Brief Summary of findings

“DR FRIDTJOF NANSEN”

Ecosystem survey of Sri Lanka 2018

DISCLAIMER

This document is produced by National Aquatic Resources Research and Development Agency (NARA), Sri Lanka and includes extracts from the report Krakstad, et al., 2018. Survey of regional resources and ecosystems of the Bay of Bengal: part 1. Sri Lanka, 24 June – 16 July 2018. NORAD-FAO PROGRAMME GCP/GLO/690/NOR, CRUISE REPORTS DR FRIDTJOF NANSEN, EAF-Nansen/CR/2018/8. 162 pp. The report is intended to highlight some of the main findings from the survey with the R/V Dr. Fridtjof Nansen in 2018. The document does not present a full overview of the results but is based on the preliminary cruise report. This summary is not an official document from the cruise nor represent any official statement from the organisations involved in the cruise.

INTRODUCTION

The coastal fishery resource on the narrow shelf of Sri Lanka is under immense pressure from several different actors. The number of fishermen has been increasing since the 2004 Tsunami, aquaculture and tourism put pressure on coastal resources and the growing population of Sri Lanka has substantially increased the pressure. Important habitats like estuaries, mangroves, and coral reefs are vulnerable to human activities from both local pollution and construction activities as well as from global climate change and general heating.

The coastal fish stocks of Sri Lanka have not been assessed by independent surveys since the four surveys carried out as part of the 1978-1980 investigation of fishery resources with "Dr Fridtjof Nansen". Those survey provided information on the fish distribution, composition and abundance of key fish resources on the shelf and to describe their environment. The results of these surveys have been used in the management of the coastal fishery resources and in ongoing fishery monitoring programs in Sri Lanka.

As a part of "Sri Lanka – Norway Bilateral project" to improve the management of the fish resources of Sri Lanka, is requested to FAO to conduct ecosystem survey using research vessel "Dr Fridtjof Nansen". This survey was planned as part of a synoptic coverage of the Bay of Bengal marine resources and ecosystems to be conducted by the RV *Dr Fridtjof Nansen* in 2018 as part of the EAF-Nansen Programme (2017-2021). In connection with this phase of the Programme, a Science Plan has been developed that addresses 11 different topics within three main lines of research related to resources, impacts of oil/mining activities and pollution on resources and ecosystems and climate change. Therefore, in addition to providing key information on the abundance and distribution of main pelagic stocks, the survey programme was designed to also support research projects under the science plan. Within this framework, the survey scope and objectives for the Bay of Bengal were discussed and agreed to during a regional meeting held in Colombo (Sri Lanka) in August 2017.

The ecosystem survey of Sri Lanka started in Colombo on 24 June 2018 and covered the continental shelf and upper slope of Sri Lanka until 16 June (Figure 1).

This report describes the ecosystem survey along the coast of Sri Lanka covering hydrographic conditions, phytoplankton, zooplankton and ichthyoplankton, an abundance of pelagic and demersal resources, biodiversity from trawl catches, pollution (microplastics), the occurrence of top predators. Additional analysis of data collected will take place as part of the work under the EAF-Nansen Science Plan.

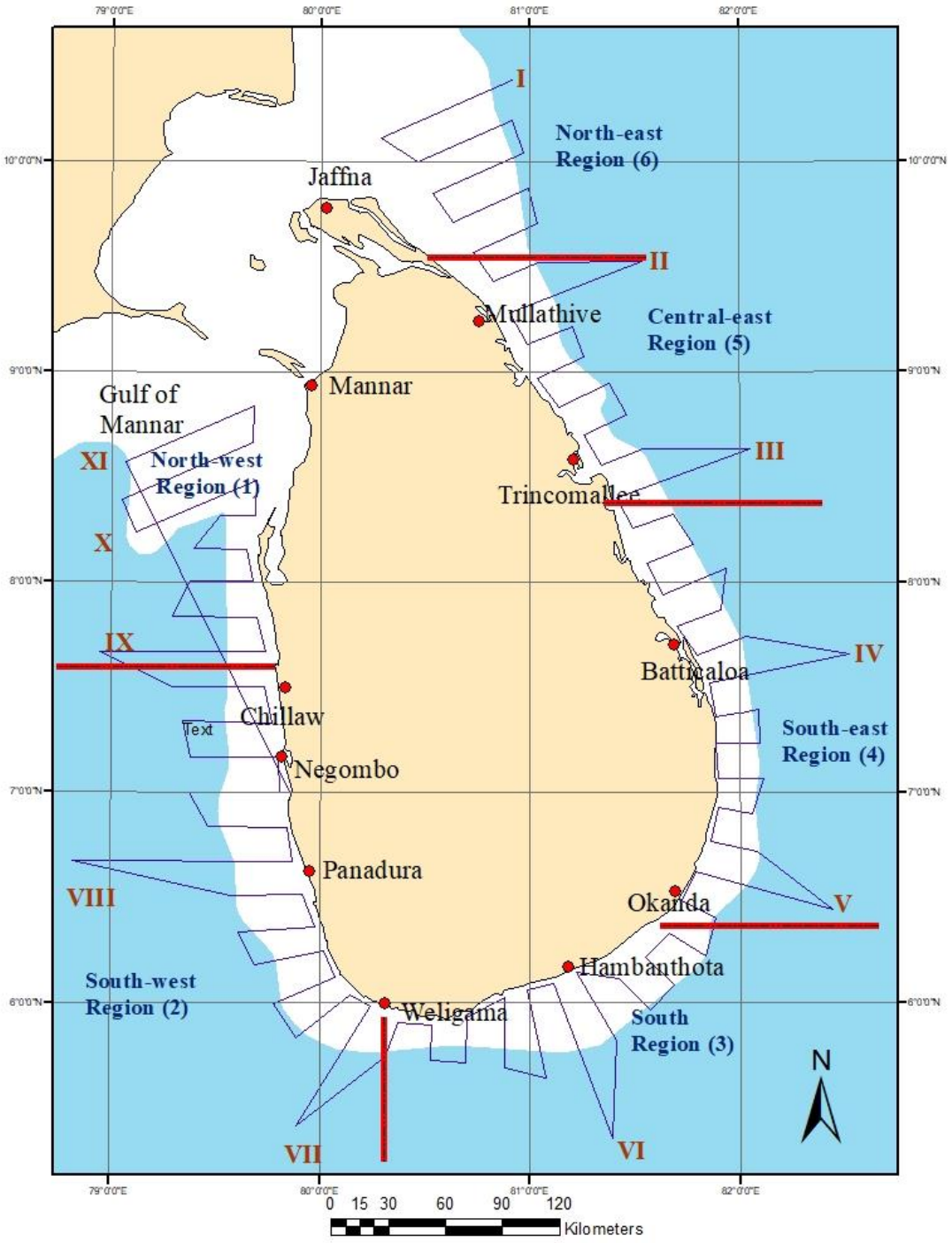


Figure 1: RV Dr Fridtjof Nansen Survey Programme 2018, Leg 3.1. Note: Survey regions (1-6) were designed according to the dir. Fridtjof Nansen surveys carried out in 1978 – 1980 in Sri Lanka. Roman numbers I-XI describes the numbering of the ecosystem transects carried out.

Survey objectives

Hydrography:

- To map the hydrographic/environmental conditions in the survey area (temperature, salinity, oxygen, chlorophyll, nutrients and pH values).

Phytoplankton, zooplankton, ichthyoplankton, and jellyfish:

- To establish as far as possible, the distribution, abundance, and composition of photos- and zooplankton (including jellyfish), and species composition of fish eggs and larvae.

Pelagic and demersal fish stocks:

- To obtain information on abundance, distribution (also by size) of the main pelagic fish species and considering the pelagic sub-groups PEL 1 (clupeids, engraulids) and PEL2 (carangids, scombroids, barracudas, hairtail), using acoustic methods in a systematic grid survey strategy and conducting targeted trawling.
- To obtain information on abundance, distribution (also by size) of the main demersal fish species, crustaceans, and squids, using a swept-area method with bottom trawls.
- To collect information on the biodiversity of fish from trawl catches
- To collect information on maturity stages, for the main pelagic fish, demersal fish, crustaceans and squids.
- To collect samples for genetic analysis for selected species.
- To collect stomach samples for analysis of contents (diet) including microplastics.

Mesopelagic fish:

- To identify the main species of mesopelagic fish in coastal waters around Sri Lanka

Contaminants:

- To collect samples of fish species consumed locally, the most abundant/less exploited depth water fish species and other indicator species, for analysis of contaminant levels and nutrient values.

Top predators:

- To record the occurrence of seabirds and marine mammals along the cruise track.

Participation

A total of 29 scientists and technicians from Sri Lanka and Norway participated in the survey.

Cruise leader: Jens-Otto Krakstad (Institute of Marine Research, Bergen, Norway)

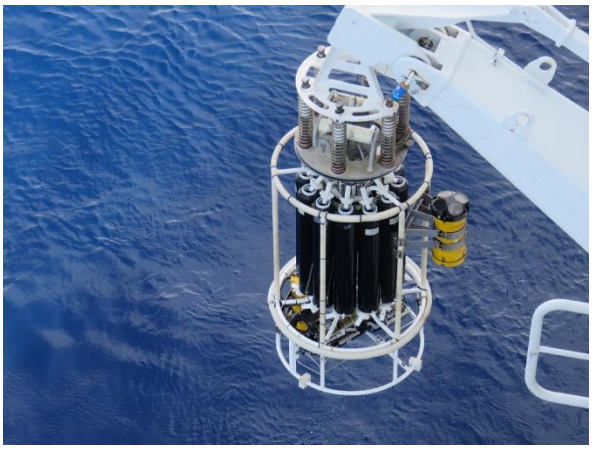
Co-cruise leader: Prabath Jayasinghe (NARA, Sri Lanka)

The full list of the participants and their affiliations are given in the cruise report.

Survey effort

The design of the survey track consisting of pseudo-parallel acoustic transect lines perpendicular to the coastline, from 20 m to 1 500 m depth, equally spaced approximately 10 nautical miles apart. Every degree latitude an ecosystem transect were carried out with detailed hydrographic sampling with CTD, and photo and zooplankton sampling stations at predefined bathymetric depths.

Besides acoustic sampling for pelagic fish biomass estimation, the survey design also allowed a continuous recording of data from the multibeam bottom mapping echo sounder EM302, thermosalinograph and weather station. The bottom penetrating echo sounder was used on selected locations along the ecosystem transects.



Hydrographic sampling with CTD

Pelagic trawling in operation

Bottom trawling for biomass estimation of demersal fish and crustaceans was undertaken at three different depth-strata on each transect or when bottom conditions allowed, between 20-50 m, 50-100 m and between 100-1000 m depth. Due to the steepness of the shelf, the number of trawl station beyond 100 m was low and no biomass estimate could be carried out for this depth range.

Hydrographic variables were measured at every bottom trawl station and at “ecosystem” sections perpendicular to the coastline about every 60 nm. At these transects, in addition to CTD sampling, an elaborate sampling program was conducted including for plankton, egg and larvae and water collected for chemical analysis. Table 1 summarises the survey effort in each sub-area

Sub samling fish catch on deck

Measurements at the fish wet lab

Table 1: Survey effort per region in several sampling stations. Number of CTD, Phyto - phytoplankton nets, WP2 – zooplankton nets, Multi – Multinet mammoth for eggs and larvae, Manta – nets for plastic particles in the surface, BT-bottom trawl and PT-Pelagic trawl hauls

Regions	North East	Central East	South East	South	South West	North West	Offshore West
Date	25- 28/6	28-30/6	30/6 - 3/7	4- 6/7	6-10/7	10-14/7	14- 15/7
Distance (NM)	299.5	337.1	469.1	312.8	912.6	422.1	81.7
Transect	5	8	13	9	11	9	1
BT	12	10	18	11	13	5	0
PT	2	1	2	2	7	3	2
CTD	21	20	28	18	22	18	8
Phyto	3	6	4	3	6	1	0
WP2	5	10	10	5	10	3	4
Multi	3	5	5	3	4	2	2
Manta	3	6	6	3	6	2	2
Pump sample*	7	7	9	7	7	7	4

SUMMARY OF SURVEY RESULTS

The ecosystem survey was successfully carried out and provided a wealth of new data on the marine shelf and slope ecosystem off Sri Lanka. Data collected during the survey included physical and chemical oceanography, plastic pollution, plankton distribution and abundance, pelagic and demersal fish biomass, distribution and diversity, and distribution of marine mammals around Sri Lanka. Standard acoustic and swept area fish stock assessment methods were used to estimate the distribution, abundance, and biomass of the pelagic and demersal fish stocks in the region. Some of the analyses will require additional work and will be reported separately from this report. Research activities are also planned as part of the EAF-Nansen Science Plan and the data and samples collected in Sri Lanka will be analysed and published in that context.

Oceanography

Waters off the east coast of Sri Lanka are characterized by a 50-100 m thick surface layer with high temperature and low salinity. This low-density layer prevents vertical mixing. Off the southern coast, there is active upwelling over the slope. Off the southwest coast there is also indications of some upwelling, and in addition, lower stratification and strong winds allow wind mixing bringing up waters from below the pycnocline. Below the pycnocline, warm saline water with low oxygen concentrations is observed in the whole survey area, with higher salinity observed immediately below the upper low-density layer to the east of Sri Lanka, this layer is not present off the west coast.

Figure 2 shows a schematic overview of the surface currents as observed during the survey.

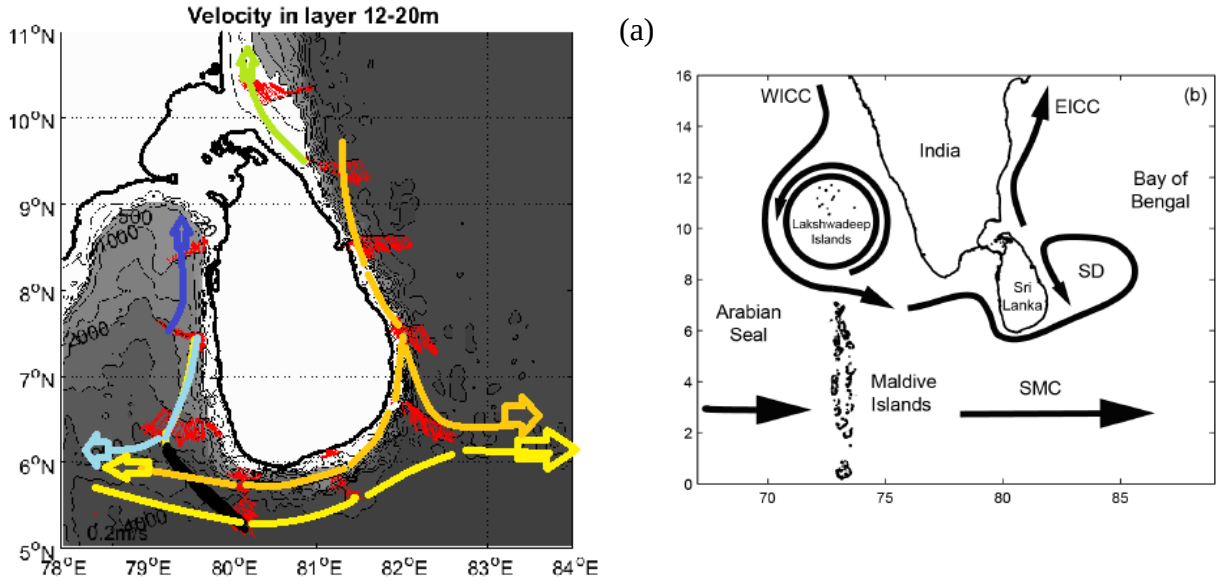


Figure 2: (a) Schematic description of the near-surface currents as observed during the survey, (b) General current pattern around Sri Lanka during Southwest monsoon

South Monsoon Current (SMC) may not contribute to Sri Lankan Dome, which is suspected to influence the local weather and seasonal climate. According to current survey results, East Indian Coastal Current (EICC) may not be limited to the Indian sub-continent, buy may continue along the east and south coast. Current between the Lakshadweep Island and west coast of Sri Lanka is established during survey period.

Horizontal distribution of oceanographic parameters

Sea Surface Temperature (SST) distribution demarcate the survey area into three zones, the warm eastern part, the intermediate southern part and the cooler western zone (Figure 3 a). Generally, the east coast of Sri Lanka hugs the Bay of Bengal (BoB) water which is situated at its east side. Usually, BoB is warmer (>28^{O}C) than the Arabian Sea (AS) at the west of Sri Lanka. The BoB region experience a freshwater inflow from the great Indian rivers (Godavari, Ganges, Irrawaddy etc.) which create a shallow mixed layer. Thus, the mixing is limited to a shallow area making the incoming solar radiation distribute within that shallow layer. Incoming solar radiation is more than enough to heat up the shallow upper ocean area, eventually making a warmer sea surface at BoB.

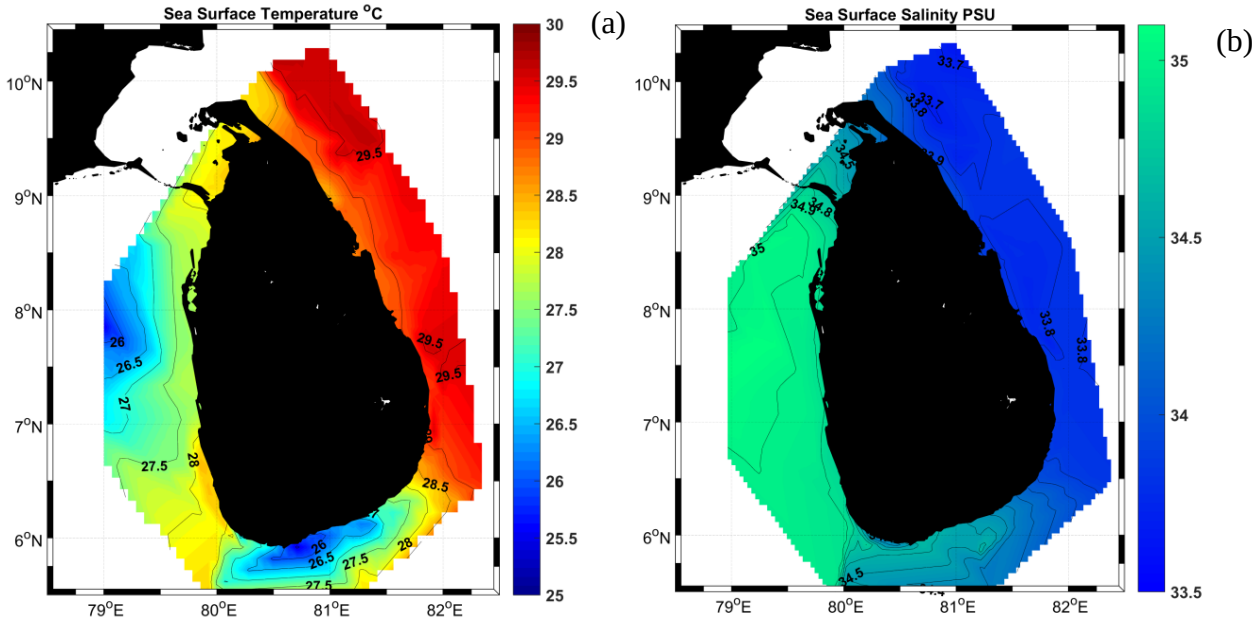


Figure 3**.** The temperature (a) and salinity (b) at the ocean surface (4 m) along the survey area

Profound cooler SST signal along the south coast is a clue for the southern coastal upwelling. During the SWM period, strong winds create offshore Ekman flow and carry surface water away from the coast, creating upwelling which brings cooler, dense and nutrient enriched water to surface. The southern coastal upwelling is an important phenomenon which is accountable for the improved ocean primary productivity.

As with the temperature distribution, sea surface salinity (SSS) also expressed a marked geographical distribution. A fresher (~33.7) ocean surface at the east coast, saline (34.8-35.0)

ocean surface at west and northwest coast coasts and an intermediate (~34.5) level salinity distribution at the southern coast can be observed (Figure 3 b).

Eastern ocean area of Sri Lanka is much more prone to fresh water mixing than the west side. Freshwater mixing in the BoB is mostly accountable for the observed relative freshness in the eastern side of the survey area. In contrast, AS is not having such a prominent freshwater inflow as in BoB, thus experience a saline environment throughout the year. Therefore, the recorded salinity at the sea surface was relatively higher (~35 PSU) in the western side of the survey area.

At the southern tip of Sri Lanka, an intermediate SSS was observed. This area is a transitional area for ocean currents which passes seasonally either way. This survey was carried out in SWM period, thus a strong current (South Monsoon Current) passes from AS to BoB touching the southern tip of Sri Lanka. It carries more saline water from AS towards the BoB. At the southern part of Sri Lanka, high saline AS waters and low saline BoB waters are mixing laterally, thus an intermediate SSS (~34.5) and an east-west SSS gradient could be observed during the survey period.

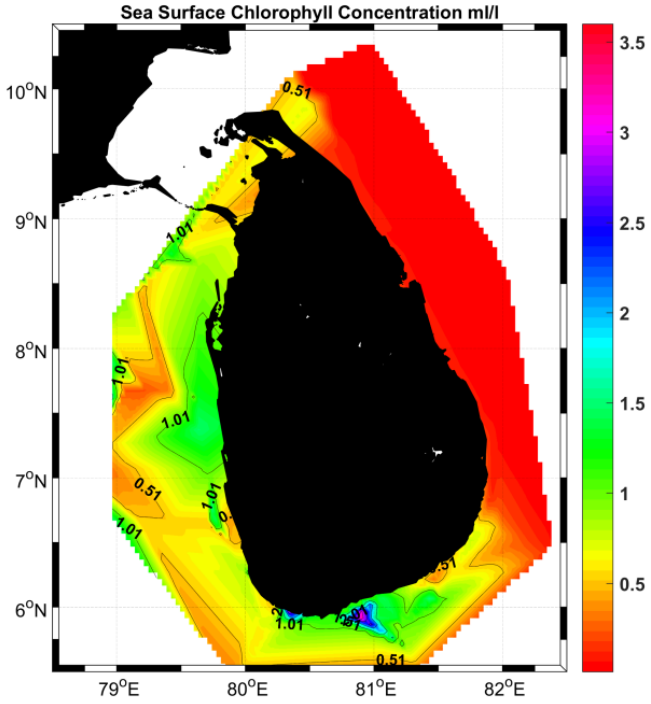


Figure 4**.** The sea surface chlorophyll in the survey area

The Chlorophyll concentration depicts the productivity of an area. According to Figure 4, the east coast is less productive (>0.5 ug/l) than the west coast. A significant chlorophyll increment could be observed in two places (south coast and the far offshore western area). They could be attributed to the southern upwelling zone and a potential offshore upwelling eddy. This southern upwelling and offshore upwelling eddy spotted two surface cooling area as observed in Figure 3a.

Plankton

Integrated data overall depths showed the lowest zooplankton biomass was recorded on the North East coast while the highest biomass was observed in the South Coast of Sri Lanka. The zooplankton species diversity was highest in the South West and North West regions. Regarding ichthyoplankton distribution, an important indicator of fish nursery areas. The highest average number of fish larvae was observed in the South East region while the lowest average number of fish larvae was recorded on the North East coast.

Results of fish larvae abundance and diversity

Results from the Multinet Mammoth catches showed that dominant fish larvae off Sri Lankan waters belonged to the families Engraulidae, Carangidae, Lutjanidae, Scombridae, Labridae, and Myctophidae (Table 5, Figure 3). The highest average number of fish larvae was observed in the South East region (1183 fish larvae $1000m^{-3}$) followed by Central East region (604 fish larvae/ $1000m^3$) and South West region. Lowest average number of fish larvae was observed in the North-east region with 103 fish larvae $1000m^{-3}$ (Table 2 Figure 5). Four shelf regions showed a higher average number of fish larvae compare to the deep-sea areas i.e. Central East, South East, South West, and North West except North East and South regions. The highest species diversity was observed in the South-west region whereas the lowest was in the North-east region.

Table 2. Summary of the average density of fish larvae and dominant families in different regions from Multinet Mammoth catches

Area / Region	**Average no of fish larvae per $1000m^3$**	**Dominant families**
North East	103	Engraulidae, Nomeidae, Bregmacerotidae, Myctophidae, Scombridae
Central East	604	Engraulidae, Scombridae, Carangidae, Bregmacerotidae
South East	1183	Carangidae, Lutjanidae, Tetraodontidae, Diodontidae
South	189	Carangidae, Lutjanidae, Myctophidae, Scombridae
South West	552	Carangidae, Bothidae, Myctophidae, Lutjanidae
North West	192	Myctophidae, Bregmacerotidae, Sebastidae, Lutjanidae

North East region mainly consisted of pelagic and mesopelagic fish families i.e. Engraulidae, Scombridae, Bregmacerotidae, Nomeidae, and Myctophidae. The Central East was mainly dominated by pelagic families (Engraulidae, Scombridae, and Carangidae). In the South East and South West regions, demersal families were dominated followed by pelagic fish groups, the demersal families dominated i.e. Lutjanidae and Bothidae. In the South and North West regions mesopelagic fish families Myctophidae, Bregmacerotidae and Sebastidae were dominated.

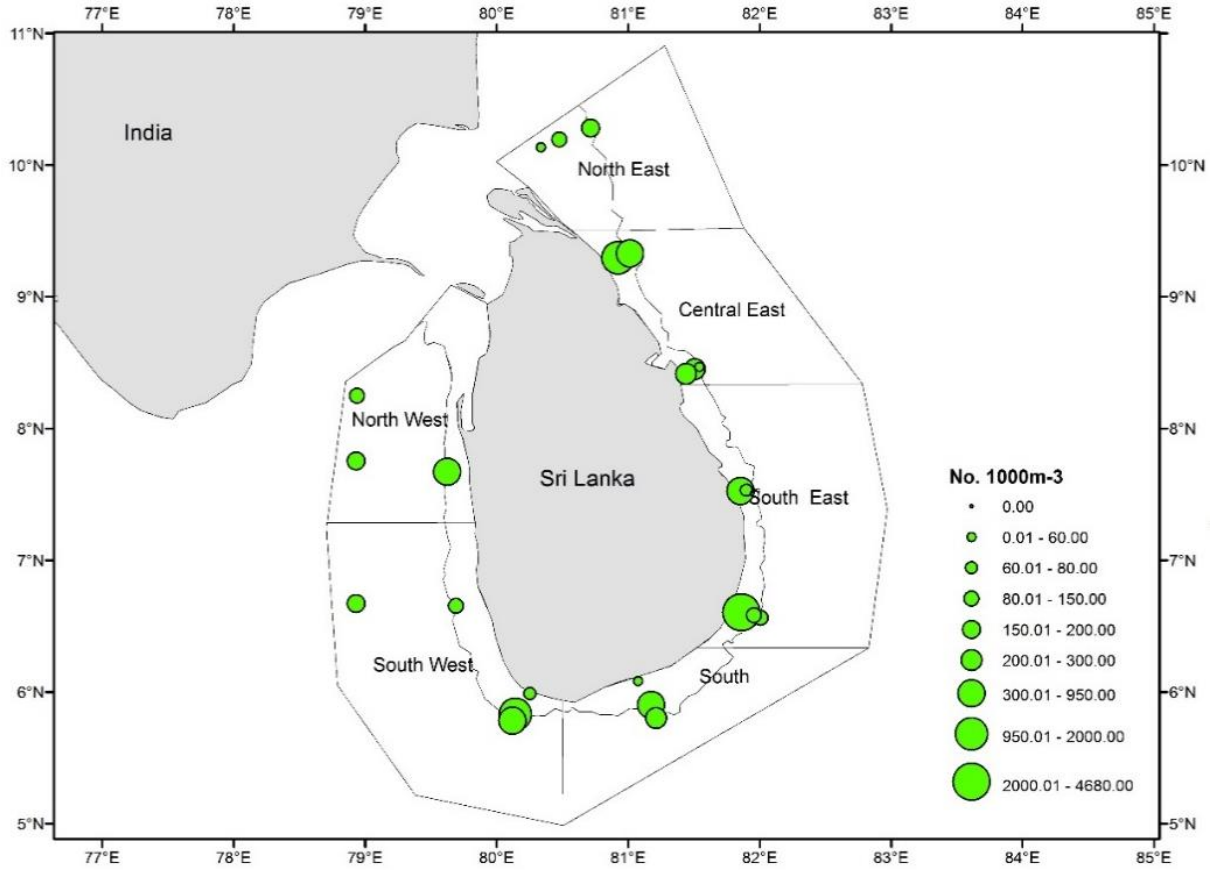
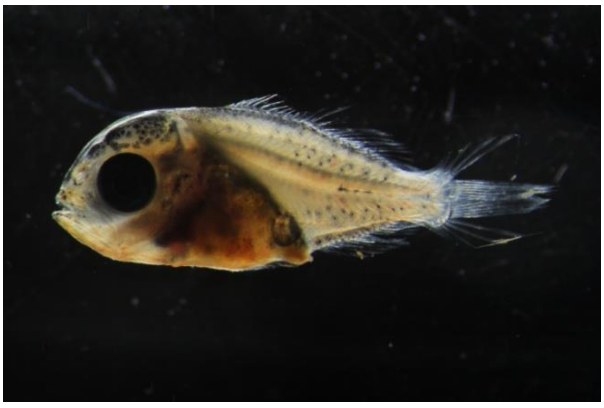
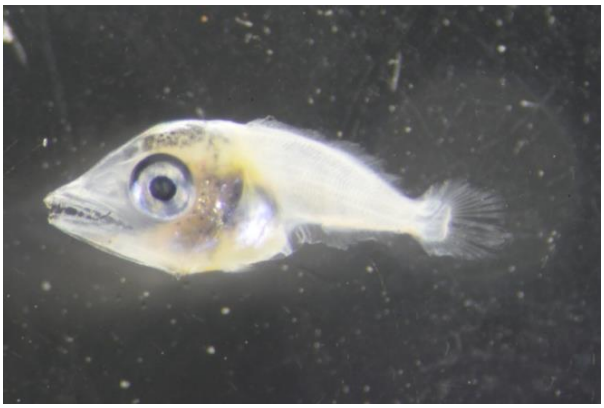


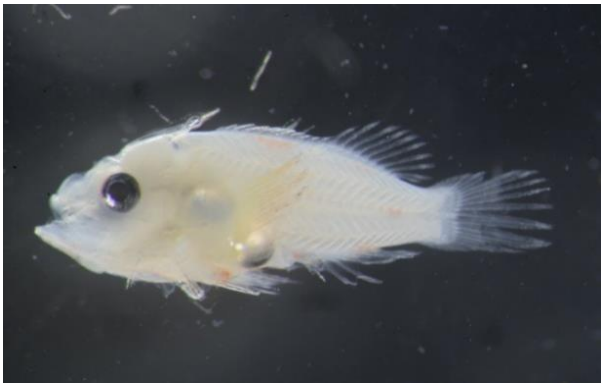
Figure 5. The abundance of fish larvae around the Sri Lankan waters (No. 1000^{-3})



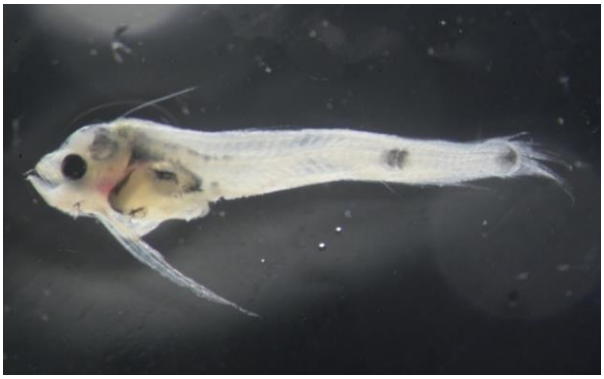
Family: Nomeidae, *Cubiceps* spp. Postflexion (7.2 mm), North East Region



Family: Scombridae, *Auxis* spp. (6.2 mm), North East Region



Family: Lethrinidae Postflexion (7.5 mm), Central East Region

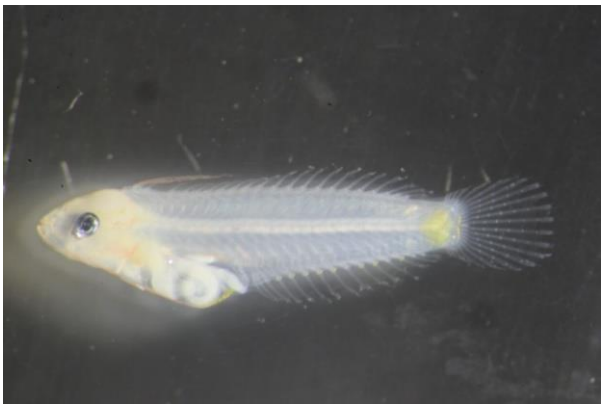


Family: Bregmacerotidae Postflexion (9 mm), North East Region

Family: Lutjanidae, *Lutjanus* spp. Postflexion (16.2 mm), Central East Region

Family: Bothidae Postflexion (18 mm), Central East Region

Family: Menidae, *Mene maculata* Postflexion (6.5 mm), South West region



Family: Labridae, *Halichoeres zeylonicus* Postflexion (11.3 mm), South region

Figure 6. Examples of fish larvae collected during the survey.

Zooplankton Biomass

The zooplankton biomass showed huge variations around Sri Lankan waters. In general, high levels of zooplankton biomass was recorded in the South and South-West regions. In the East Coast, the biomass was comparatively low. Furthermore, for all depths, the lowest and highest zooplankton biomass was recorded in the North East coast (0.8467 gm^{-2} dry wt.) and the in the South Coast of Sri Lanka (2.7046 gm^{-2} dry wt.). Figure 7 show the recorded biomass distribution integrated from surface to 200 m depth during the study period.

The contribution of larger individuals to the total zooplankton biomass (2000 µm fraction) was observed mainly in the shallow waters of the Central East, South West, in shelf and deeper waters of South East and South and deep waters of North West. In addition, the contribution of smaller zooplankton to the total biomass (180-1000µm) was generally high in all the regions, however, spatial variances were observed. The WP2 net generally tends to underestimate the larger organisms such as euphausiids (krill) due to avoidance. The overall total zooplankton biomass results indicated that there were low productive areas in the North East, Central East, South East, and North West regions while high productive areas were observed in the South, South West and North West regions off Sri Lanka during the study period. Some zooplankton species found during the survey are shown in Figure 8.

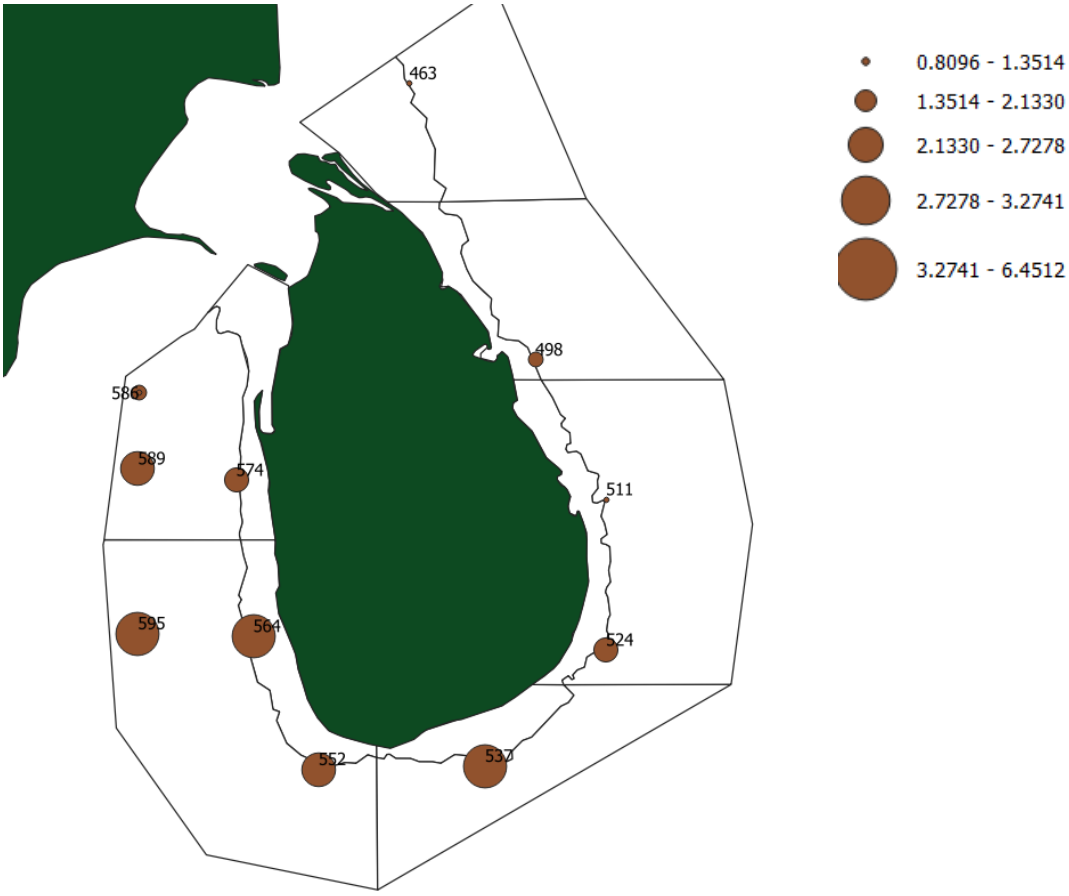
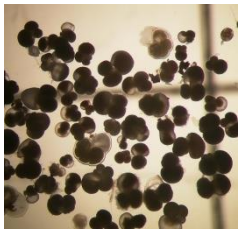


Figure 7: 0 - 200 m biomass distribution map around Sri Lanka

Acrocalanus sp.

Eucalanus sp.



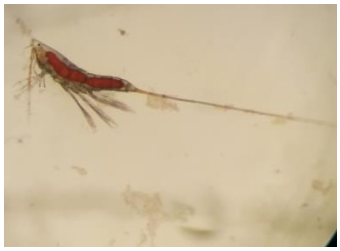
Globigerina spp.

Krill

Euchaeta sp.

Candacia sp.

Pontella plumata



Macrosetella sp.

Figure 8: Some of the zooplankton species collected during the survey.

Phytoplankton abundance

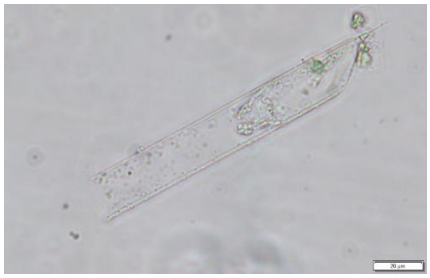
High phytoplankton counts were observed in South and North West part of the area (Table 3). Lowest phytoplankton abundance was recorded in the Central East region of Sri Lanka (43.8 X 10^3 cells/ml). Sample sites owing higher concentrations of phytoplankton were 527, 542, 566 and phytoplankton concentration (cells/ml) at each site were 146,119 ^{3},101 X 10^3 respectively.

Rhizosolenia, Proboscia and *Pseudo-nitzschia* species were dominant in almost all the samples (Figure 9). *Ceratium longipes* and *Oscillatoria* sp. were recorded as dominant in sample number 500 and 513 respectively.

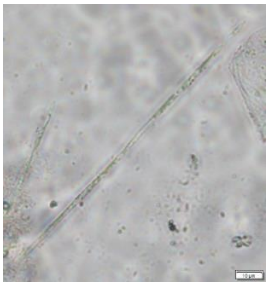
Table 3: Phytoplankton abundance (cells/ml) of different region of Sri Lankan water

Depth (m)	Survey region	Name of region	No. of stations in the polygon	Phytoplankton count (cells/ml) (X 10^3)
0-30	1	North West	1	85.00
	2	South West	6	72.33
	3	South	3	84.66
	4	South East	4	64.00
	5	Central East	5	43.80
	6	North East	3	61.33

Rhizosolenia sp



Proboscia sp



Pseudo-nitzschia sp

Ceratium longipes

Oscillatoria sp

Figure 9: Dominant phytoplankton species found in survey

Microplastic

The results reveal that the waters around Sri Lanka are contaminated with microplastics, and the vast majority of microplastics found are in the secondary category, indicating that the packaging material, industrial applications, and fishing gear are major sources. The survey covered one season of the year, and the results as such are a snapshot. Microplastic particles were found throughout the survey area on all sampling stations. The highest concentrations were found in the off North Western region of Sri Lanka. This region was highly polluted with microplastics, compared to other regions, while the northeast coast and the south coast showed the lowest number of microplastic particles in the samples (Figure 10).

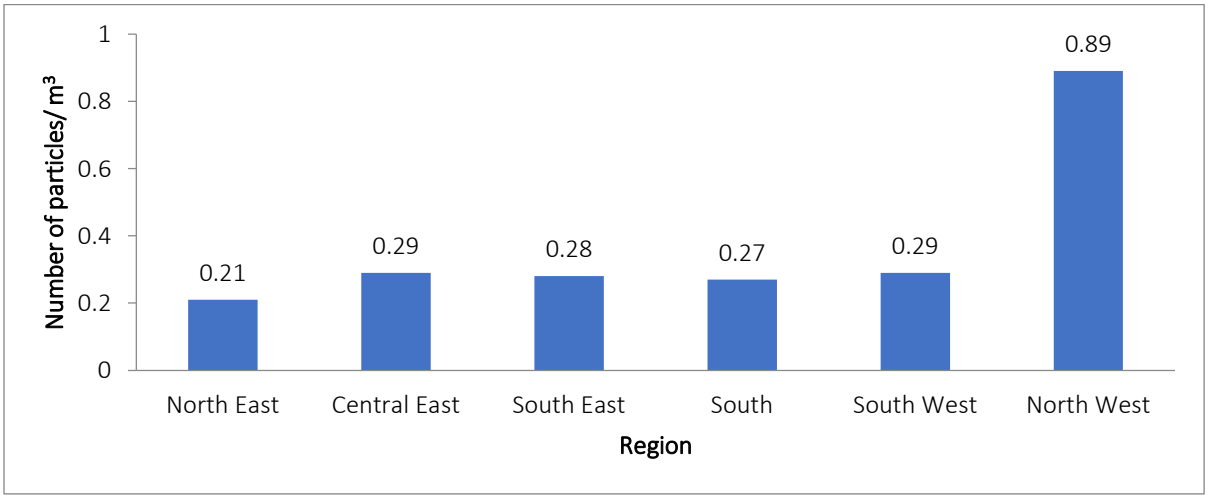


Figure 10: Abundance of microplastics in pumped water samples collected from the six regions.

Biomass estimates

Pelagic estimates

Acoustic biomass estimates were calculated for Clupeidae, Dussumieriidae, and Engraulidae (PEL1), while the PEL2 species consisted of the families Carangidae, Scombridae, Barracuda and Hairtails. The total PEL1 biomass of Sri Lanka was 21 000 tonnes, of this more than 18 000 tonnes were found in the South West coast region (off Negombo) Clupeoids were the most important group. Of the Pel2 group, total estimated biomass was of 101 000 tonnes with the highest abundance found along the south and west coast. Different Carangid species dominated. The numbers should be considered as relative indices and reflect the standing stock in the area surveyed by the vessel. There are indications that some pelagic fish was distributed outside the area surveyed close to the coast and far offshore.

Demersal estimates

The total swept area biomass (t) estimated from the survey was 53 000 tonnes excluding jellyfish, garbage, coral debris and sponges that came up with the trawl. Looking at the biomass on the shelf (20-100 m depth) in the different regions the North West coast gave the lowest biomass estimate of Sri Lanka with an estimate of 967 tonnes. The highest biomass in the coastal zone was found on the shelf off Batticaloa in the South East region with an estimate of 8173 tonnes, the South West coast had the second highest biomass estimate on the shelf with biomass of 7894 tonnes. On the South coast, the Hambantota banks, the biomass was 6901 tonnes. On the Central East coast, 4003 tonnes were recorded while in the far North East on the Pedro Bank biomass of 4485 tonnes was estimated. The biomass of jellyfish was 15 600 tonnes with a majority (14 200 tonnes) from the shelf off Batticaloa in the East region.

Marine Mammals

The present survey provides the opportunity for the first marine mammal observation carried out in Sri Lanka covering the whole coastal areas within a season. During the survey, five species of cetaceans were recorded. Blue whale *Balaenoptera musculus* is the most commonly observed (72% of total observations) and showed a wide distribution with a record of 151 (best) individuals. Since there were very low sightings of blue whales in the East of Sri Lanka, the current survey results indicated that during the southwest monsoon period the blue whale in Sri Lanka is found mainly in the southwestern part of the country. Importantly, the highest blue whale aggregations were recorded on the dense shipping lane from Dondra to Galle in the South coast of Sri Lanka (Figure 11).

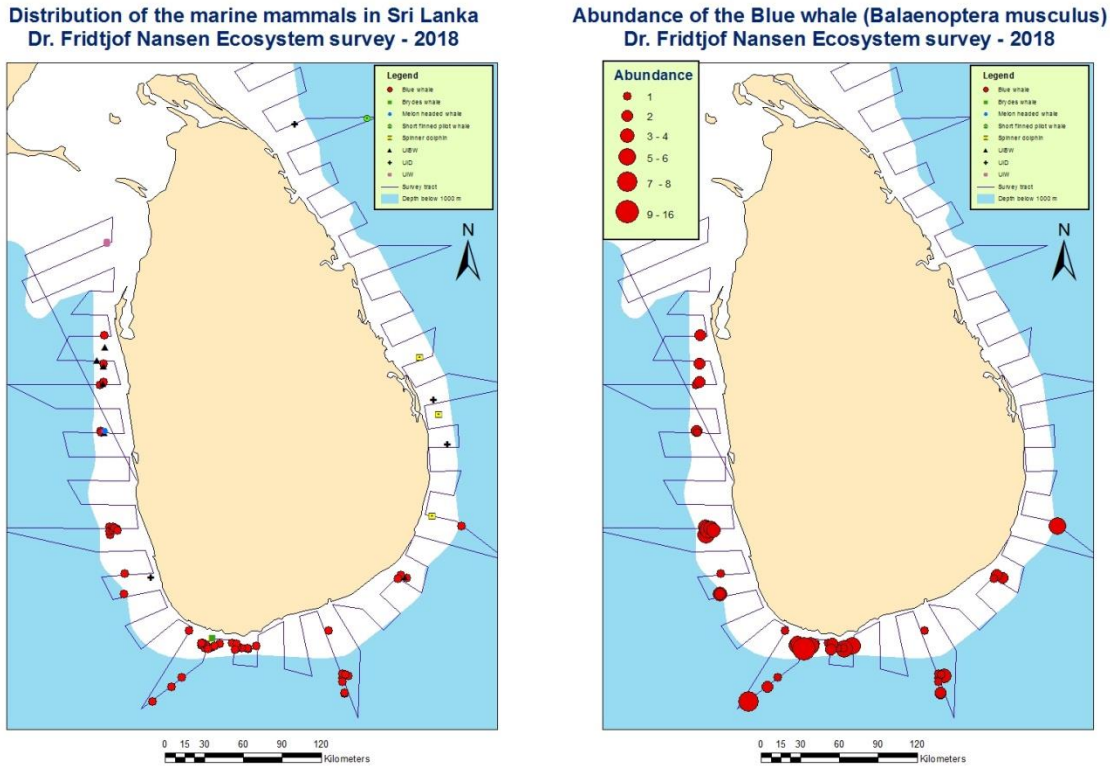


Figure 11: Distribution of the marine mammals around Sri Lanka during the southwest monsoon 2018. UIW-Un - identified whale, UID-Unidentified dolphin, UIBW-Unidentified baleen whale.

Taxonomy

A total of 593 different species were recorded during the survey (preliminary data, including material identified only to a higher taxonomic level). A number of these have yet to be identified. The largest taxonomic group was the bony fish with >400 different species recorded belonging to >100 different families, followed by, 21 different rays and13 different shark species (Figure 10).

Figure 13: Number of species recorded during the 2018 survey in the different regions. NW-Northwest, SW- Southwest, S-South, SW-Southeast, CE-Central East and NE-Northeast.

The results from these will be published separately after the survey. It is too early to conclude regarding the number of new records observed for Sri Lanka. However, it is a reason to believe that several species found during the survey are new to science while others have been registered around Sri Lanka for the first time (Figure 12).

Figure 14: Probably new records of ray and skate species

Participants of the cruise