°41'	79°49'	2	3	Small fish sp. (unidentified) (1.3)	-
										Myctophidae and krill (1.1)	-
12.01	0355	18	PTR	100	100	05°47'	79°48'	7	14	Myctophidae (7)	-
12.01	0823	19	LL (Bottom)	60	60	05°59'	70°58,5'	42	68.43	Lethrinidae (30.5)	2.54
										Lutjanidae (1.0)	0.50
										Shark (5.0)	2.50
										Epinephelus tauvina (0.9)	0.90
										Caranx sansun (4.8)	4.80

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
19.01	2203	42	BTR	12	12	07°25.7'	79°46'	158	317	Lethrinidae (91.7)	3.28
										Plectorhynchus pictus (18.3)	1.31
										Gaterin sp. (8.4)	1.20
										Small fish (40.0)	-
20.01	0700	43	BTR	8	8	07°45'	79°45'	29	57	Plectorhynchus pictus (1.8)	0.90
										Selaroides leptolepis (2.8)	-
										Sillago sihama (1.6)	-
										Leiognathidae (22.4)	-
20.01	1550	44	BTR	11	11	08°33'	79°44'	9	18	Gnathanodon speciosus (4.7)	4.70
										Scomberomorus commerson (3.1)	1.55
										Squid (0.5)	-
										Misc. fish (1.0)	-
21.01	0656	45	BTR	14	14	08°46'	79°41'	64	141	Leiognathidae (37.0)	-
										Mullidae (8.8)	-
										Carangidae (17.2)	-
										Rastrelliger kanagurta (0.6)	-
21.01	1110	46	BTR	17	17	08°53'	79°33.5'	38	76	Plectorhynchus pictus (6.1)	3.05
										Lethrinidae (21.6)	0.77
										Lutjanus argentimaculatus (2.4)	2.40
										Blue parrot (5.2)	5.20
										Misc. fish (2.2)	-
21.01	1353	47	BTR	12	12	08°58'	79°35'	5	9	Scomberomorus commerson (2.4)	1.20
										Lethrinus rhodopterus (2.2)	0.04
21.01	2259	48	PTR	400	0	08°29'	79°16'	10	20	Myctophidae and deep sea fish (10.0)	-
22.01	0142	49	PTR	40	40	08°38'	79°22'	13	20	Small squid (2.7)	-
										Myctophidae (10.0)	-
										Exocoetidae (0.2)	0.10
										Decapterus russelli (0.4)	0.10
22.01	0525	50	LL	85	85	08°43'	79°36.5'	180		Lethrinus nebulosus (152.0)	2.41
										Lutjanidae (14.1)	3.53
										Carangidae (1.0)	1
										Epinephelus merra (8.4)	2.10
										Shark (3.9)	1.90
										Gnathodentex mossambicus (1.4)	0.70
22.01	0950	51	BTR	270	270	08°44'	79°32'	3480	6520	Chloropthalmus and deep sea fish (3400.0)	-
										Puerulus sewelli (Lobster) (72.8)	-
										Metapenaeopsis andamaensis (Prawn) (6.0)	-
22.01	-	52	Oyster dredge	12	12	08°42'	79°45'	0	-	Margertifera vulgaris (oyster) (1.0)	0.2
22.01	-	53	Oyster dredge	10	10	08°41'	79°45'	0	-	No catch	-
22.01	1453	54	BTR	14	14	08°43'	79°42'	241	453	Lethrinidae (16.2)	0.63
										Plectorhynchus pictus (10.4)	1.16
										Epinephelus undulosus (12.3)	2.05
										Lutjanus sanguineus (1.3)	1.30
										Small fish (200.9)	

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
22.01	1840	55	BTR	300	300	08°44.6'	79°33'	1052	2105	Deep sea fish (1000.0)	-
										Puerulus sewelli (lobster) (48.7)	-
										Aristaeus semidentatus } (Prawn)	
										Heterocarpus gibbosus } (3.6)	-
23.01	0532	56	LL	80	80	08°41'	79°38'	76	29	Lutjanidae (36.2)	4.02
										Lethrinus nebulosus (29.2)	2.09
										Serranidae - Epinephelus sp. (7.2)	2.40
										Plectorhynchus pictus (1.7)	1.70
										Small fish (1.9)	
23.01	0958	57	BTR	271	271	08°45.4'	79°31.5'	3080	6160	Puerulus sewelli (lobster) (283.0)	-
										Prawn (12.0)	-
										Deep sea fish (2800.0)	-
23.01	0200	58	BTR	17	17	08°53'	79°35.5	7	14	Lutjanus argentimaculatus (5.5)	1.37
										Scomberomorus commerson (1.6)	1.6
										Unmeasured quantities of red bait	
23.01	1937	59	BTR	260	260	08°46'	79°31'	905	1810	Puerulus sewelli (lobster) (115.4)	-
										Prawn (estimated) (30.0)	-
										Deep sea fish (760.0)	-
24.01	0347	60	BTR	271	265	08°46'	79°32'	1430	2860	Puerulus sewelli (lobster) (130.0)	-
										Prawn (estimated) (80.0)	-
										Deep sea fish (1200.0)	-
24.01	0554	61	LL	68	68	08°36.5'	79°39'	53		Lethrinidae (32.5)	2.32
										Epinephelus undulosus (12.2)	3.05
										Lutjanus bohar (2.4)	2.4
										Shark (6.1)	2.03
24.01	1113	62	BTR	273	273	08°46'	79°31'40	1440	2880	Puerulus sewelli (160.0)	-
										Deep sea fish and prawn (1280.0)	-
24.01	1625	63	LL	30	30	08°33'	79°40'	34	68	Shark (34.0)	1.89
25.01	0628	64	LL	22	22	08°32'	79°41'	5		Shark (3.1)	1.6
										Lethrinus nebulosus (2.3)	2.3
25.01	1046	65	PTR	254	40	08°23'	79°40.5'	0.5	1	Plankton (0.45)	
25.01	1810	66	BTR	15	15	07°35'	79°40.5'	26	51	Sphyraenidae (24.2)	3.02
										Nemipteridae (0.4)	0.40
										Squid (1.0)	-
25.01	2056	67	BTR	10	10	07°33.5'	79°45'	26	52	Selar crumenophthalmus (5.4)	0.10
										Sillago sihama (11.4)	0.02
										Nemipteridae (5.6)	0.05
										Small fish (3.5)	0.04
25.01	2335	68	BTR	14	14	07°27.5'	79°43'	37	75	Selar crumenophthalmus (1.2)	0.05
										Sphyraenidae (14.7)	1.84
										Alutera monoceros (2.1)	2.10
										Small bottom fish and squid (19.3)	-

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
26.01	1034	69	BTR	20	20	07°14.5'	79°43'	0	0	No catch (only one basket of porcupine fish)	-
26.01	1145	70	BTR	19	19	07°13.5'	79°45'	163	327	Lethrinus nebulosus (107.8)	2.40
										Sphyraenidae (4.8)	4.80
										Gnathanodon speciosus (16.5)	8.25
										Drepane punctata (13.3)	1.90
										Plectorhynchus pictus (18.8)	2.35
										Misc. fish (2.1)	
27.01	1447	71	BTR	13	13	07°29.5'	79°42'	8	16	Small fish (8.1)	-
26.01	1912	72	PTR	>500	45	07°06'	79°36.5'	60	120	Myctophidae (58.0)	-
										Small fish and squid (2.0)	-
31.01	0648	73	BTR	73	73	10°07.4'	80°27.6'	44	87	Carangidae (33.0)	-
										Lethrinus nebulosus (1.8)	1.80
										Rachycentron canadus (2.9)	1.45
										Shark (2.6)	2.60
										Small fish and squid (3.4)	-
31.01	0827	74	PTR	46	26	10°08.5'	80°23.5'	28	55	Juvenile fish and squid (27.7)	-
31.01	1311	75	BTR	74	74	10°03'	80°33'	2	3	Small squid (1.5)	-
31.01	1640	76	BTR	198	198	10°06.5'	80°46.5'	2	4	Metapenaeopsis andamaensis (Prawn) (0.5)	-
										Deep sea fish and squid (1.0)	-
										Deep sea halibut (0.5)	0.50
										Myctophidae (0.2)	0.01
31.01	2100	77	BTR	158	158	10°03'	80°45.6'	171	342	Nemipteridae (50.0)	-
										Deep sea fish and crab (115.0)	-
										Metapenaeopsis sp. (prawn) (6.0)	-
31.01	2236	78	PTR	114	70	10°04.5'	80°42'	87	100	Scomberomorus commerson (3.9)	3.9
										Carangidae (87.2)	0.03
01.02	1110	79	BTR	148	148	09°57'	80°48.5'	142	285	Nemipterus marginatus (114.0)	-
										Small fish (6.5)	-
										Deep water crabs (21.8)	-
01.02	1540	80	PTR	46	0	09°48'	80°41'	4	7	Fish fry (3.6)	-
01.02	1640	81	BTR	47	47	09°47.5'	80°40'	11	23	Scomberomorus commerson (2.6)	1.30
										Lutjanidae (0.5)	0.50
										Serranidae - Epinephelus sp. (1.8)	1.80
										Lethrinus nebulosus (2.9)	0.90
										Misc. fish (3.5)	0.39
01.02	2138	82	BTR	22	22	09°40.7'	80°40.5'	35	70	Lutjanidae (3.9)	0.49
										Lethrinus nebulosus (5.2)	0.87
										Carangidae (2.2)	1.10
										Scomberomorus commerson (3.9)	3.90
										Sphyraena jello (5.2)	0.26
										Plectorhynchus pictus (7.8)	3.95
										Shark (1.1)	1.10
										Misc. fish (6.0)	0.18

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position		Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
						Lat. N	Long. E				
02.02	0353	83	BTR	16	16	09°32'	80°43,5'	40	60	Carangidae (5.1)	0.27
										Sphyraenidae (6.0)	0.22
										Small fish (28.6)	-
02.02	0548	84	LL		78	09°31'	80°52'	20	8	Carangoides gymnostethus (8.7)	8.70
										Carangidae (1.6)	0.53
										Shark (3.1)	1.55
										Arius sp. (6.5)	1.30
02.02	1027	85	BTR	24	24	09°25.6'	80°51.8'	213	426	Carangidae (60.2)	0.11
										Leiognathidae (16.6)	0.22
										Gerres filamentosus (17.2)	0.25
										Sciaenidae (84.8)	1.32
										Scomberomorus commerson (22.0)	22.0
										Alectis indicus (2.8)	-
										Ambassis lucidus (1.6)	-
										Small fish (7.8)	-
02.02	1205	86	BTR	16	16	09°31'	80°43.5'	0			
02.02	1345	87	BTR	25	25	09°40'	80°41'	9	18	Fistularia petimba (0.6)	0.30
										Scombridae (5.8)	5.80
										Carangidae (1.5)	0.50
										Thenus orientalis (1.2)	0.24
02.02	1555	88	BTR	21	21	09°49'	80°34.5'	67	134	Lethrinidae (35.10)	1.40
										Epinephelus undulosus (2.6)	2.6
										Plectorhynchus pictus (10.1)	3.36
										Lutjanus rivulatus (1.9)	1.90
										Gnathanodon speciosus (10.0)	2.50
										Caranx ciliaris (7.0)	1.16
02.02	1803	89	BTR	17	17	09°57,3'	80°27'	79	158	Scomberomorus commerson (7.3)	1.83
										Lethrinus nebulosus (3.8)	1.90
										Plectorhynchus pictus (3.8)	3.80
										Carangidae (1.0)	0.50
										Thenus orientalis (2.0)	0.22
										Sphyraenidae (0.2)	0.20
										Small fish (1.0)	0.11
										Skate (60)	60.00
02.02	1946	90	BTR	20	20	10°04'	80°21'	21	41	Sphyraena jello (4.1)	0.32
										Saurida tumbil (2.3)	0.14
										Shark (1.8)	1.80
										Therapon jarbua (0.3)	1.00
										Thenus orientalis (1.1)	0.18
										Squids (1.2)	0.15
										Small fish (9.5)	

Appendix Table I, continued.
Record of fishing operations.
BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position		Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
						Lat. N	Long. E				
02.02	2104	91	BTR	32	32	10°05'	80°23'	177	355	Lethrinus nebulosus (50.8)	1.45
										Lutjanidae (24.4)	1.36
										Argyrops spinifer (29.3)	0.67
										Serranidae (15.8)	2.25
										Carangidae (5.7)	0.39
										Gymnocranius griseus (14.8)	1.23
										Saurida tumbil (3.4)	0.37
										Sphyraenidae (2.4)	0.26
										Shark (1.8)	1.80
02.02	2253	92	BTR	35	35	10°01'	80°27'	124	248	Lutjanidae (30.8)	3.08
										Plectorhynchus pictus (19.4)	3.23
										Epinephelus undulosus (8.5)	2.13
										Lethrinus nebulosus (24.3)	1.87
										Acanthurus strigosus (7.2)	0.60
										Carangidae (13.8)	0.73
										Gymnocranius griseus (2.7)	0.87
										Psettodes erumei (2.6)	2.60
										Sphyraenidae (3.4)	0.85
										Mixed fish sp. (6.9)	0.26
03.02	0210	93	BTR	27	27	09°50'	80°35.5'	48	90	Lutjanidae (13.1)	4.37
										Lethrinus nebulosus (4.7)	1.18
										Plectorhynchus pictus (12.8)	2.13
										Gymnocranius griseus (16.0)	0.84
										Sphyraenidae (1.6)	1.60
03.02	0428	94	BTR	24	24	09°46'	80°39'	34	86	Lutjanidae (11.88)	1.18
										Plectorhynchus pictus (12.00)	3.00
										Scaridae (4.00)	4.00
										Sphyraenidae (1.0)	1.00
										Sharks (6.0)	1.50
03.02	0550	95	LL	25	25	09°45.5'	80°39'	12	5	Lethrinus nebulosus (6.9)	2.30
										Rachycentron canadus (4.75)	4.75
03.02	1014	96	BTR	14	14	09°42'	80°34.5'	0			
03.02	1132	97	BTR	15	15	09°49'	80°30'	129	257	Serranidae (29.8)	3.73
										Plectorhynchus pictus (19.8)	3.90
										Lutjanus argentimaculatus (28.6)	2.86
										Alectis indicus (6.1)	6.10
										Psettodes erumei (2.6)	2.60
										Plectorhynchidae Gaterin sp. (1.8)	1.80
03.02	2238	98	BTR	14	14	09°56.5'	80°23.5'	60	280	Lutjanus lineolatus (0.5)	0.07
										Lethrinus nebulosus (3.7)	1.85
										Psettodes erumei (5.6)	1.40
										Black pompfret (3.8)	1.90
										Sphyraenidae (2.8)	0.17
										Scolopsidae (0.3)	0.10
										Small fish (4.5)	0.02
										Skate (60)	60.00

Appendix Table I, continued.
Record of fishing operations.
BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
04.02	0641	99	BTR	223	223	10°16'	80°38.5'	2700	5400	Chloropthalmidae (30.0)	
										Deep water sp. (57.1)	
										Prawns (0.9)	
										Swimming crabs (2.0)	
04.02	1619	100	BTR	36	36	09°54'	80°32'	0			
04.02	1800	10	BTR	54	54	09°57.6'	80°36'	105	210	Lethrinus nebulosus (2.5)	0.83
										Lutjanidae (4.3)	1.07
										Scomberomorus commerson (33.9)	2.82
										Sharks (38.8)	2.77
										Serranidae (4.40)	1.46
										Gymnocranius griseus (0.2)	0.20
										Sphyraenidae (4.7)	0.18
										Psettodes erumei (2.3) (Indian halibut)	1.15
										Saurida tumbil (3.1)	0.31
										Small fish (21.10)	-
04.02	1939	102	BTR	46	46	09°53.5'	80°38.4'	14	28	Lutjanidae (1.4)	0.47
										Lethrinus nebulosus (2.6)	0.87
										Acanthurus strigosus (2.4)	1.20
										Argyrops spinifer (0.2)	0.20
										Pentapodidae (1.2)	0.24
										Small fish and squids (16.2)	-
04.02	2317	103	BTR	52	52	09°32'	80°52.5'	80	200	Lutjanidae (64.3)	1.74
										Lethrinus nebulosus (12.3)	1.12
										Aprion virescens (0.6)	0.6
										Mixed small fish (3.0)	-
05.02	0228	104	PTR	69	40	09°23'	80°56'	96	912	Puerulus sewelli (64)	-
										Sphyraenidae (9.1)	-
										Carangidae (19.8)	-
										Leiognathidae (1.2)	-
										Small fish (1.9)	-
05.02	0530	105	LL	40	40	09°17'	80°58'	28		Tachysuridae (20.0)	0.50
										Carangidae (0.5)	0.50
										Sharks (7.0)	2.33
05.02	0957	106	BTR	15	15	09°10.5'	80°54'	85	170	Carangidae (2.3)	-
										Rachycentron canadus (3.0)	-
										Small fish (10.0)	-
05.02	1924	107	BTR	28	28	09°09'	80°58.4'	160	320	Lutjanidae (6.3)	0.45
										Lethrinus nebulosus (20.5)	1.85
										Plectorhynchus pictus (5.9)	1.95
										Chirocentrus dorab (0.3)	0.30
										Argyrops spinifer (2.1)	0.52
										Carangidae (58.60)	-
										Polynemidae (5.6)	0.32
										Sphyraenidae (8.4)	-
										Clupeidae (17.7)	-
										Mixed small fish (mainly Leiognathus) (36.0)	-

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
05.02	2042	108	BTR	35	35	09°09'	80°59'	116	231	Carangidae (4.5)	0.64
										Polynemidae (6.00)	0.28
										Sphyraenidae (3.1)	0.77
										Psettodes erumei (5.3)	0.25
										Sciaenidae (8.4)	1.20
										Trichiuridae (1.2)	0.40
										Mixed small fish (81.2)	-
05.02	2152	109	Oyster dredge	35	35	09°11'	80°57'	Soft green mud bottom, dead shells			
05.02	2300	110	Oyster dredge	36	36	09°08'	80°59.5'	Soft green mud bottom, dead shells			
06.02	0106	111	PTR	>500	0	09°04.5'	81°07.5'	0.1	-	Myctophidae	
										krill	
06.02	0540	112	LL	54	54	09°01'	81°04'	13	-	Lethrinus nebulosus (3.5)	3.50
										Carangoides malabaricus (1.3)	0.43
										Argyrops spinifer (0.8)	0.80
										Arius thalassinus (7.7)	2.56
										Saurida tumbil (0.1)	0.10
06.02	1746	113	BTR	43	43	08°31'	81°23.5'	0			
06.02	2025	114	PTR	>500m	30	08°26.8'	81°33'	1		Myctophidae	
										krill	
										Various fish larvae	
06.02	2253	115	BTR	29	29	08°21'	81°29'	6	12	Platax orbicularis (5.4)	5.40
										Sardinella sirm (0.05)	0.05
										Sphyraenidae (0.1)	0.10
										Few nullipores	
07.02	0214	116	PTR	-	0	08°10'	81°42.5'	0	-		
07.02	0522	117	BTR	22	22	08°08'	81°31'	390	780	Carangidae (108.2)	-
										Lutjanidae (73.2)	0.10
										Lethrinus nebulosus (29.0)	0.95
										Serranidae (24.2)	8.06
										Acanthurus strigosus (101.9)	3.39
										Plectorhynchus pictus (7.4)	1.48
										Gerridae (7.8)	0.22
										Scomberomorus commerson (5.0)	2.50
										Sphyraenidae (20.2)	1.55
										Shark (10.9)	10.9
										Platacidae (1.1)	0.22
07.02	0728	118	BTR	34	34	08°05'	81°34.5'	2	4	Scomberomorus commerson (1.8)	1.8
										Small fish sp. (0.3)	
07.02	1029	119	BTR	46	46	07°57.6'	81°39'	0	-		

Appendix Table I, continued.

Record of fishing operations.

BTR = Bottom trawl. PTR = Pelagic trawl. LL = Long line.

Date	Time Start	St. no.	Gear type	Bottom depth (m)	Gear depth (m)	Position Lat. N	Position Long. E	Total catch (kg)	Catch per hour (kg)	Dominant species (or group) Total catch (kg)	Mean weight (kg)
07.02	1404	120	BTR	53	53	07°46'	81°47'	38.60	77.20	Lutjanidae (10.40)	5.20
										Caranx malabaricus (2.9)	0.36
										Plectorhynchus pictus (15.4)	3.85
										Epinephelus undulosus (4.9)	4.90
										Gymnocranius griseus (2.9)	2.90
										Zonichthys nigrofasciata (0.5)	0.50
										Shark (1.6)	1.60
07.02	1736	121	BTR	27	27	07°56'	81°37.5'	0	-		
08.02	0433	122	BTR	30	30	07°32.5'	81°51.5'	2	4	Small fish only (1.70) (mainly Nemipteridae and Sphyraenidae)	0.06
08.02	0530	123	LL	60	60	07°32'	81°53.5'	12	-	Lutjanus rivulatus (10.4)	3.46
										Serranidae (1.3)	0.65
08.02	0955	124	BTR	27	27	07°26'	81°53'	24	48	Plectorhynchus pictus (6.6)	3.30
										Serranidae (15.7)	7.85
										Gymnocranius griseus (1.7)	1.70
08.02	1248	125	BTR	25	25	07°24'	81°53'	34	68	Lutjanus lineolatus (16.9)	4.22
										Plectorhynchus pictus (17.25)	3.45
08.02	1556	126	BTR	23	23	07°14.5'	81°53'	9	17	Sphyraenidae (1.9)	1.90
										Amblygaster sirm (1.0)	0.05
										Nemipteridae (5.9)	
										Squids (0.1)	
08.02	1900	127	BTR	15	15	07°06'	81°53'	49	98	Lutjanidae (22.42)	0.47
										Lethrinus nebulosus (6.6)	3.30
										Plectorhynchus pictus (10.1)	3.36
										Platacidae (0.1)	0.10
										Small fish sp. (Mainly Nemipteridae) (8.00)	
										Penaeus canaliculatus	
08.02	2224	128	BTR	24	24	06°58'	81°55'	16	32	Lutjanidae (2.10)	
										Lethrinus miniatus (5.1)	0.06
										Scolopsis bimaculatus (1.6)	
										Nemipteridae (6.3)	
09.02	1012	129	BTR	35	35	06°46'	81°53.5'	3	5	Silago sihama (0.4)	0.06
										Nemipteridae (1.9)	0.05
										Saurida tumbil (0.11)	0.05
										Mullidae (0.1)	0.03
09.02	1620	130	BTR	28	28	06°31.5'	81°46'	7	8	*Aprion virescens* (3.3)	3.30
										Epinephelus undulosus (3.1)	3.10
										Platacidae (0.5)	0.50
09.02	1730	131	BTR	17	17	06°30.5'	81°44'	186	371	Scomberomorus commerson (23)	1.44
										Leiognathidae (12.6)	-
										Sharks (50)	50
										Skates (100)	5
09.02	2014	132	BTR	24	24	06°18.5'	81°39'	146	584	Epinephelus tauvina (7.0)	7.00
										Lutjanidae (26.8)	3.83
										Lethrinus nebulosus (46.7)	2.34
										Plectorhynchus pictus (13.6)	3.40
										Blue parrot fish (5.7)	5.70
										Acanthurus strigosus (27.9)	2.33
										Small fish sp. (18.4)	-
10.02	0630	133	LL	34	34	06°08.1'	80°23.5'	14	-	Caranx sexfasciatus (10.3)	5.15
										Gymnocranius griseus (1.6)	1.60
										Sharks (1.9)	1.90

Appendix Table II A. Size distribution (%) of selected species by areas.
Length in 1 cm groups. FL (Fork length).

	N	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Rose finned pigface bream (Lethrinus rhodopterus)																	
Area I	19								11		11	32	11	21	11	5	
Area II	79							2	13	20	18	8	15	15	8	1	
Area III	44					2			2	2	4	2	11	18	39	15	2
Area IV	0																
Area V	0																
Area VI	0																
Yellowstripe trevally (Selaroides leptolepis)																	
Area I	74	15	7		12	32	20	12	1								
Area II	0																
Area III	0																
Area IV	0																
Area V	0																
Area VI	47																
Indian mackerel (Rastrilliger kanagurta)																	
Area I	41						2	24	59	10					2		2
Area II	6																
Area III	1																
Area IV	0																
Area V	0																
Area VI	2																
Russels scad (Decapterus russelli)																	
Area I	43							26	56	12	2	2	2				
Area II	0																
Area III	0																
Area IV	0																
Area V	0																
Area VI	84								53	31	5	6	6				
Silver sillago (Silver sihama)																	
Area I	78						5	33	54	8							
Area II	0																
Area III	0																
Area IV	16									19	31	44	6				
Area V	0																
Area VI	0																
Lobster (Puerulus sewelli)																	
Area I Male	106					8	40	24	22	4	2						
Female	116						6	12	39	26	15	2					
Without eggs	11					9	27	9	37	18							

Table II B. Size distribution (%) of selected species by areas.
Length in 5 cm groups. FL (Fork length).

	N	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Starry pigface bream (Lethrinus nebulosus)															
Area I	220	3	12	20	8	2	5	5	13	24	8				
Area II	296			13	14	5	1	1	13	23	20	8	1	0.33	0.33
Area III	69		6	16	16	19	17	3	6	7	9	1			
Area IV	32					34	38	16	3	6		3			
Area V	12					8	8	33		25	25				
Area VI	105		1		1	6	19	21	31	14	5				
Long face emperor (Lethrinus miniatus)															
Area I	11														
Area II	14						7			21	57	7	7		
Area III	7														
Area IV	82	7	26	28	27	6	4	3							
Area V	0														
Area VI	7														
Sweet lip (Plectorhynchus pictus)															
Area I	39					15	28	30	13	10	3				
Area II	16				44		6	6	19	6	6	13			
Area III	18						6	11	28	11	17	28			
Area IV	11					9	9		9		55	9	9		
Area V	3														
Area VI	27					4		4	11	11	41	22	7		
Grouper (Epinephelus undulosus)															
Area I	12						8	17		8	33	33			
Area II	14								7		21	14	50	7	
Area III	36									6	14	67	11	3	
Area IV	3														
Area V	0														
Area VI	19						5		5	21	58	11			
Surgeon fish (Acanthurus strigosus)															
Area I	0														
Area II	0														
Area III	12								58	42					
Area IV	0														
Area V	53							6	51	39	4				
Area VI	5														
Mangrove Red Snapper (Lutjanus argentimaculatus)															
Area I	3														
Area II	17			18	47	12	12					12			
Area III	3														
Area IV	7														
Area V	0														
Area VI	18							11	50	11	17	11			
Snapper (Lutjanus rivulatus)															
Area I	7														
Area II	24						8	13	17	25	13	4	8	8	4
Area III	14										7	14	50	29	
Area IV	8														
Area V	1														
Area VI	1														

APPENDIX I.

Acoustic instruments, settings and operation.

The vessel was equipped with two echo sounders, one operating at 38 kHz and one at 120 kHz.

The 38 kHz echo sounder was the main instrument for the acoustic assessment. One analog echo integrator was connected to this instrument, its two channels mostly integrating in the depth layers 5-50 and 50-100 m, or otherwise as appropriate according to depth. The gain setting was 30 dB and threshold 2 or 3.

Settings of the 38 kHz echo sounder were: Basic range 0-100/ 100-200 m. Transmitter 10/1, external. Pulse length and band width 0.6 m/sec. - 1 kHz. Receiver TVG and gain 20 log R - 20 dB. Recorder gain 7.

During this cruise the amplification of the receiver was reduced from 85 to 79 db. In terms of integrator deflections this brought about an increased value of the integrator units. This difference was, however, allowed for in the processing of the acoustic data. The indices of echo abundance entered in the distribution charts (Figs. 14-16) are equivalent with the indices applied during Survey II.

The settings of the 120 kHz echosounder were: Basic range 0-100 m. Pulse length and band width 0.6 m/sec. - 3 kHz. TVG and gain 20 log R 0 dB. Recorder gain 6.

One analog integrator was connected to the 120 kHz echo sounder, integrated in the same depth layers as the 38 kHz system, but to maximum 100 m depth.

According to regular calibrations of the acoustic equipment, its performance has remained unchanged since Survey II. The density coefficients to be applied in the assessment of the fish resources can therefore be based on the general which is given in Report II, Appendix II.

$$C = 9.3 \cdot 10^6 \, L^{-1.9}$$

Here L represents the average body length of the fish and the fish density is given in number of individuals.

Based on averages of length and weight of the species in the three categories of fish the following density coefficients are given in terms of tonnes.

Type A: 14 tonnes/mm $(nm)^2$.
(One unit of integrator deflection indicates a fish density of 14 tonnes per square nautical mile).
Type B: 12 tonnes/mm $(nm)^2$.
Type C: 6 tonnes/mm $(nm)^2$.

APPENDIX II

Erratum, Report II.

By a deplorable mistake a figure belonging to Report III was presented as Fig. 1 in Report II. The correct figure is presented here.

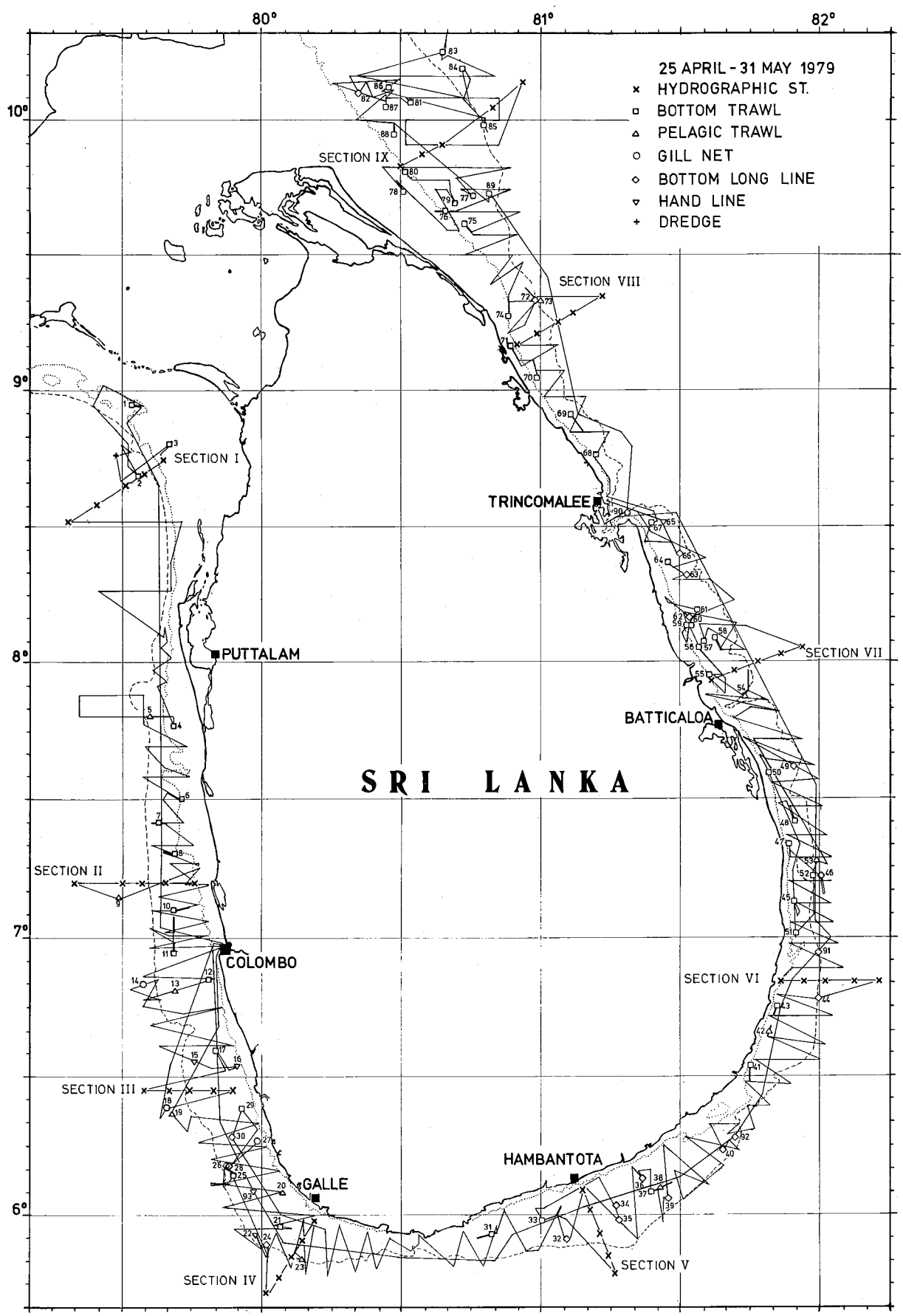
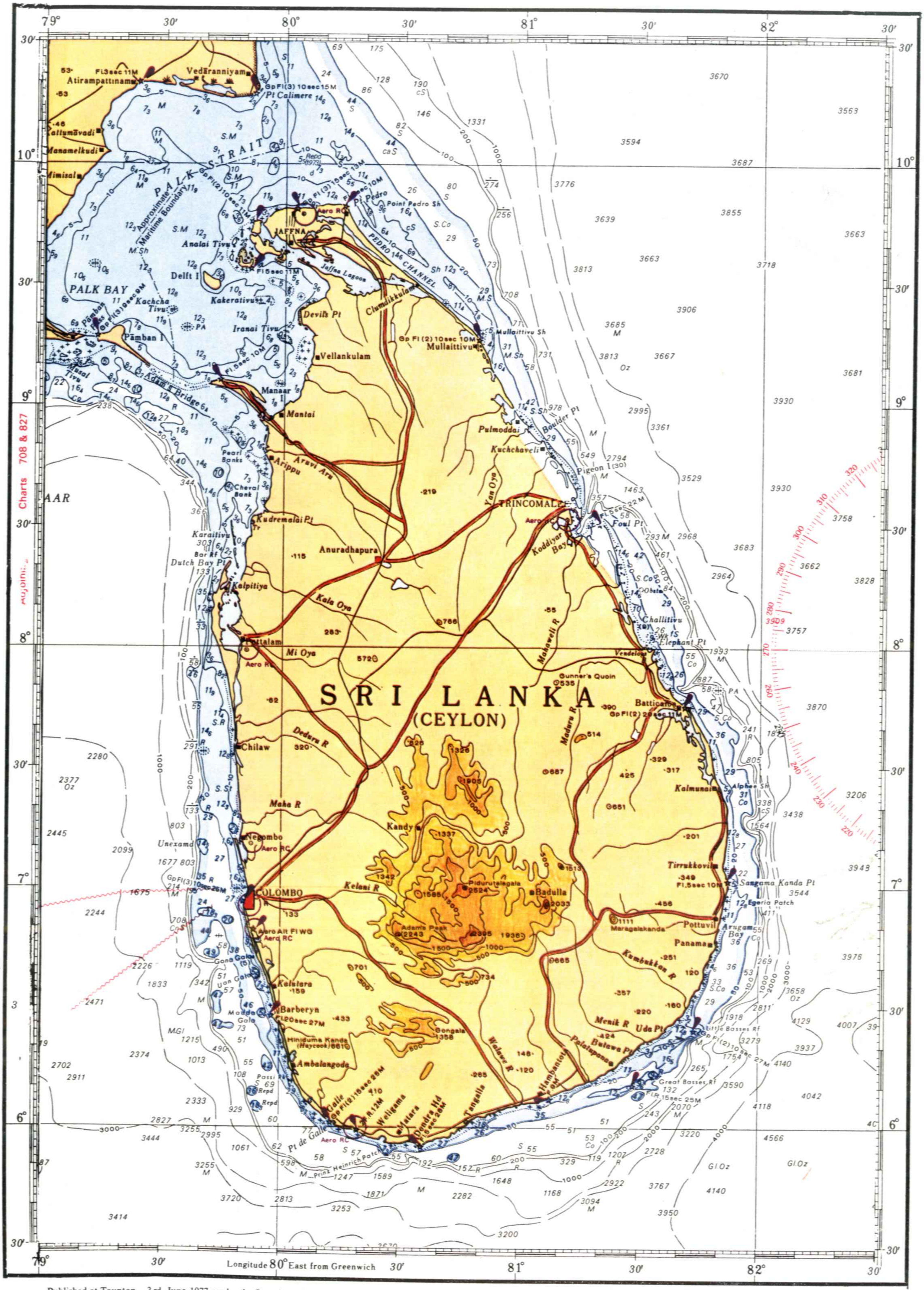


Fig. 1, Report II. Cruise tracks and stations worked in the period 23 April - 31 May.



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A.S JOHN GRIEG