# ATSEA
# CRUISE REPORT

# ATSEA CRUISE REPORT

## SECOND EDITION

Global Environment Facility
United Nation Development Programme
United Nation Office for Project Services
Agency for Marine and Fisheries Research and Development, Ministry of Marine Affairs and Fisheries, Indonesia
Arafura and Timor Seas Ecosystem Action Program

2011

Full citation of this publication is as follows:
ATSEA Cruise Report, 2010, S.Wirasantosa,T.Wagey,S.Nurhakim and D.Nugroho.(editors).ATSEA Program, 209pp

ISBN : 978-979-3692-26-5

# ATSEA CRUISE REPORT

## SECOND EDITION

**Editors:**
Sugiarta Wirasantosa
Tonny Wagey
Subhat Nurhakim
Duto Nugroho

**Concept Design:**
Ivonne Rawis
Adi Pramudya

**English editor:**
Susan Anthony

Global Environment Facility
United Nation Development Programme
United Nation Office for Project Services
Agency for Marine and Fisheries Research and Development, Ministry of Marine Affairs and Fisheries, Indonesia
Arafura and Timor Seas Ecosystem Action Program

# FOREWORDS

The Arafura and Timor Seas region is one of the last remaining hotspots of marine biodiversity in the world. The area has dynamic and diverse ecosystems which support one of the most important fisheries in Indonesia, the Arafura Trawl Fisheries. Further to the West, the Timor Sea serves as an important migratory path for many marine mammals which make their journey across the Pacific and through to the Indian Ocean in search for food. The emerging transboundary issues for the countries surrounding the Arafura and Timor Seas have become increasingly apparent. The regional cooperation involving Australia, Indonesia and Timor Leste neighboring the Arafura and Timor Seas is key to achieving the sustainable use of marine and fisheries resources in this area.

I am pleased to present the 2nd edition of ATSEA Cruise Report, which is a compilation of report activities conducted during the ATSEA Cruise in May 2010. This publication provides an important baseline to the description of this region, hence the development of Arafura and Timor Seas Transboundary Diagnostic Analysis (TDA) and later the Strategic Action Programs (SAP).

The ATSEA cruise is funded partially by the Global Environmental Facility (GEF), as part of the TDA – SAP development of the Arafura and Timor Seas. Support from the Indonesia Agency for Marine and Fisheries Research and Development as well as from Indonesian Institute of Science (LIPI) for this cruise, made it possible for the R.V.Baruna Jaya VIII to complete a 17-day voyage covering 23 sampling sites. This has been a tremendous achievement by the scientists involved in the cruise and it is proof that they can work together collectively, and I congratulate them.

I am very grateful for the participation of the scientists from BRKP, LIPI, University of Nusa Cendana, University of Papua, University of Pattimura, Ministry of Agriculture and Fisheries Timor-Leste, and the Australian Institute of Marine Science. The 1st edition of this report was kindly published by the Indonesian Agency for Marine and Fisheries Research and Development. The English draft was edited by Ms. Susan Anthony who spent a few weeks in our office. Thank you, Susan..! Finally, by having this report, I hope to see more oceanographic and fisheries expeditions in the near future and wish for sound management of our resources for the benefit of all people.

Jakarta, June 2011

**Dr. Tonny Wagey**
ATSEA Regional Project Manager

# TABLE OF CONTENTS

# List of Figures

# List of Tables

# List of Appendices

# List of Annexes

## Chapter I

# GENERAL INTRODUCTION

**Tonny Wagey, Sugiarta Wirasantosa**

Arafura and Timor Seas Ecosystem Action (ATSEA) Program
Email: *t.wagey@fisheries.ubc.ca*

The waters of the tropical and semi-enclosed Arafura and Timor Seas (ATS) are shared by Indonesia, Timor Leste, Papua New Guinea (PNG) and Australia. The Arafura and Timor Seas are considered to be semi-enclosed seas under Part IX, paragraph 122-123 of the United Nations Convention on the Law of the Sea, which places an obligation on the countries bordering the enclosed and semi-enclosed seas to cooperate in resource management, the protection of the marine environment and marine scientific research. The ATS region is extremely rich in living and non-living marine resources, including major fisheries and oil and gas reserves. The ATS region is located at the intersection of the two major Large Marine Ecosystems (LMEs), the Indonesian Seas to the north and the Northern Australian Waters to the south, and is also an integral part of the Coral Triangle Zone considered to have the highest marine biodiversity in the world. The ATS region exhibits high productivity that sustains both small- and large-scale fisheries, including several high-value, shared, transboundary fish stocks, that provide livelihoods for millions of people in the region, and make a significant contribution to food security for both regional coastal populations, and large populations in the export market countries to the north, including China.

The gross annual production from commercial, artisanal and subsistence fisheries in the ATS region is difficult to estimate, given existing gaps in data collection and analysis as well as the extremely high level of illegal, unregulated and unreported (IUU) fishing in the region, involving small and large fleets from several countries to the north of Indonesia. While foreign fishing is a major threat, there is also a substantial amount of Indonesian unregulated and unreported activities in this region. In addition to unsustainable and IUU fishing, the Arafura and Timor Seas face significant threats from a number of other pressures, including the potential for increased natural threats associated with climate change, as well as rapidly expanding coastal populations and increasing urbanization. In addition, high levels of poverty and limited economic opportunities can increase exploitative pressures on natural resources, degradation of coastal habitats, marine pollution from both land- and sea-based sources, and aquatic invasive species.

The Arafura Sea is an important area for shrimp and demersal fishes that have been heavily exploited for decades. Shrimp trawling poses a threat to the demersal fish stock due to its damaging catch methods. In the Indonesian parts of the Arafura and Timor Seas management area, all fish stocks (demersal, shrimp, small and large pelagic) are fully exploited, and demersal fish and shrimp in the Arafura Sea are overfished. High-value sedentary species, such as sea cucumbers, of which there are 350 species in Indonesia, are commercially targeted in the ATS region, but little data exist on the status of the resource.

In the Southeast Asia-Australia region, the Arafura and Timor Seas are one of the last remaining centers of tropical marine biodiversity, including fishery resources. The Arafura and Timor Seas interact intensively with the atmosphere, and are one of Asia's largest natural carbon sinks, well in excess of the average carbon sequestration rates in the coastal ocean. However, relatively less information is available for this region.

The Arafura Sea has relatively shallow water on the Arafura Shelf which lies between Indonesia and northern Australia. It has approximately 1850 km (115 miles) of coastline with an average depth of 50 – 80 m (165 – 265 feet). The Timor Sea covers an area of 615,000 km$^2$ (235,000 miles$^2$) located between the southeast of Timor Island and the North West of Australia.

The threats facing the Arafura and Timor Seas region are transboundary in nature, and can only be effectively addressed through multi-lateral cooperation between all four littoral nations. The rationale for the Global Environment Facility (GEF)

Full Sized Project (FSP) is the need for the littoral nations to work cooperatively to sustain the ATS shared living resources, conserve the biota of the seas and coasts, and improve sustainable socio-economic conditions and opportunities for coastal peoples.

Through the intervention of the GEF, including the undertaking of a Trans-Boundary Diagnostic Analysis (TDA), development of a Strategic Action Programme (SAP), and implementation of innovative demonstration projects, the littoral nations will be greatly assisted in collaboratively understanding and addressing the problems facing the shared waters; problems that cannot be solved by any one country on its own.

This study was conducted in the Arafura and Timor Seas from May 10 to 23, 2010, with a total of 23 CTD casts over eight stations in the Timor Sea, five stations in the waters to the south of Lemola-Tanimbar Islands and ten casts in the Arafura Sea. Figure 1.1 and Table 1.1 show the location of the 23 stations.

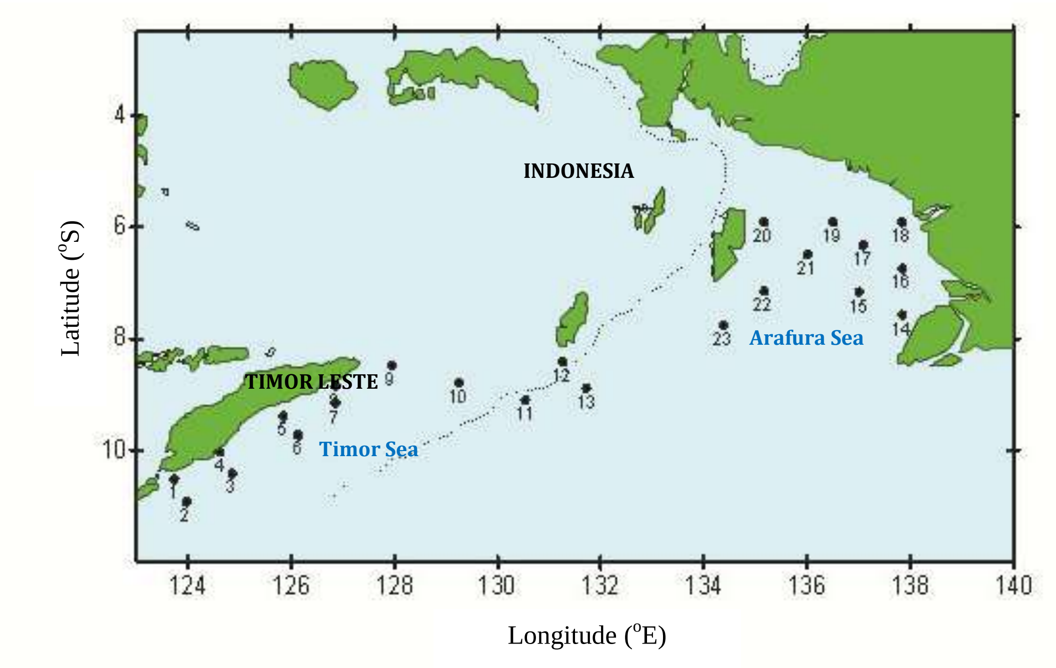



**Figure 1.1.** Distribution of observation stations in the Arafura and Timor Seas

**Table 1.1.** Station position, depth and time of observation

| No. | Station | Date | Western Indonesia Time | Position | | Depth (m) |
|---|---|---|---|---|---|---|
| | | | | Longitude | Latitude | |
| 1. | ATSEF_01 | 10 May | 18:24 | 123° 43.968' | -10° 31.011' | 272 |
| 2. | ATSEF_02 | 10 May | 23:10 | 123° 58.055' | -10° 55.478' | 2,000 |
| 3. | ATSEF_03 | 11May | 09:34 | 124° 51.090' | -10° 25.102' | 1,939 |
| 4. | ATSEF_04 | 11 May | 15:05 | 124° 37.184' | -10° 01.772' | 746 |
| 5. | ATSEF_05 | 12 May | 07:06 | 125° 50.940' | -09° 23.030' | 1,029 |
| 6. | ATSEF_06 | 12 May | 15:05 | 126° 07.907' | -09° 43.893' | 2,584 |
| 7. | ATSEF_07 | 13 May | 10:00 | 126° 51.623' | -09° 09.055' | 1,589 |
| 8. | ATSEF_08 | 13 May | 07:17 | 126° 51.487' | -08° 50.899' | 583 |
| 9. | ATSEF_09 | 13 May | 20:35 | 127° 56.767' | -08° 29.229' | 2,016 |
| 10. | ATSEF_10 | 14 May | 09:40 | 129° 14.310' | -08° 47.405' | 1,615 |
| 11. | ATSEF_11 | 14 May | 21:45 | 130° 32.074' | -09° 05.925' | 633 |
| 12. | ATSEF_12 | 15 May | 07:17 | 131° 16.029' | -08° 25.007' | 1,506 |
| 13. | ATSEF_13 | 15 May | 15:38 | 131° 43.331' | -08° 53.266' | 339 |
| 14. | ATSEF_14 | 18 May | 13:43 | 137° 50.722' | -07° 34.590' | 19 |
| 15. | ATSEF_15 | 19 May | 01:09 | 137° 00.500' | -07° 09.705' | 35 |
| 16. | ATSEF_16 | 19 May | 11:23 | 137° 50.610' | -06° 44.645' | 29 |
| 17. | ATSEF_17 | 19 May | 22:34 | 137° 05.383' | -06° 19.758' | 35 |
| 18. | ATSEF_18 | 20 May | 08:39 | 137° 50.616' | -05° 54.806' | 37 |
| 19. | ATSEF_19 | 20 May | 23:40 | 136° 30.347' | -05° 54.738' | 48 |
| 20. | ATSEF_20 | 21 May | 14:46 | 135° 10.184' | -05° 54.711' | 57 |
| 21. | ATSEF_21 | 22 May | 01:49 | 136° 00.283' | -06° 29.776' | 35 |
| 22. | ATSEF_22 | 22 May | 13:36 | 135° 10.350' | -07° 08.750' | 38 |
| 23. | ATSEF_23 | 23 May | 01:23 | 134° 22.470' | -07° 45.961' | 59 |

To complete the TDA and SAP processes, a number of approaches will be undertaken, including the use of research vessels to conduct oceanographic surveys of the area determined by the project. There is a lack of oceanographic information and data for the Arafura and Timor Seas. As recommended in the framework report of the Arafura and Timor Seas Ecosystem Action (ATSEA) during the Project Preparation Grant (PPG) stage, one key activity in developing the Transboundary Diagnostic Analysis (TDA) of the ATS is to conduct a survey of these regions. This program involved scientists from the national and local stakeholders that are relevant to the ATS.

Therefore, a joint research cruise was undertaken by Indonesia, Timor Leste and Australia in the Arafura and Timor Seas. The cruise is part of Component 1 of the ATSEA Project Document (ProDoc), namely the TDA, which includes the development of a biophysical profile of the ATS and its coastal areas, including fisheries and biodiversity assessment; socio-economic and governance profile including resource user groups, market networks, productive value chains, and market access opportunities; a stakeholder assessment; and causal chain analysis and options to address national and transboundary problems.

The research cruise was focused on physical and biological aspects of the ATS, including surface sediments, biodiversity and fisheries analysis of the region. The scientists involved in this study consist of government and university researchers from Timor Leste, Indonesia and Australia. Figure 1.2 shows the survey area that includes the Timor Sea, Lemola (Leti, Moa, and Lakor area) and the Arafura Sea.

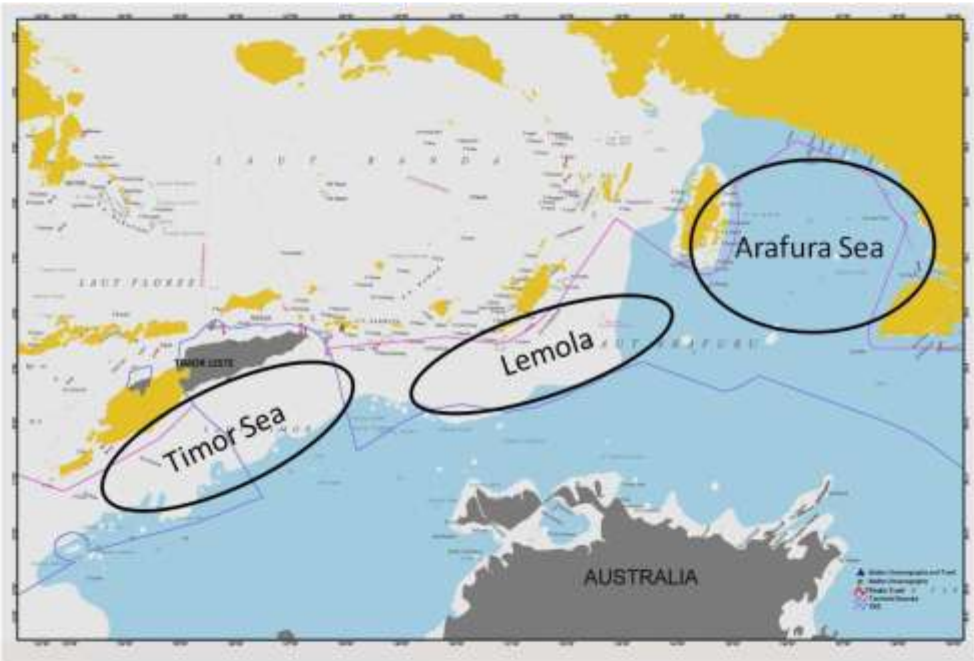



**Figure 1.2.** Survey areas showing the area of the Timor Sea, Lemola (Leti, Moa, and Lakor) and the Arafura Sea

The ATSEA cruise is expected to produce information on oceanographic characteristics of this study area and its relation to the biological profile and status of living marine resources. The result of the cruise will provide optimal benefits to coastal communities. Information obtained through the ATSEA cruise will also be important to a wide range of stakeholders including scientists, policy and decision makers, and coastal communities.

This report is an oceanographic and fisheries cruise report, covering various aspects, including: physical oceanography, bathymetry, marine mammals, fisheries acoustics, shrimp and demersal fishes stock assessment, phytoplankton biomass, nutrients, surface sediment, Polycyclic Aromatic Hydrocarbons (PAH) and heavy metal contamination, geochemical and nutrient analysis of sediment samples, and IUU fishing documentation.

This report is structured so that each aspect covered by the cruise is reported individually. Results and discussions of each aspect are provided in each chapter.

Chapter II

# PHYSICAL OCEANOGRAPHY

**Herlisman[1], Simon Tubalawony[2], Muhammad Ramdhan[3], Bobby F. Talakua[2]**

[1]Research Institute for Marine Fisheries,
Ministry of Marine Affairs and Fisheries, Indonesia
Email: *yellherlisman@gmail.com*

[2]Faculty of Fisheries, University of Pattimura, Ambon, Indonesia

[3] Research and Development Center for Ocean and Coastal Resources,
Ministry of Marine Affairs and Fisheries, Indonesia

## 2.1. Introduction

The Arafura and Timor Seas are part of Indonesian waters that are directly bordering the Indian Ocean. Each sea has significantly different characteristics. The Timor Sea is a deep-sea habitat with depths of more than 2000 m, whereas the Arafura Sea is a shallow sea of less than 60 m depth. The circulation of the Arafura and Timor Seas, particularly at the surface, is affected by the monsoon wind pattern. The changes of wind strength and direction that blow on the sea surface produce changes in water dynamics. According to Clark et al. (1999), strengthening of the monsoon wind will result in increased Ekman transport, vertical mixing and greater heat loss due to evaporation during summer, causing a decrease in sea surface temperatures. However, during weak wind, the vertical mixing of water masses is weak, causing less heat loss through evaporation. The latter condition causes higher sea surface temperatures.

In May, the southeast monsoon begins to blow in parts of the Indonesian region, including in the Arafura and Timor Seas. This wind condition causes surface water masses to move westward, affecting the water mass characteristics of both seas, particularly in the Arafura Sea and the waters adjacent to the Tanimbar Islands. The westward movement of the water mass may create an upward movement that affects the fertility of the water.

The Timor Sea is one of the main conduits of the Indonesian Ocean, being a through flow from the Pacific to the Indian Oceans. The source of the through flow comes from the northern and southern parts of the Pacific Ocean (Tomascik *et al*., 1997; Wyrtki, 1961; Ilahude and Gordon, 1996; Gordon, 1986; Gordon *et al*., 1994; Molcard *et al*., 1996; Fieux *et al*., 1996). Ocean currents in the Timor Sea flow in a southeasterly direction parallel to the Timor coast for most of the year. The dynamics and characteristics of water masses in the Timor Sea is thus influenced mostly by the change of the speed and direction of monsoon winds and the strength of the through flow in this area.

## 2.2. Objective of the study

The aim of this study is to assess the characteristics of the water masses of the Arafura and Timor Seas.

## 2.3. Method

Oceanography parameters including temperature, salinity and sigma-t were measured at every station in the ATSEA Cruise using a SBE 911+ type CTD. Ocean currents were measured with an Acoustic Doppler Current Profiler (ADCP) using a frequency of 75 kHz at 10 m depth intervals to a depth of 200 m in the Timor Sea, and at 5 m intervals to the bottom of the Arafura Sea. .

Temperature, salinity and density of the water column are represented by oceanographic profiles at depths of 0, 25, 50, 75 and 100 m using Excel 2007, Surfer 9 and Ocean Data View (ODV) version 3.2.0-2006. Current patterns at each station were analyzed by using Surfer 9 software.

## 2.4. Observations

Observations were made at all 23 stations along the cruise track (Figure 2.1).

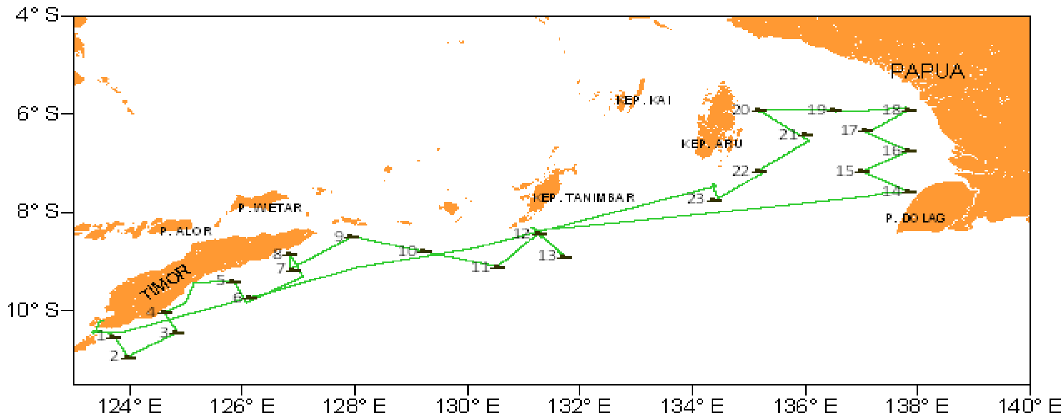
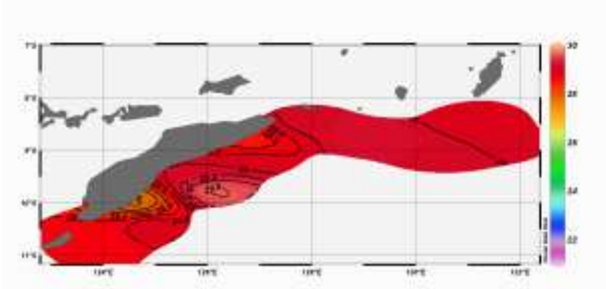



**Figure 2.1.** ATSEA cruise track showing data collection stations

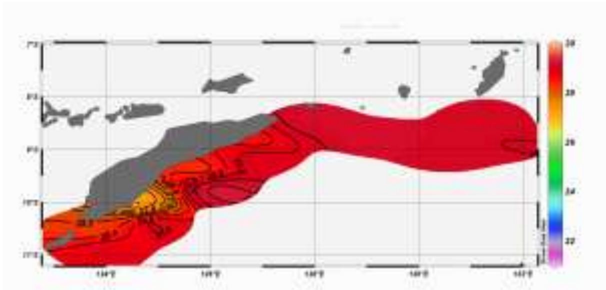
## 2.4.1. Sea surface temperature

### Timor Sea

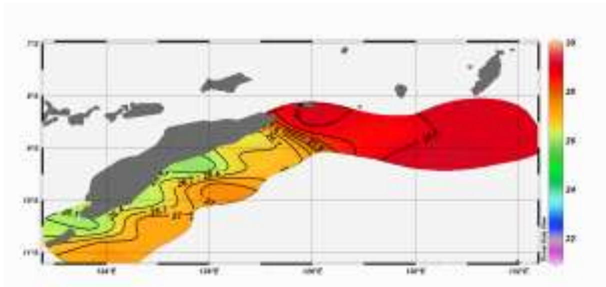
Sea surface temperatures during the ATSEA cruise ranged from 27.66 to 29.68°C with an average of 28.75 ± 0.59 $^{o}$C. The highest temperature was observed at Station 6 and the lowest was found at Station 4. At 25 m depth in all stations, the temperature was between 27.05 and 29.34 $^{o}$C with an average of 28.51 ± 0.71 $^{o}$C. Sea water temperature at 50 m was between 25.75 and 27.56 $^{o}$C with an average of 26.64 ± 0.71 $^{o}$C. Water temperature decreased with water depth, and at 75 m, temperatures were between 24.09 and 25.55 $^{o}$C with an average of 24.77 ± 0.47 $^{o}$C. The water temperature at 100m ranged from 22.06 to 23.94 $^{o}$C with an average of 23.13 ± 0.64 $^{o}$C (Figure 2.2).



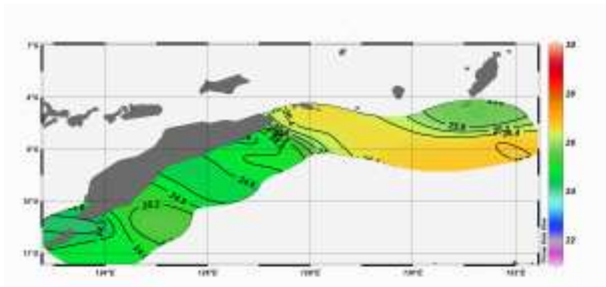
**(2.2.a)**



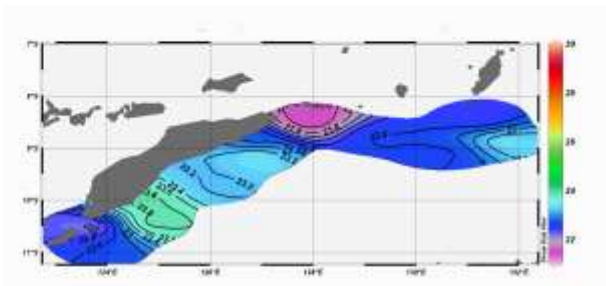
**(2.2.b)**



**(2.2.c)**



**(2.2.d)**



**(2.2.e)**

**Figure 2.2.** Horizontal distribution of temperature at depths of (a) 0m, (b) 25m, (c) 50m, (d) 75m, (e) 100m, based on observation at Stations 1 – 13.

The temperature distribution at 25 and 50 m depths (Figure 2.2) have higher temperature variations compared with other depths. Horizontal patterns of temperature at 0, 25 and 50 m show that the lowest temperature was found at Station 4, and the highest at Station 9 (Figure 2.2). Temperature distribution patterns at 75 and 100 m show the great influence of cold water masses at Station 4. The colder temperature at Station 4 may have been due to deep water upwelling. Further indications of upwelling can be seen at 25 and 50 m and is also reflected in the vertical distribution of temperature along coastal waters at Stations 1, 4, 5, 8 and 9. In this case, an isotherm of 27.5 $^{o}$C comes up from approximately 50 m at Station 9 towards the surface at Station 4, and from 15 m at Station 1 towards the surface at Station 4 (Figure 2.3).

The vertical temperature patterns across stations located far away from coast (Stations 2, 3, 6, 7) reflect homogeneous distribution at every depth. In this case, their isotherms tend to be flat between stations, suggesting that they originated from the same water mass.

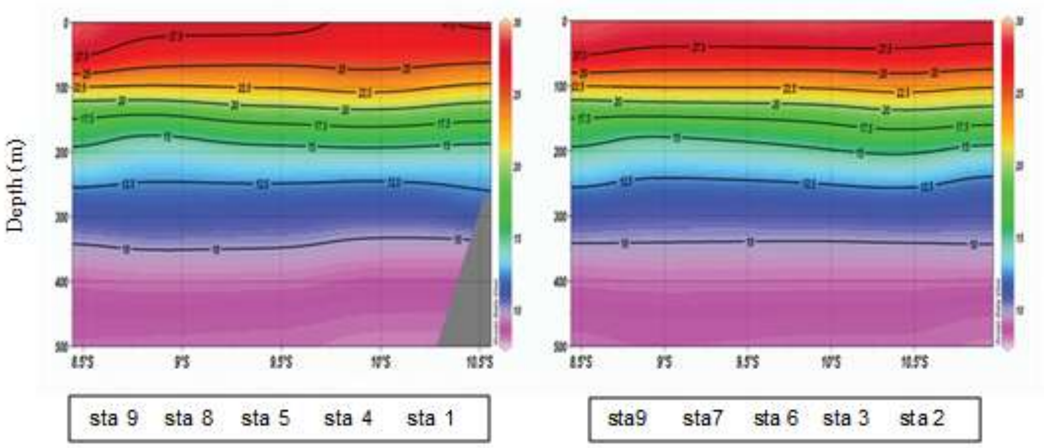



**Figure 2.3.** Vertical distribution of temperature across stations in the Timor Sea

The vertical distribution of temperature in the Timor Sea shows that the thermocline varies in depth among stations, generally occurring at less than 50 m. The thickness of the mixed layer also varies, with deeper thicknesses at Stations 4, 6 and 7 (Figure 2.4). According to Tubalawony (2000), surface temperatures in the Timor Sea during the east monsoon in 1991 were between 26.23 and 26.85 °C. The average thickness of the mixed layer, where the temperature was relatively homogeneous, was 70 m. Ilahude and Gordon (1996) stated that the surface temperature of the Timor Sea varies between 26.2 and 27 °C during the east monsoon, similar to the Maluku Sea, which varies between 26.1 and 27 °C, but a little higher than the Banda Sea, which varies between 25.7 and 26.1 °C.

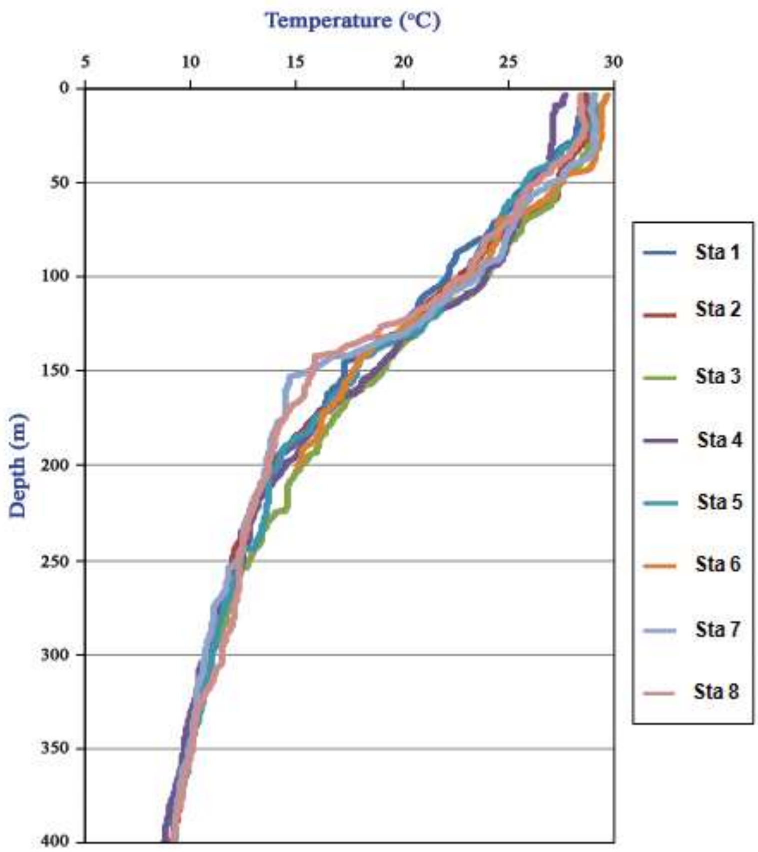



**Figure 2.4.** Vertical distribution of temperature in the Timor Sea

## The waters south of Leti Moa Lakor (The Lemola Islands) - Tanimbar

Distribution patterns of temperature south of the Lemola Islands – Tanimbar at depths of 0, 25 and 50 m were observed to be homogeneous, with sea surface temperatures (SSTs) between 28.86 and 29.18 °C, with an average of 29.03±0.13 °C. At 25 m, temperatures ranged from 28.99 to 29.12 °C with an average of 29.08 ± 0.05 °C. Temperatures were between 28.50 and 29.07 °C with an average of 28.86 ± 0°C at 50 m. Water temperature decreased with increasing depth to 25.52 to 26.75 °C with an average of 26.40 ± 0.50 °C at a depth of 75 m and 21.44 to 23.29 °C with an average of 22.48 ± 0.70 °C at a depth of 100 m (Figure 2.5).

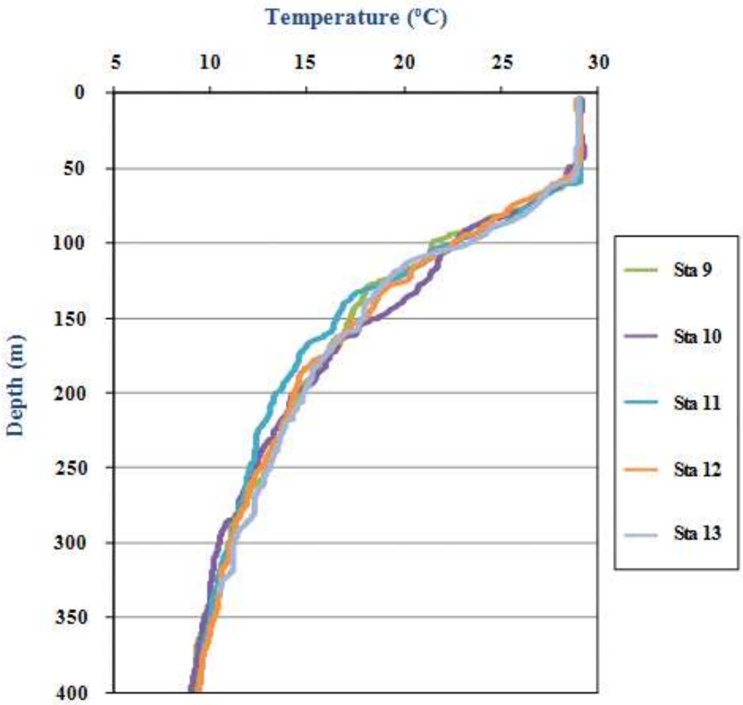



**Figure 2.5.** Vertical distribution of temperature in the south of the Lemola Islands

The pattern of horizontal distribution of the water temperature at various depths shows that the mixed layer in the south of the Lemola Islands – Tanimbar occurs from the surface to 50 m, atop the thermocline. Stratification of the water column was observed beneath a 60 m deep mixed layer (Figures 2.6).

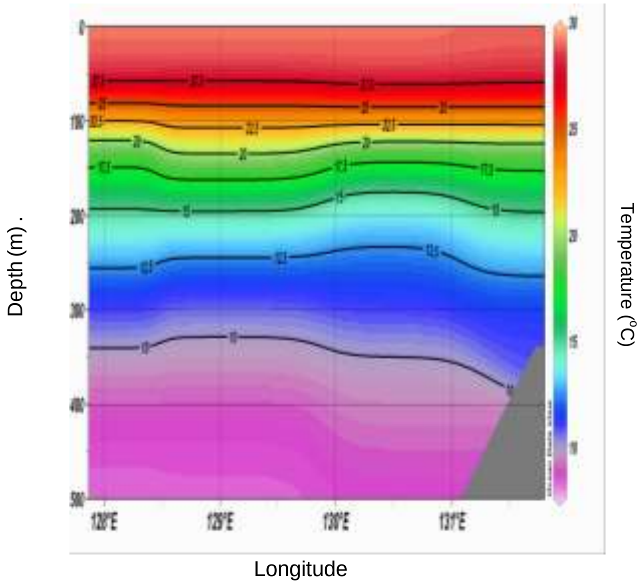
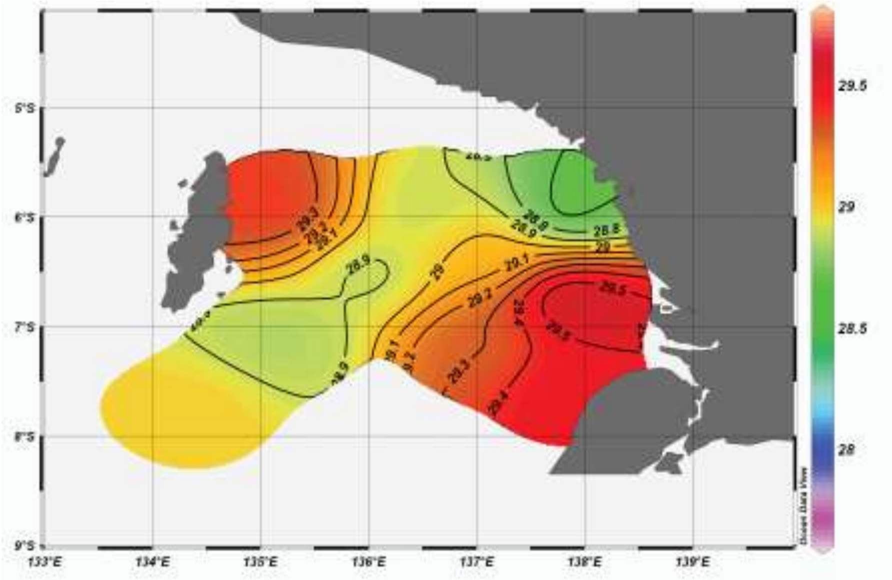



**Figure 2.6.** Vertical distribution of temperature in the south of the Lemola Islands -Tanimbar (Stations 9, 10, 11 and 13)

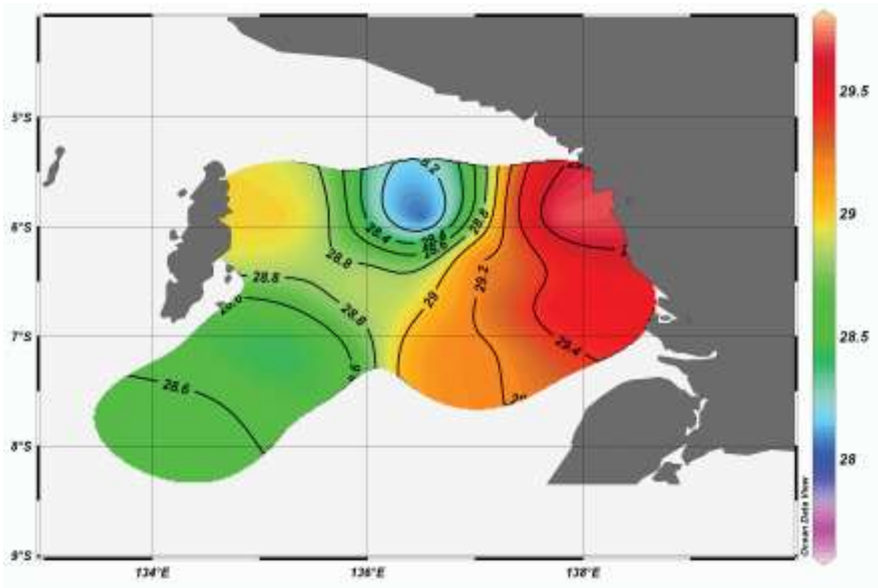
The horizontal distribution patterns of temperature indicate a cold water mass at 75 and 100 m. At 75m, cold water occurs at Station 12 (25.52 $^{o}$C) while water temperatures at other stations range from 26.51 to 26.74$^{o}$C. To the south of the Lemola Islands, cold water occurs at Station 9 at 100 m, probably originating from deep water masses from the Banda Sea flowing to the Timor Sea, deflected upwards due to the bathymetry.

## Arafura Sea

The Arafura Sea is shallow consisting of depths of less than 60 m. CTD casts indicate that SST's in the Arafura Sea range from 28.65 to 29.61 $^{o}$C with an average of 29.10 ± 0.32 $^{o}$C. Water temperature at 25 m is between 27.93 and 29.73 $^{o}$C with an average of 28.94 ± 0.56 $^{o}$C. Warmer waters occur at Stations 14 to 17 and Station 20, while a significant difference in temperature is evident between surface water and 25 m at Station 18 (Figure 2.7). Temperature variation in the Arafura Sea may be partly due to the effect of the sea-air interaction, as weather and winds varied greatly during the period of observation.




(2.7.a)




(2.7.b)

**Figure 2.7.** Horizontal distribution of temperature at the surface (a) and (b) at a depth of 25 m in the Arafura Sea.

The vertical temperature distribution appears homogeneous, with the exception of Stations 20 and 23, where the temperature decreases significantly (>1$^{o}$C) at depths of 30 to 40 m (Figures 2.8 and 2.9). The temperature distribution at 10 m at Station 18 increased significantly, probably due to atmospheric influences on the surface water.

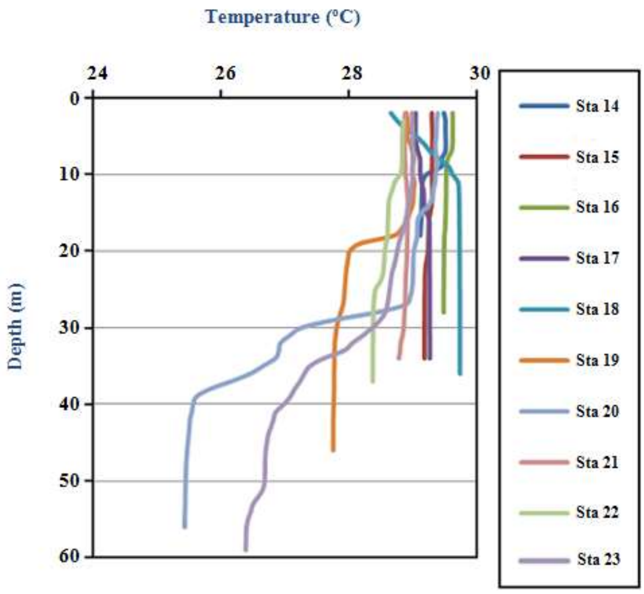



**Figure 2.8.** Vertical distribution of temperature in Arafura Sea (Stations 14-23)

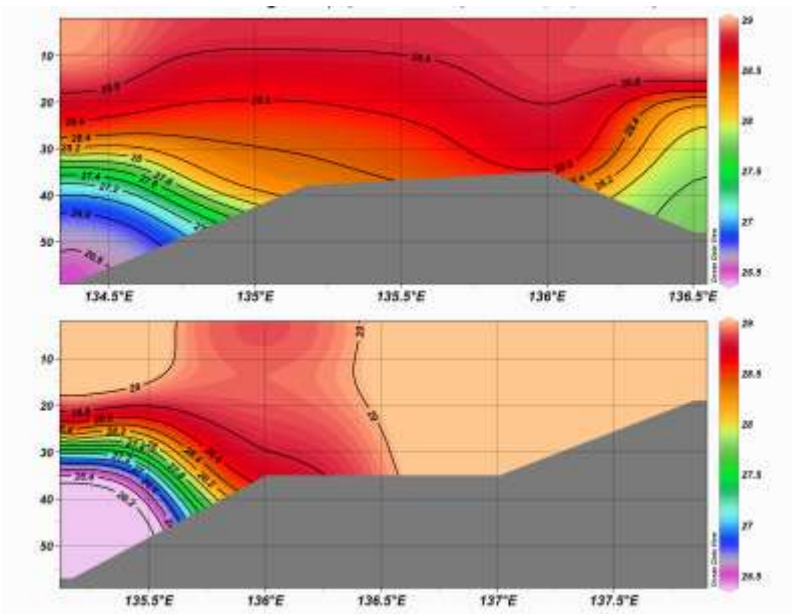
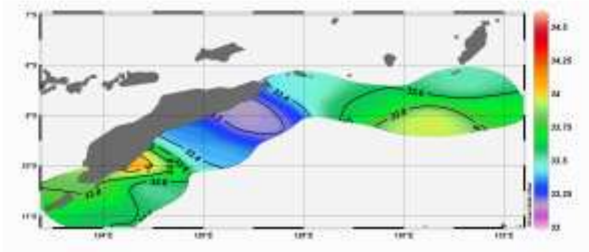



**Figure 2.9.** Vertical distribution of temperature in the Arafura Sea

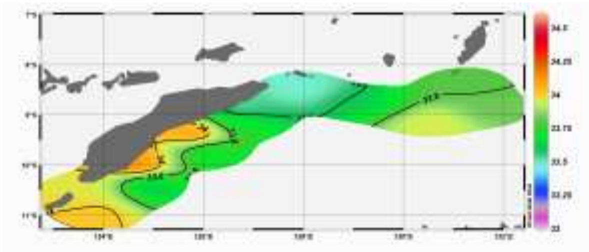
## 2.4.2. Salinity

### Timor Sea

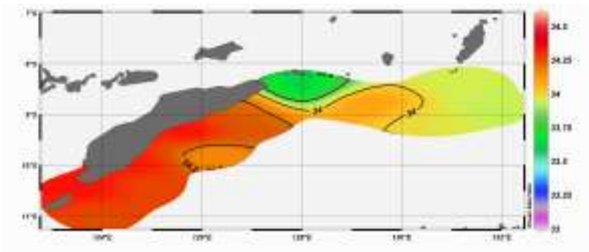
Salinity at the surface was between 33.15 and 34.11 psu, except at Station 4. Salinity distribution in the southern Timor Sea (Stations 1 to 4) indicates a higher psu value compared with the northern Timor Sea (Stations 5 to 8). Salinity in the southern Timor Sea ranges from 33.47 to 34.11 psu, while salinity in the north is between 33.15 and 33.37 psu (Figure 2.10).



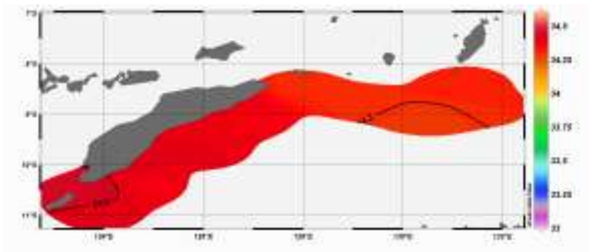
(2.10.a)



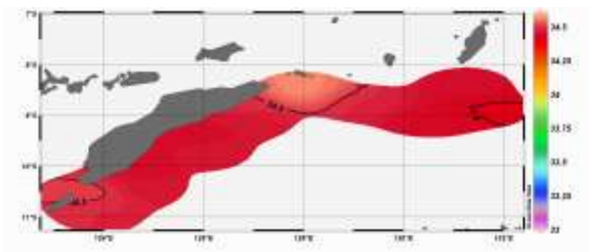
(2.10.b)



(2.10.c)



(2.10.d)



(2.10.e)

**Figure 2.10.** Horizontal distribution of salinity at (a) the surface and at depths of (b) 25 m, (c) 50 m, (d) 75 m, (e) 100 m

Salinity in the Timor Sea at 25 m ranged from 33.52 to 34.16 psu with an average of 33.83 ± 0.26 psu. Higher salinity is observed at the stations located near the coast (Stations 4 and 5) and to the south (Stations 1 and 2), while the stations farther from the coast (Stations 3 and 6) and in the northern part (Stations 7 and 8) are of a slightly lower salinity (Figure 2.10). At 50, 75 and 100 m, horizontal distribution of salinity is homogeneous. Salinity at 50 m ranges from 34.14 to 34.35 psu with an average of 34.27 ± 0.07 psu.  At 75 m, the salinity is between 34.36 and 34.44 psu with an average of 34.38 ± 0.02 psu; and at 100 m, salinity is 34.44 to 34.51 psu with an average of 34.47 ± 0.03 psu.  In general, the horizontal distribution of salinity in the Timor Sea fluctuates more widely at depths <50 m. Salinity fluctuations are also observed in the northern part of Timor Sea, but of lesser degree than those in the southern part (Figure 2.11).

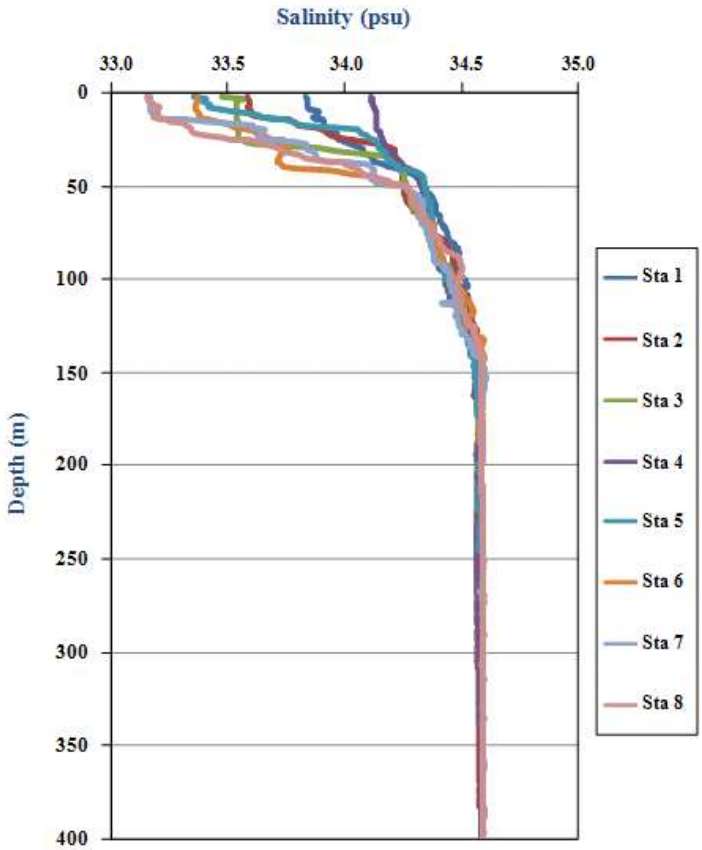



**Figure 2.11.** Distribution of vertical salinity in the Timor Sea (Stations 1– 8)

Recordings from the Snellius Expedition in the Timor Sea, from October 1929 (Wyrtki, 1961), at the end of the east monsoon indicate that the water salinity at 20 m depth was between 34.5 and 34.6 psu. Minimum salinity (< 34.4 psu) was observed between 50 and 100 m, and was greater than 34.5 psu at 125m. The salinity of the surface waters in the Timor Sea was also recorded during the Snellius Expedition, with measured values between 34.2 and 34.4 psu and water temperature of 26 $^{o}$C. This water mass probably originated from the eastern Banda and the Arafura Seas.

The horizontal and vertical distributions of salinity in the Timor Sea during the ATSEA cruise indicate that the salinity of the upper layer (0 to 50 m) at Station 4 is higher than that at the other stations (Figure 2.11). The high salinity at Station 4 is probably related to the upwelling of cold saline water from the deep.

The sectional distribution of salinity across the near-coastal Stations 1, 4, 5, 8 and 9 show that isohalines of 34.0 psu and 34.2 psu are ascending from Stations 9 and 8 to Station 4. The isohaline of 34.0 psu begins at a depth of 70 m at Station 9 and ascends to the surface at Station 4. The isohaline of 34.2 psu also ascends to a depth of 30 m at Station 4, but from a depth of 80 m. The isohaline ascension reflects the occurrence of upwelling of deeper water, particularly from the water at depth of 75 m, causing the increase of salinity at the surface. The section consisting of stations located further from the coast (Stations 2, 3, 6, 7 and 9) shows that salinity from the surface to 100 m ascends from the North to the South of the Timor Sea (Figure 2.12). This agrees with the fact that salinity of the southern water mass is higher than that of the northern water mass.

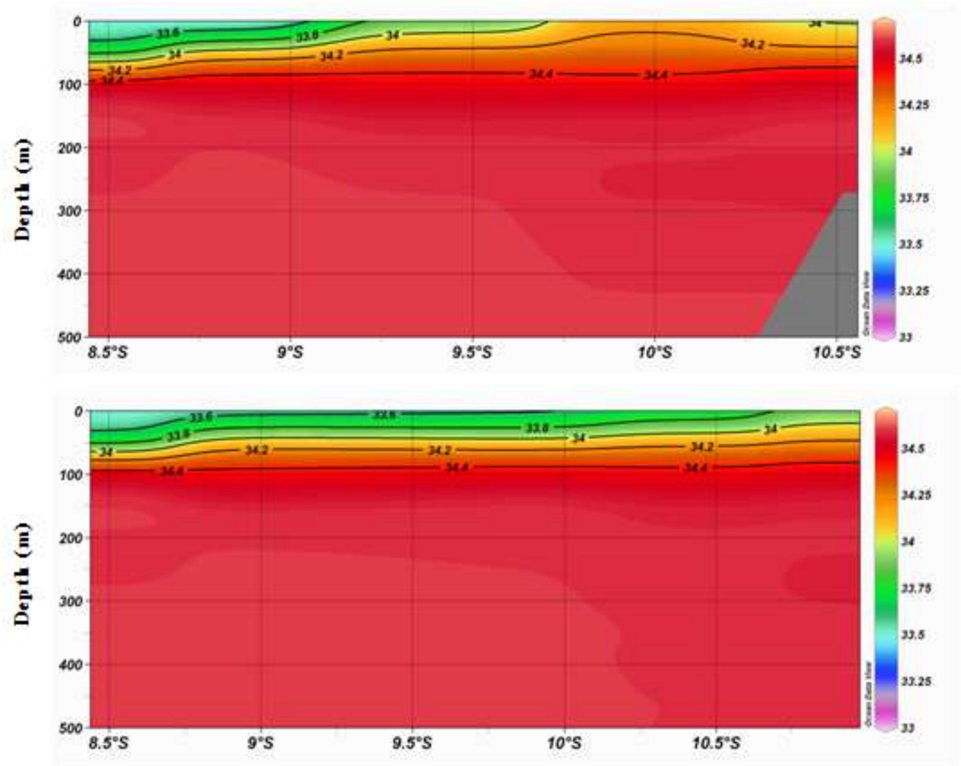



**Figure 2.12.** Sectional distribution of salinity in the Timor Sea

## The waters south of Leti Moa Lakor (The Lemola Islands) - Tanimbar

The horizontal distribution of salinity in the surface water of the southern part of Leti Moa Lakor (The Lemola Islands) - Tanimbar was between 33.46 and 33.97 psu with an average of 33.65 ± 0.21 psu. Stations 9 and 12 show lower salinity than Stations 10, 11 and 13 which are located further south (Figure 2.13). The lower salinity at Stations 9 and 12 may be caused by heavy rains during the ATSEA cruise. A similar condition is observed at 25 and 50 m. Salinity at 25 m ranges from 33.47 to 33.97 psu with an average of 33.73 ± 0.19 psu, and at 50 m, salinity ranges between 33.59 and 34.12 psu with an average of 33.91 ± 0.19 psu. Lowest salinities at both 25 and 50 m are at Station 9.

The salinity values at 75 and 100 m are homogeneous. However, salinity patterns in the western part of the study area indicate a pattern distinct from that of the surface water. The highest salinity at 75 and 100 m is observed at Station 9, probably related to the influence of a deep water mass from the Banda Sea which flows to the south and deflects.

The distribution pattern of salinity in the waters south of The Lemola Islands – Tanimbar indicate that the salinity varies from the sea surface to 60 m. The upper layer is mixed, with the halocline located at 60 m. Salinity distribution in the mixed layer indicates that the water mass at Station 9 has lower salinity and the water mass at Station 11 has higher salinity. However, salinity at each station is more homogeneous at a depth >100 m; higher salinity is found at Station 9 (Figure 2.13).

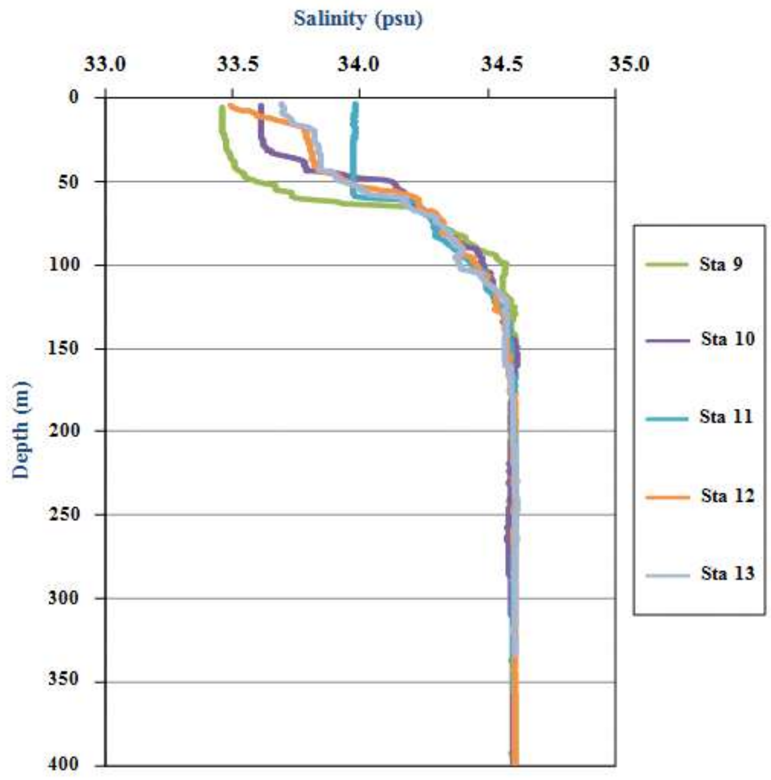



**Figure 2.13.** Vertical distribution of salinity in the waters south of the Lemola Islands – Tanimbar (Stations 9 – 13).

With the exception of Station 9, the waters south of the Lemola Islands – Tanimbar have similar salinity to one another (Figure 2.14). Therefore, the water mass in the area, particularly at >50 m depth, probably originated from the same source.

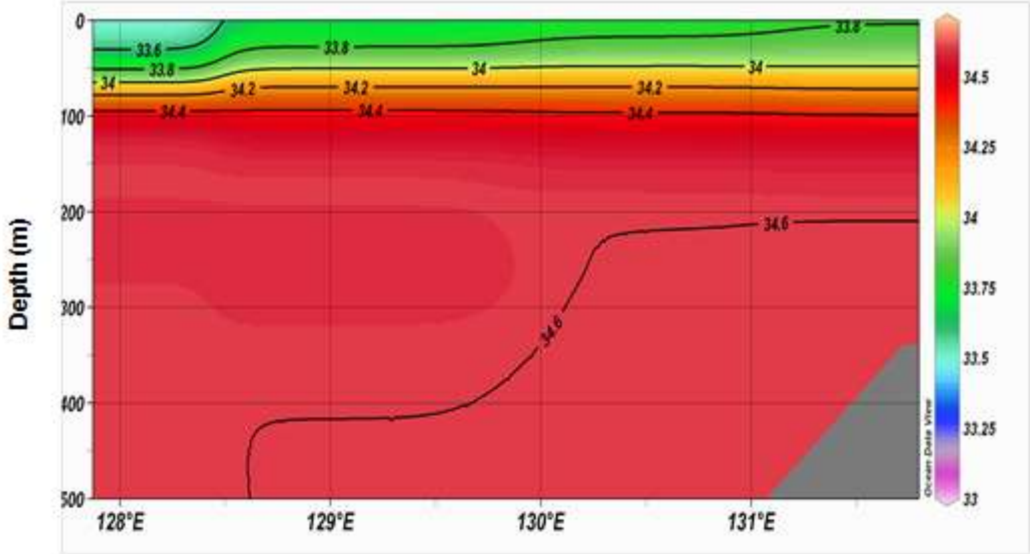
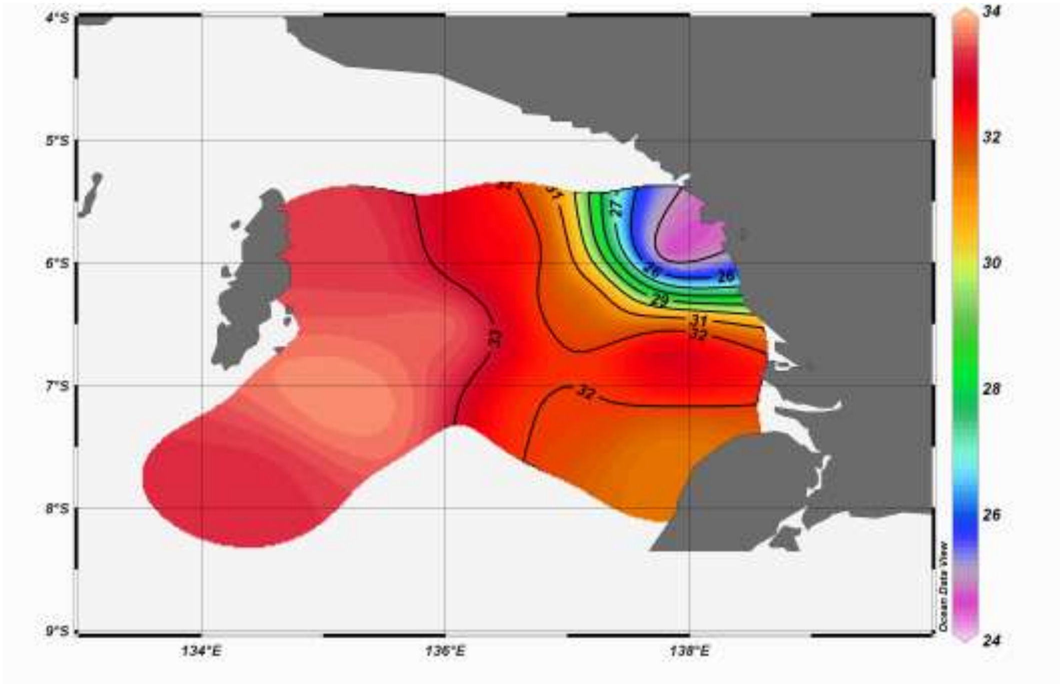



**Figure 2.14.** Vertical distribution of salinity in the waters south of the Lemola Islands – Tanimbar

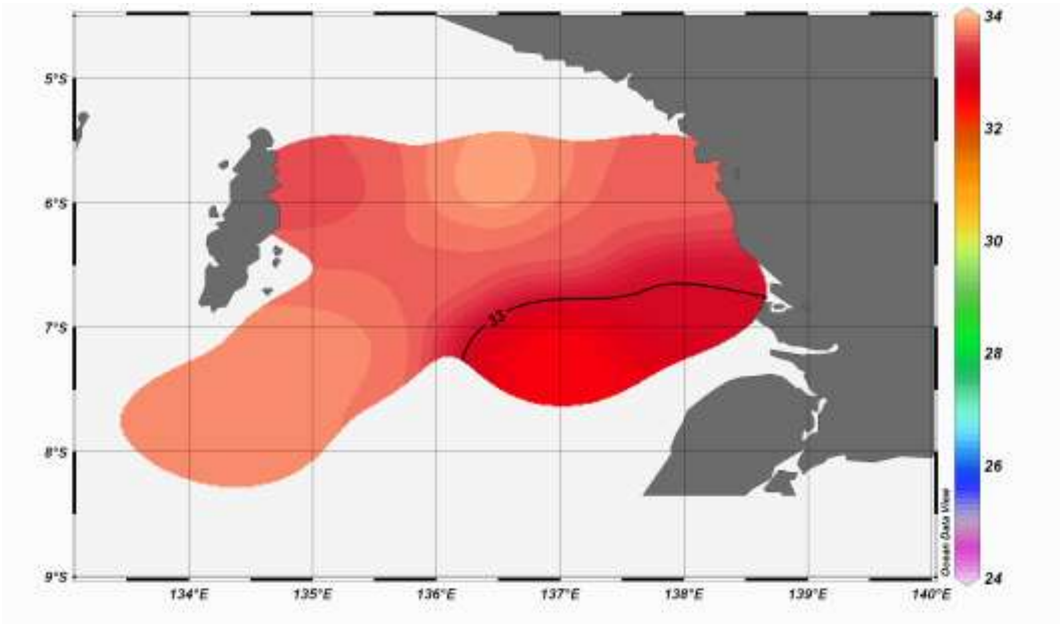
## Arafura Sea

The salinity of the surface water in the Arafura Sea varies spatially, with higher salinity in the west part than in the east. The salinity distribution in the western Arafura Sea is 33.21 to 33.71 psu and in the east, from 24.14 to 32.91 psu. Lower salinity in the east is due the numerous rivers flowing from Papua. A low salinity lens of water at Station 18 (24.14 psu) may have been due to dilution by rain. Salinity distribution of the surface water ranges from 24.14 to 33.71 psu with an average of 31.82 ± 2.82 psu (Figure 2.15).

In the Arafura Sea, the salinity at 25 m is homogeneous but lower at Stations 14 and 15 (32.44 psu and 32.95 psu, respectively); the influence of river inputs is obvious at these two stations. At the other stations, the salinity at 25 m is 32.44 to 33.88 psu with an average of 33.46 ± 0.46 psu (Figure 2.15 b)




(2.15.a)




(2.15.b)

**Figure 2.15.** Horizontal salinity distribution of surface water (a) and at a depth of 25 m (b) in the Arafura Sea

The vertical distribution of salinity in the Arafura Sea indicates complete mixing from the surface to the bottom, except at Station 18, where salinity differences from the surface to 10 m were quite significant (Figure 2.16). Salinity at the surface of Station 18 was quite low.

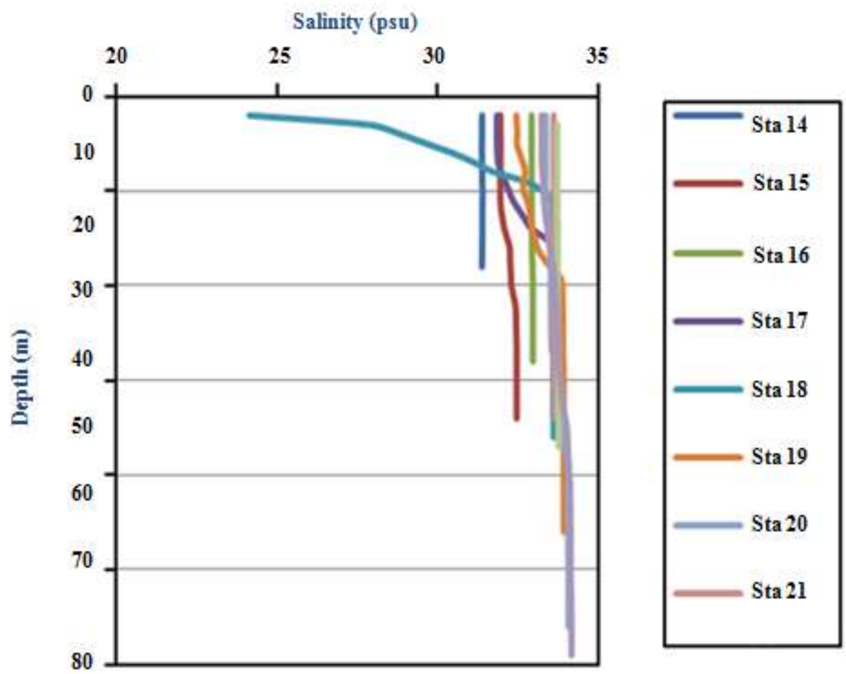



**Figure 2.16.** Vertical distribution of salinity in Arafura Sea (Stations 14 – 21)

The vertical distribution of salinity in the Arafura Sea across all stations is shown in Figure 2.17. The salinity profile across Stations 19, 21, 22 and 23 shows salinity stratification at Station 23. The salinity is quite homogeneous from the surface to the bottom at Stations 21 and 22, and relatively low salinity water is present at Station 19, in the eastern Arafura Sea. The salinity distribution across Stations 14, 15, 20 and 21 indicate an increase in salinity from east to west.

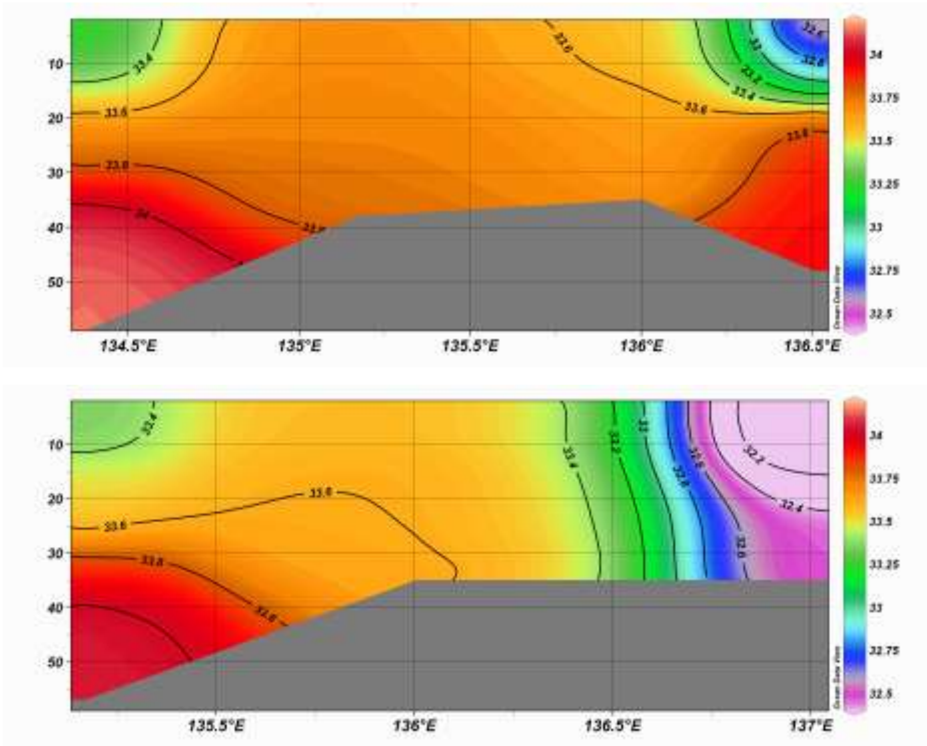
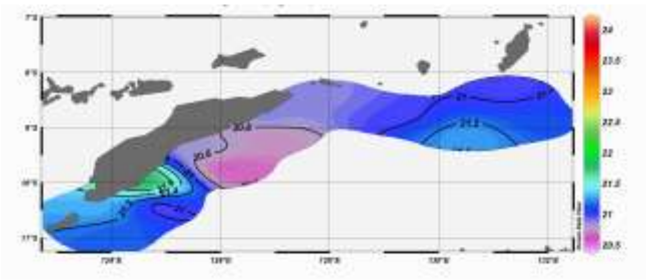



**Figure 2.17.** Distribution of salinity across stations in the Arafura Sea

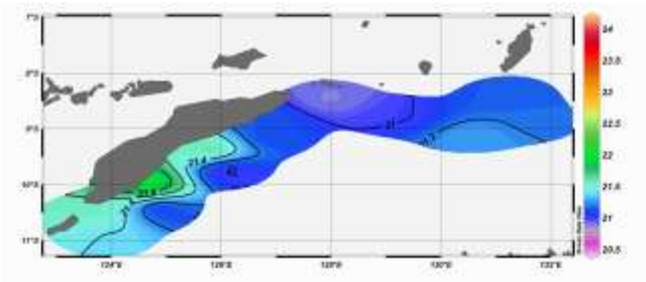
## 2.4.3. Sigma-t

### Timor Sea

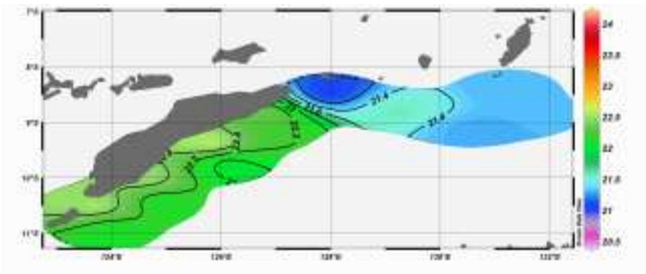
The horizontal distribution of sigma-t in the surface water of the Timor Sea show a higher sigma-t value at Station 4 (21.84 kg/m³) (Figure 2.18). The sigma-t of the surface waters ranges between 20.62 and 21.84 kg/m³ with average of 21.03 ± 0.40 kg/m³. The distribution pattern of sigma-t in the surface water may be influenced by the salinity distribution. The northern part of the Timor Sea shows lower density water compared to the southern part. An indication of the influence of deep water mass at Station 4 is reflected by the occurrence of a higher density water mass. A water mass of a higher sigma-t can also be observed at 25 m, where the value of sigma-t is 22.07 kg/m³ at Station 4, greater than that of the other stations, where sigma-t was between 20.94 and 21.65 kg/m³ (Figure 2.18).



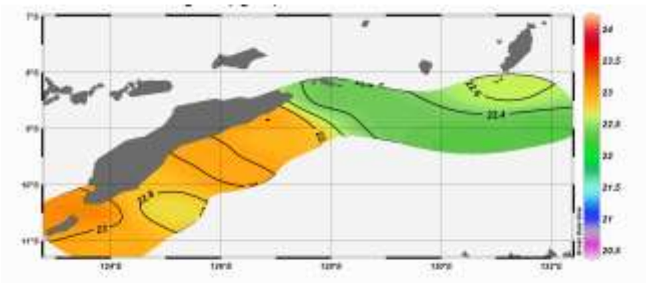
**(2.18.a)**



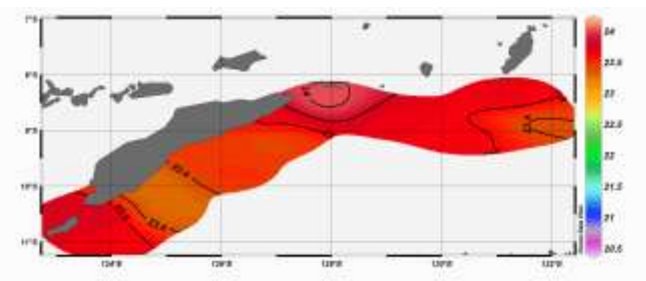
**(2.18.b)**



**(2.18.c)**



**(2.18.d)**



**(2.18.e)**

**Figure 2.18.** Horizontal distribution of sigma-t at (a) the surface water and at depths of (b) 25 m, (c) 50 m, (d) 75 m, and (e) 100 m (Stations 1 – 13).

The horizontal distribution of sigma-t in the Timor Sea is quite homogeneous but increases with depth. At a depth of 50 m, sigma-t varies between 21.89 and 22.62 $kg/m^3$ with an average of 22.28 ± 0.27 $kg/m^3$. Sigma-t at 75 m ranges from 22.69 to 23.19 $kg/m^3$ with an average of 22.95 ± 0.16 $kg/m^3$ and at 100 m sigma-t increases to 23.25 to 23.83 $kg/m^3$ with an average of 23.49 ± 0.20 $kg/m^3$ (Figure 2.19). The horizontal distribution of sigma-t values at 50 m show that isopycnal lines continue from the north to south, reflecting a similar characteristic of the water mass that flows from north to south in the Timor Sea. The sigma-t distribution also indicates that the water mass density is lower towards the open sea. The higher density water mass near the coast may be due to the influence of deeper water masses, especially at Station 4. This effect is also shown in the cross section of sigma-t distribution through the near coastal Stations 1, 4, 5, 8 and 9 (Figure 2.19). The cross section indicates the occurrence of upwelling at Station 4, particularly along the water layer at 75 m, as shown by the upward curve of isopycnal 22 $kg/m^3$ toward Station 4. The distribution of sigma-t along the stations further from the coast (Stations 2, 3, 6, 7 and 9) reflects characteristics of a similar water mass (Figure 2.20).

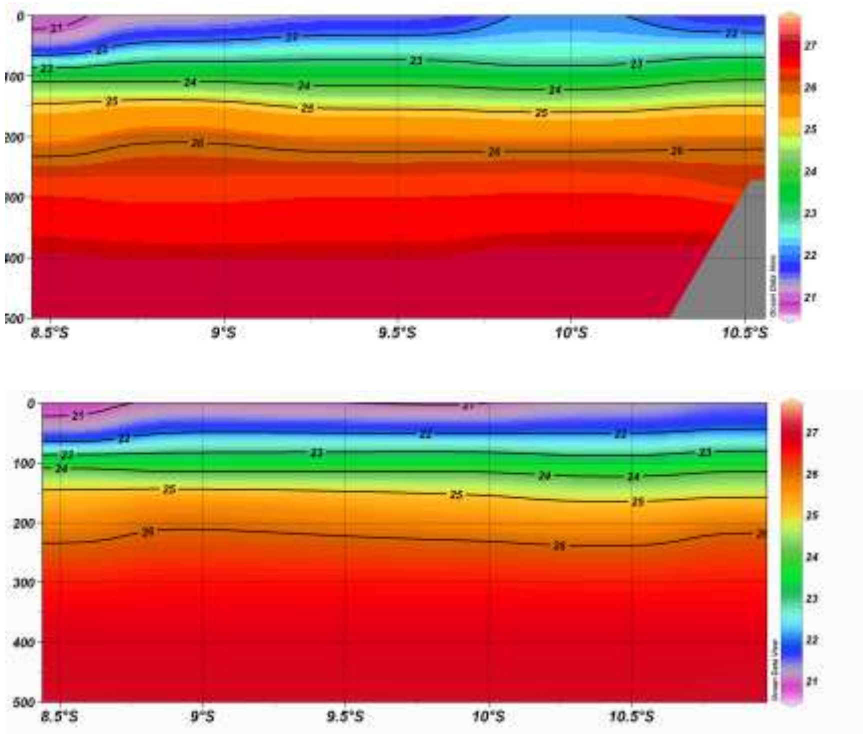



**Figure 2.19.** Cross section of sigma-t distribution in the Timor Sea

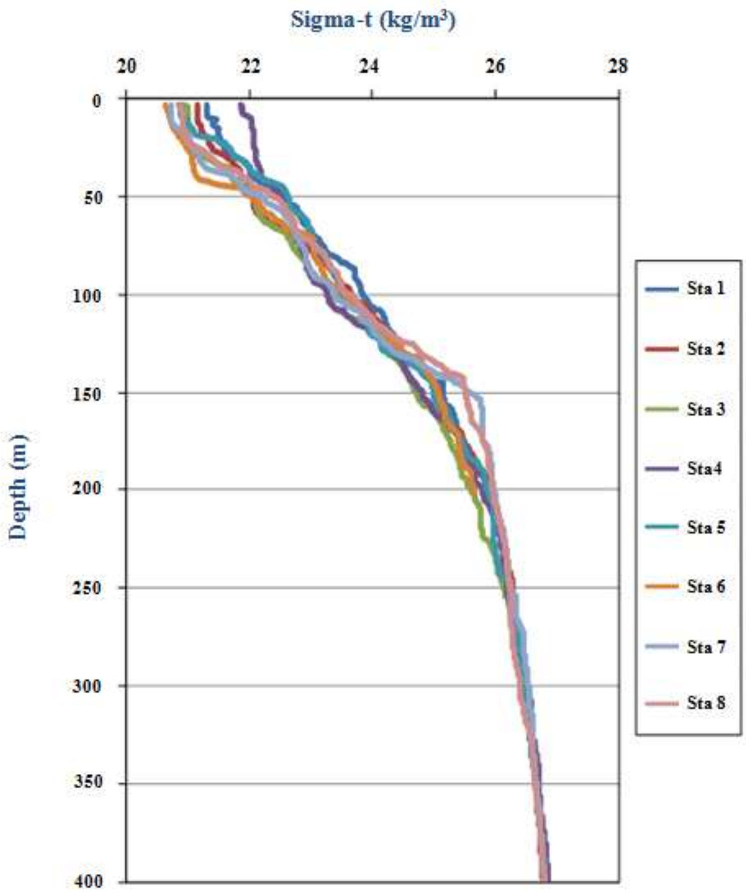



**Figure 2.20.** Vertical distribution of sigma-t in the Timor Sea (Stations 1-8)

The vertical distribution of sigma-t indicates a stratification of the water column. The thickness of the mixed layer in the Timor Sea is less than 50 m. Water density in the mixed layer appears to be homogeneous across all stations, except at Station 4 where the water density is higher (Figure 2.20). According to Tubalawony (2000), surface water density in the Timor Sea ranges between 22.25 and 22.65 kg/m$^3$, and the pycnocline occurs at a depth of 50 m.

### The waters south of Leti Moa Lakor (The Lemola Islands) - Tanimbar

The horizontal distribution of water mass density in the waters south of Leti Moa Lakor (The Lemola Islands) - Tanimbar indicates a different distribution pattern at 0, 25 and 50 m depth from that of water at 100m depth. At 0, 25 and 50 m, water density in the western part is less than that of the eastern part. Conversely, at 100 m the density of the water mass is greater in the west than the east. The lower density of the water mass in the western part (Station 9) within the water column, from the surface to a depth of 50 m, is due to low salinity water. At the greater depth, however, the density of the water mass is greater because the temperature is lower (Stations 12 and 13). Therefore, the horizontal distribution of water mass density in the upper layer of 0 to 50 m is considerably different from that of deeper water at 100 m.

The water mass densities at different depths in the Timor Sea are shown by the horizontal distribution of sigma-t values (Figure 2.19). In the waters south of Leti Moa Lakor (The Lemola Islands) – Tanimbar, the distribution of sigma-t in the surface water ranges between 20.88 and 21.27 $kg/m^3$ with an average of 21.04 ± 0.15 $kg/m^3$. At 25 m, the sigma-t is between 20.88 and 21.27 $kg/m^3$ with an average of 21.09 ± 0.16 $kg/m^3$, and at 50 m, the sigma-t ranges from 21.03 to 21.57 $kg/m^3$ with an average of 21.30 ± 0.19 $kg/m^3$. The sigma-t increases with depth and at 75 m, it is between 22.28 and 22.64 $kg/m^3$ with an average of 22.38 ± 0.15 $kg/m^{3.}$. At 100 m, the sigma-t ranges from 23.36 to 24.04 $kg/m^3$ with an average of 23.67 ± 0.24 $kg/m^3$.

In general, the vertical distribution of sigma-t at each station in the south of the Lemola Islands – Tanimbar shows that the depth of the mixed layer is 60 m, or the pycnocline occurred at 60 m (Figure 2.21). The sigma-t in the cross section containing Stations 9, 10, 11 and 13 is homogeneous (Figure 2.22).

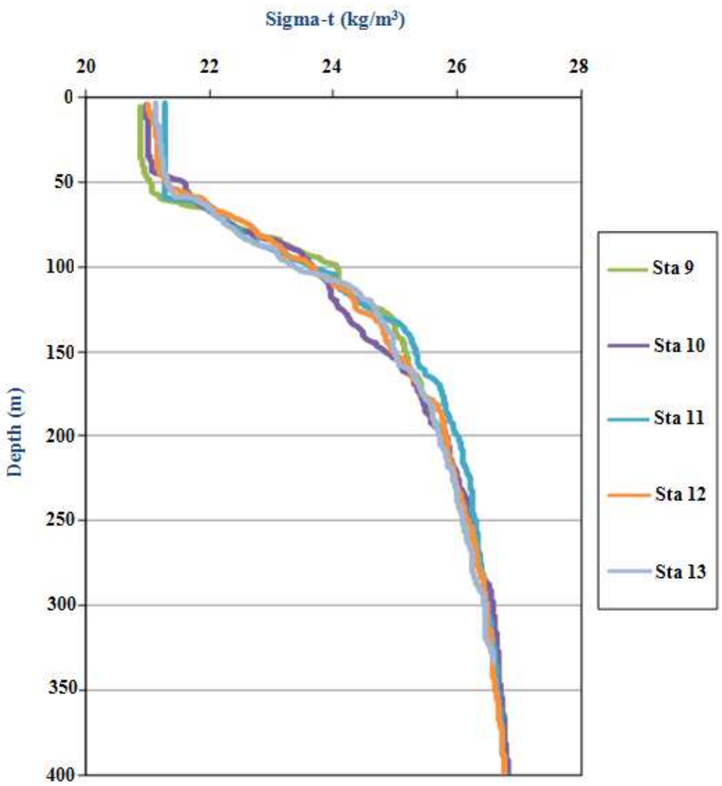



**Figure 2.21.** Vertical distribution of sigma-t in the waters south of the Lemola Islands - Tanimbar (Stations 9 – 13)

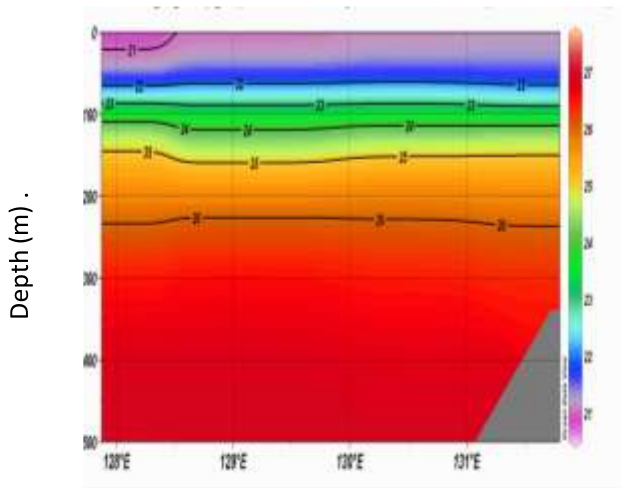



**Figure 2.22.** Distribution of sigma-t across Stations 9, 10, 11 and 13 in the waters south of the Lemola Islands – Tanimbar.

## Arafura Sea

The density of the water mass at the surface and at 25 m is homogeneous, with the exception of Station 18 located near the coast of Papua, where the water density was less (Figure 2.23). The surface water sigma-t values in the Arafura Sea ranged from 14.05 to 21.15 kg/m$^3$ with an average of 19.67 ± 2.07 kg/m$^3$ and are between 20.08 and 21.58 kg/m$^3$ with an average of 20.93 ± 0.47 kg/m$^3$ at 25 m. The water mass of the eastern waters tends to be lighter than that of the western.

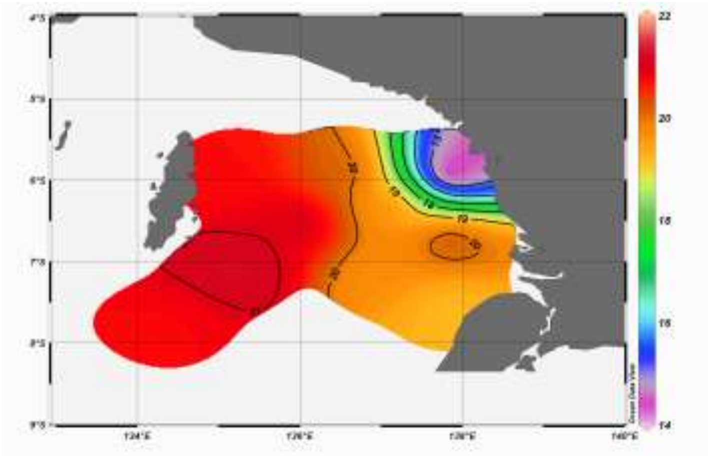


**Figure 2.23.** Horizontal distribution of sigma-t at the surface and at depth of 25 m in the Arafura Sea.

The vertical and sectional distributions of sigma-t values in the Arafura Sea indicate a similarity with the vertical distribution pattern of salinity. This shows that water mass density of the Arafura Sea is affected more by salinity than by temperature (Figures 2.24 and 2.25). The vertical distribution of sigma-t indicates that sigma-t is homogeneous down to the bottom, except at Station 18 where sigma-t drastically increases from the surface down to 10 m.

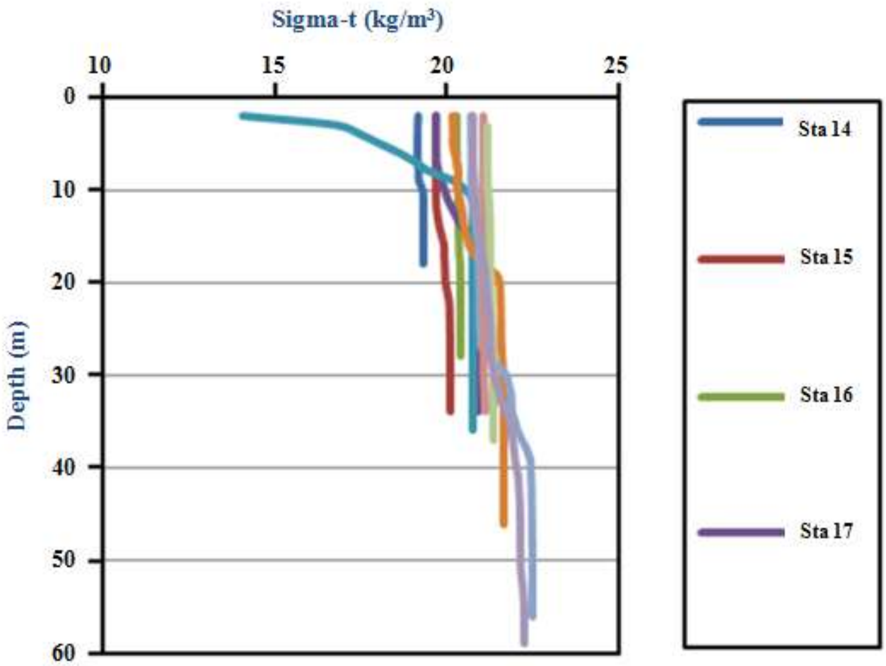



**Figure 2.24**. Vertical distribution of sigma-t in the Arafura Sea (Stations 14 – 17)

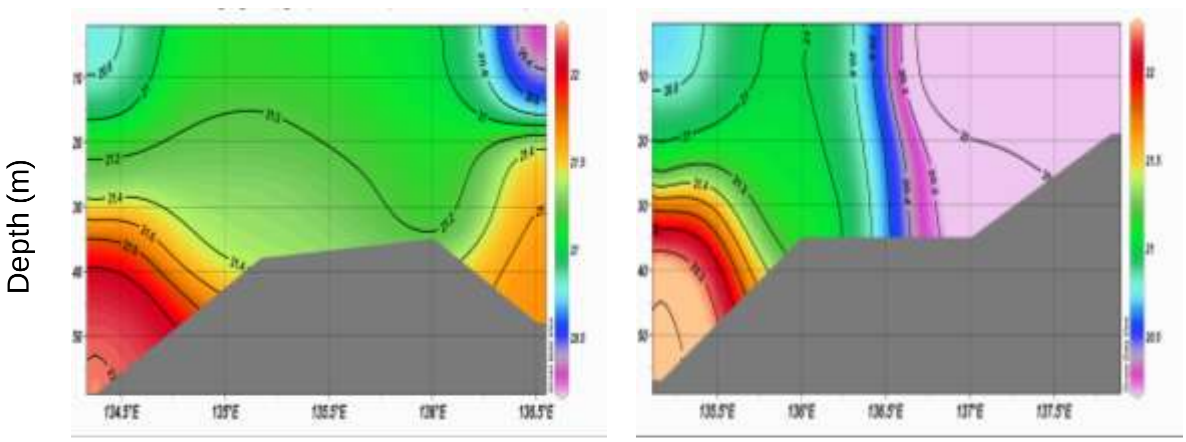



**Figure 2.25.** Distribution of sigma-t across stations in the Arafura Sea

## 2.4.4. Current

### Timor Sea

Currents in the Timor Sea at 20 to 100 m are from the southeast to northwest (115.67 - 236.19°) with an average velocity of 650.09 to 1,016.73 mm/s. The highest average velocity is at Station 1 in Rote Strait (991.85 to 1,016.73 mm/s) with current direction towards the southeast in the surface layer (20 to 30 m) and southward in the deeper layer (40 to 100 m). Lowest current velocities are at

Station 8 with velocities of 547.85 to 853.24 mm/s. At Station 8, the current at 20 to 40 m is south to southwest (165.57 - 210.55$^o$) and at 50 to 100 m the water mass moves southeast (115.67 to 148.89$^o$) (Table 2.1).

**Table 2.1.** Velocity and direction of current movement in the water layer at depths between 20 and 100 m in the Timor Sea

| Depths (m) | Station 1 | | Station 2 | | Station 3 | | Station 4 | |
|---|---|---|---|---|---|---|---|---|
| | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) |
| 20 | 1016.73 | 154.39 | 778.18 | 236.19 | 924.67 | 218.24 | 935.35 | 172.16 |
| 30 | 1011.73 | 169.49 | 920.57 | 233.78 | 924.02 | 221.22 | 936.97 | 177.79 |
| 40 | 1002.13 | 188.74 | 897.85 | 232.85 | 935.19 | 223.44 | 911.18 | 175.89 |
| 50 | 1002.16 | 194.72 | 882.45 | 232.88 | 931.49 | 221.57 | 923.20 | 184.45 |
| 60 | 1007.43 | 197.57 | 845.41 | 223.17 | 921.04 | 211.66 | 934.14 | 195.59 |
| 70 | 1007.03 | 197.05 | 822.83 | 222.83 | 907.98 | 198.63 | 942.41 | 201.67 |
| 80 | 1001.57 | 195.58 | 819.80 | 221.51 | 891.44 | 203.23 | 950.24 | 205.68 |
| 90 | 1001.85 | 203.12 | 800.95 | 219.93 | 900.51 | 203.32 | 960.86 | 208.45 |
| 100 | 991.85 | 201.04 | 780.19 | 210.84 | 891.45 | 202.89 | 944.80 | 207.80 |

| Depths (m) | Station 5 | | Station 6 | | Station 7 | | Station 8 | |
|---|---|---|---|---|---|---|---|---|
| | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) | Velocity (mm/s) | Direction ($^o$) |
| 20 | 924.27 | 227.03 | 975.65 | 205.50 | 879.46 | 199.56 | 650.09 | 210.55 |
| 30 | 900.29 | 217.50 | 990.21 | 223.13 | 885.91 | 215.65 | 547.85 | 197.19 |
| 40 | 881.55 | 209.33 | 999.04 | 231.82 | 879.34 | 218.30 | 596.27 | 165.57 |
| 50 | 888.87 | 211.27 | 997.68 | 231.68 | 874.70 | 213.60 | 781.61 | 146.74 |
| 60 | 892.50 | 212.10 | 991.46 | 229.81 | 1014.82 | 216.78 | 550.52 | 148.89 |
| 70 | 891.99 | 194.68 | 989.70 | 229.76 | 1012.55 | 211.05 | 836.05 | 134.46 |
| 80 | 864.60 | 196.57 | 984.84 | 232.29 | 883.12 | 212.64 | 673.72 | 143.19 |
| 90 | 881.16 | 193.92 | 964.61 | 222.93 | 958.15 | 212.89 | 843.43 | 122.09 |
| 100 | 886.10 | 189.01 | 988.25 | 223.00 | 879.46 | 199.56 | 853.24 | 115.67 |

The pattern of current movement shows that the water mass near the coast (Stations 1, 4, 5 and 8) moves in a different direction as the water mass offshore (Stations 2, 3, 6 and 7). The movement of the current near the coast is due south, but the offshore current moved southwest, parallel to the south coast of Timor (Figures 2.26 – 2.33), in accord with the findings of Wyrtki (1961). The current reaches the Australian coast with lower velocity between April and September. Even though the surface current in the Timor Sea moves toward the southwest for most of the year, from October to March, the current in the northeast part of the Timor Sea moves northeast.

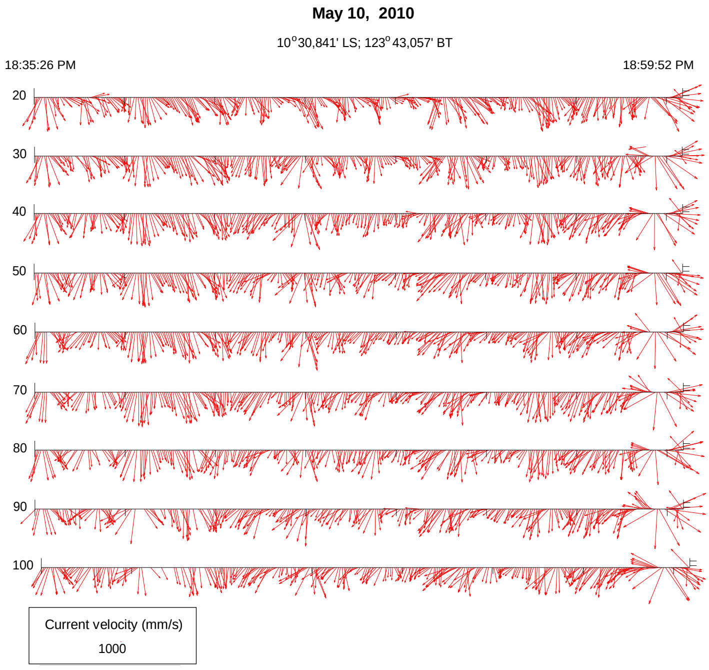



**Figure 2.26.** Current pattern of water layers at different depths at Station 1 (Timor Sea)

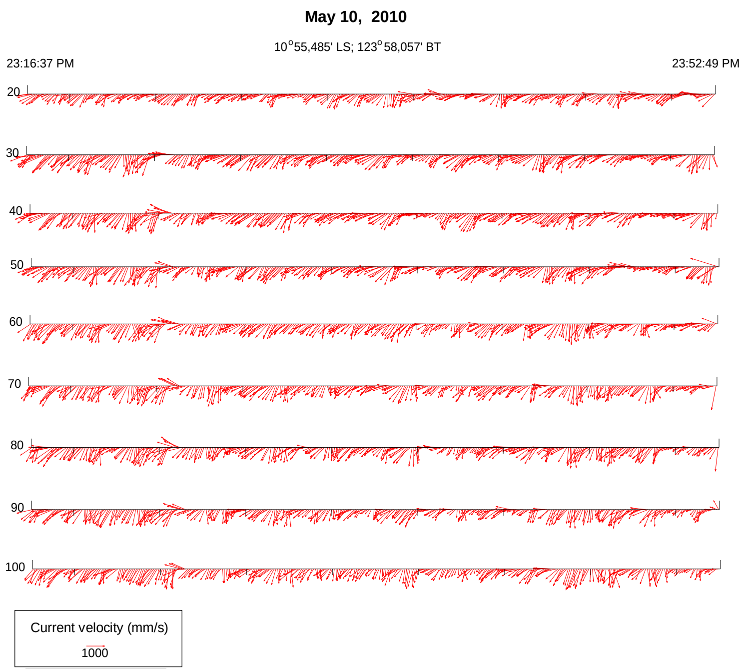



**Figure 2.27.** Current pattern of water layers at different depths at Station 2 (Timor Sea)

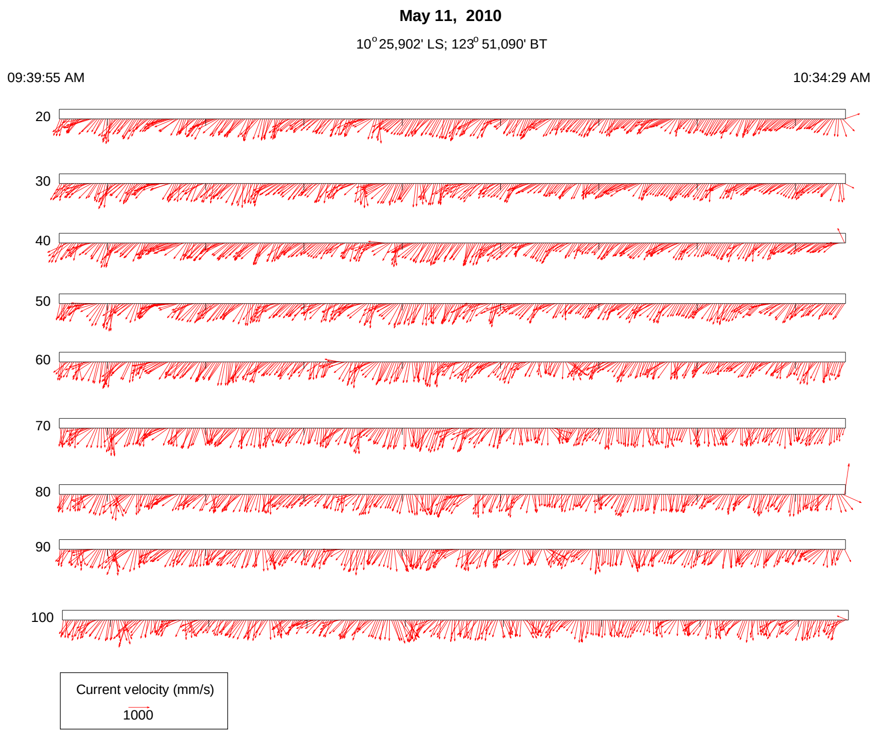



**Figure 2.28.** Current pattern of water layers at different depths at Station 3 (Timor Sea)

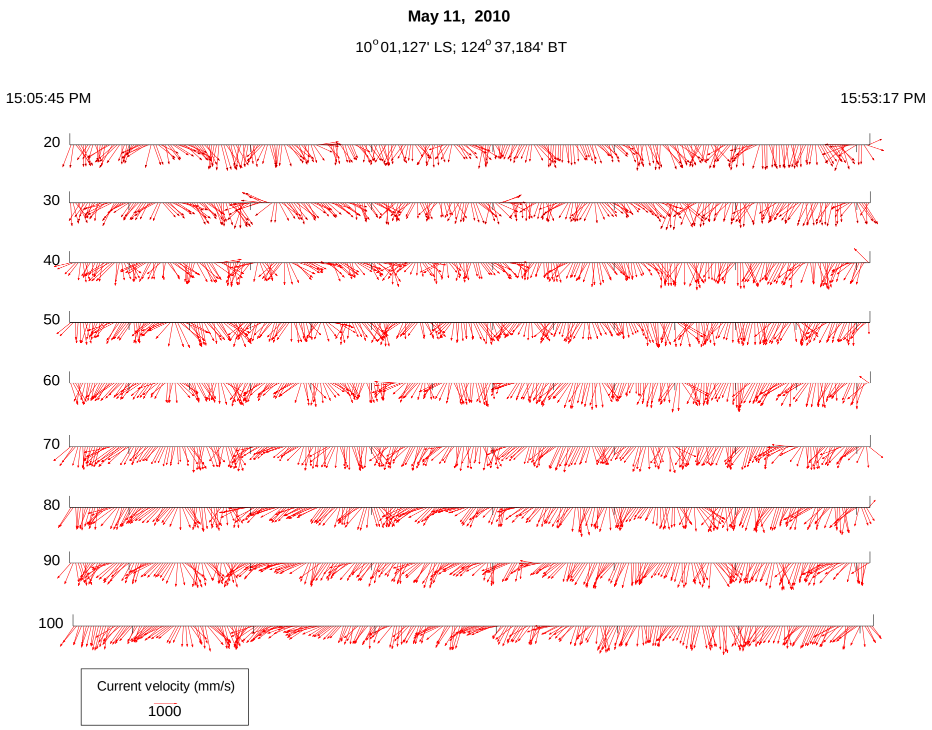



**Figure 2.29.** Current pattern of the water layers at different depths at Station 4 (Timor Sea)

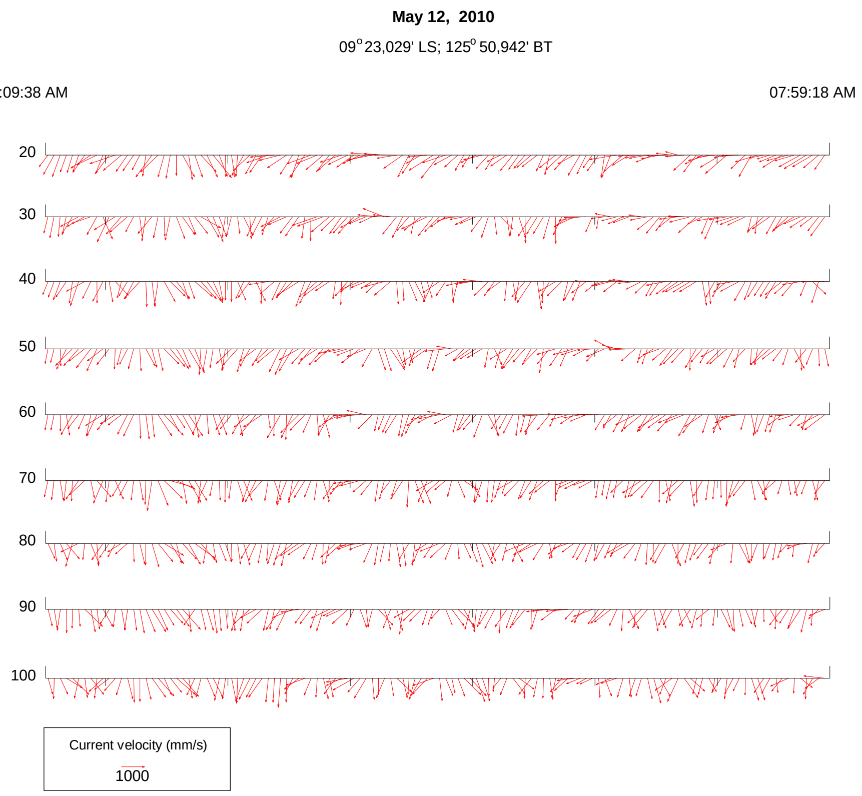



**Figure 2.30.** Current pattern of water layers at different depths at Station 5 (Timor Sea)

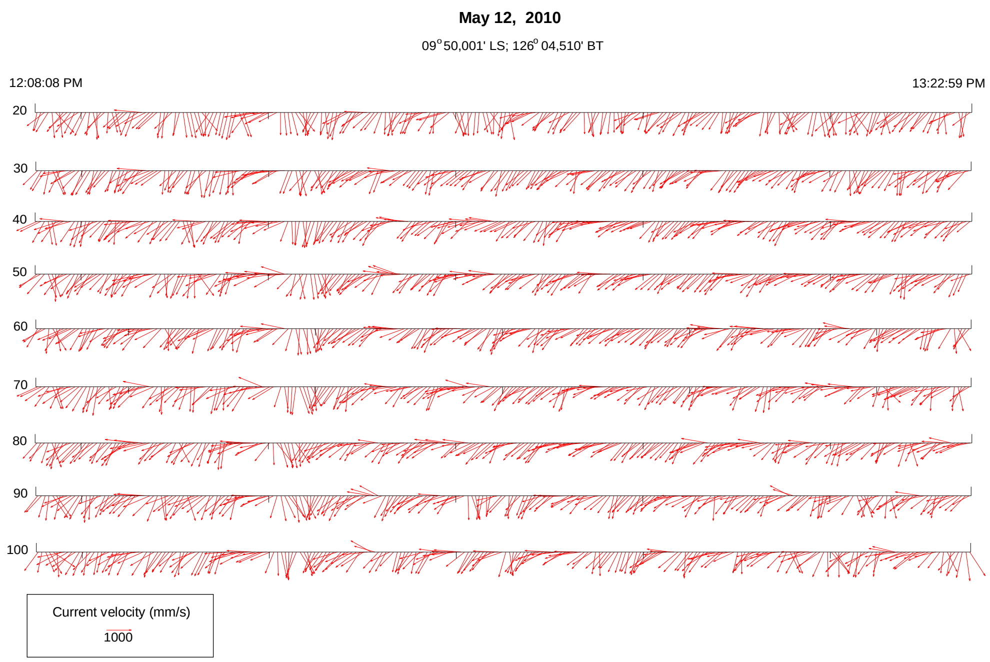



**Figure 2.31.** Current pattern of water layers at different depths at Station 6 (Timor Sea)

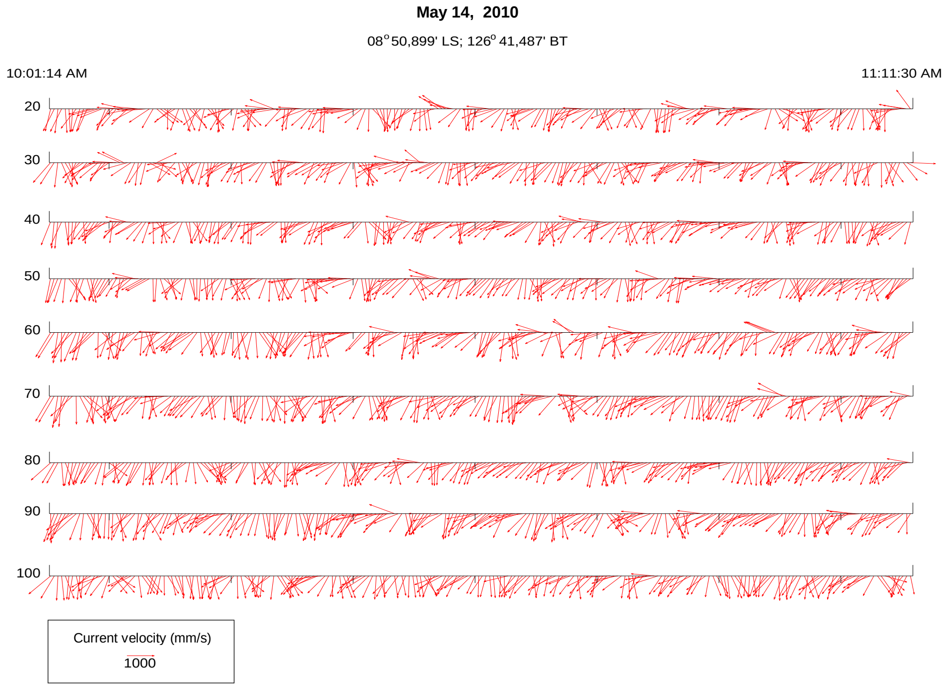



**Figure 2.32.** Current pattern of water layers at different depths at Station 7 (Timor Sea)

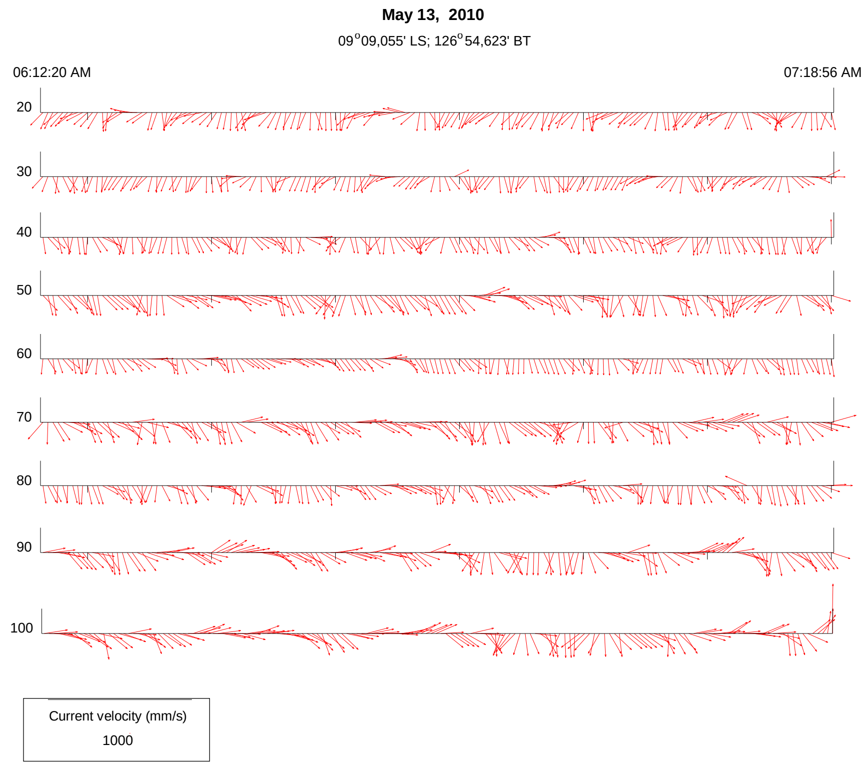



**Figure 2.33.** Current pattern of water layers at different depths at Station 8 (Timor Sea)

## The waters south of Leti Moa Lakor (The Lemola Islands) - Tanimbar

The average currents from 20 to 100 m in the waters south of the Lemola Islands – Tanimbar move southward (156.21 to 200.74°) with velocities of 758.96 to 956.14 mm/s. The current velocity in the eastern part (Station 13) is generally stronger than that of the western part (Station 9). At Station 9, a water mass with a velocity of 758.96 to 777.71 mm/s moves toward 172.90 to 200.74°, but at Station 13, the water mass moves southward (180.47 - 198.66°) with a velocity of 931.84 to 946.14 mm/s. The currents between 20 and 100 m depth in the south of the Lemola Islands – Tanimbar did not change much with depth as shown in Table 2.2 and Figures 2.34 through 2.38.

**Table 2.2.** Velocity and direction of water currents at 20 - 100 m in the waters south of the Lemola Islands – Tanimbar

| Depth (m) | Station 9 | | Station 10 | | Station 11 | | Station 12 | | Station 13 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Velocity (mm/s) | Direction (°) | Velocity (mm/s) | Direction (°) | Velocity (mm/s) | Direction (°) | Velocity (mm/s) | Direction (°) | Velocity (mm/s) | Direction (°) |
| 20 | 777.71 | 176.48 | 859.91 | 195.15 | 931.20 | 178.57 | 818.83 | 168.81 | 931.36 | 188.19 |
| 30 | 776.73 | 172.90 | 866.81 | 192.05 | 926.86 | 180.30 | 912.45 | 162.73 | 946.14 | 188.96 |
| 40 | 765.61 | 182.64 | 868.91 | 196.22 | 919.60 | 182.30 | 819.01 | 162.18 | 946.12 | 198.66 |
| 50 | 766.33 | 182.41 | 868.09 | 199.30 | 918.53 | 177.72 | 816.60 | 162.37 | 938.41 | 188.25 |
| 60 | 777.67 | 181.72 | 853.87 | 199.49 | 924.43 | 179.73 | 860.40 | 164.89 | 942.02 | 180.78 |
| 70 | 758.96 | 193.63 | 850.93 | 190.35 | 935.17 | 184.49 | 856.02 | 157.96 | 944.05 | 180.47 |
| 80 | 771.60 | 197.37 | 861.17 | 196.35 | 933.14 | 178.62 | 845.77 | 162.13 | 935.13 | 188.21 |
| 90 | 768.10 | 200.74 | 847.94 | 192.11 | 938.01 | 193.59 | 852.98 | 163.49 | 933.34 | 187.96 |
| 100 | 768.35 | 200.17 | 832.65 | 183.79 | 928.16 | 198.70 | 860.99 | 156.21 | 931.84 | 181.26 |

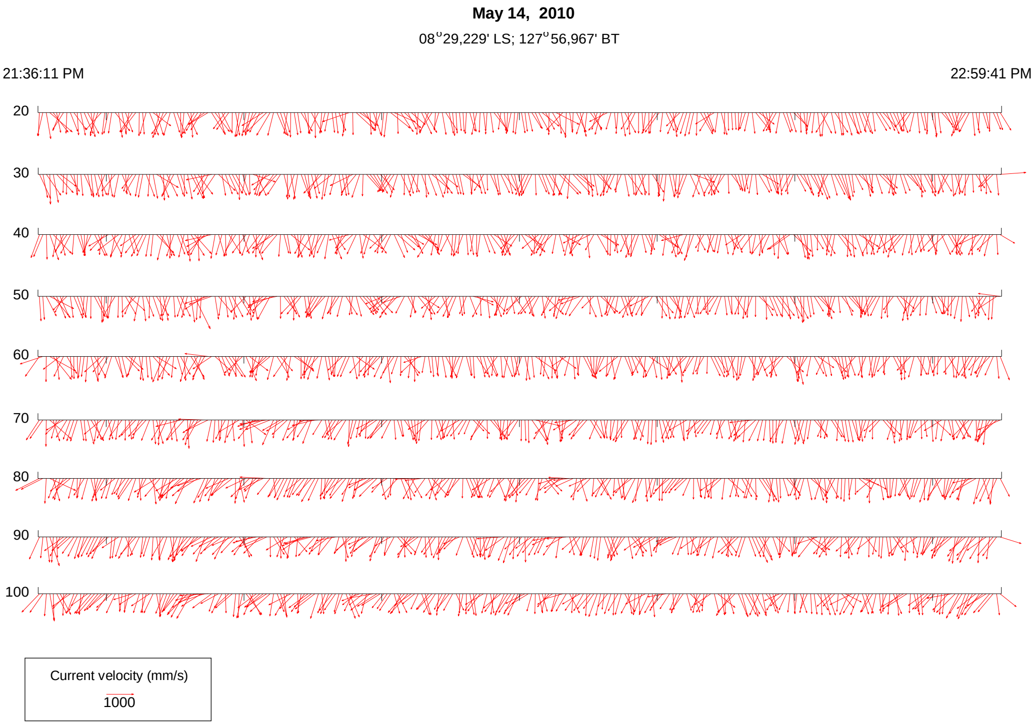



**Figure 2.34.** Current pattern of water layers at different depths at Station 9 (South of Lemola - Tanimbar)

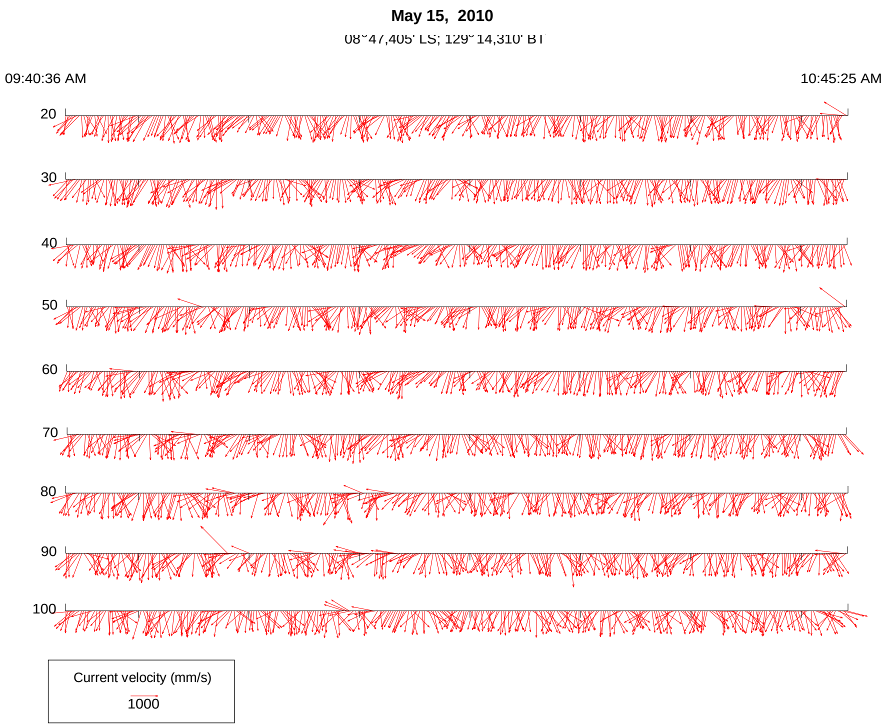



**Figure 2.35.** Current pattern of water layers at different depths at Station 10 (South of Lemola - Tanimbar)


**Figure 2.36.** Current pattern of water layers at different depths at Station 11 (South of Lemola - Tanimbar)

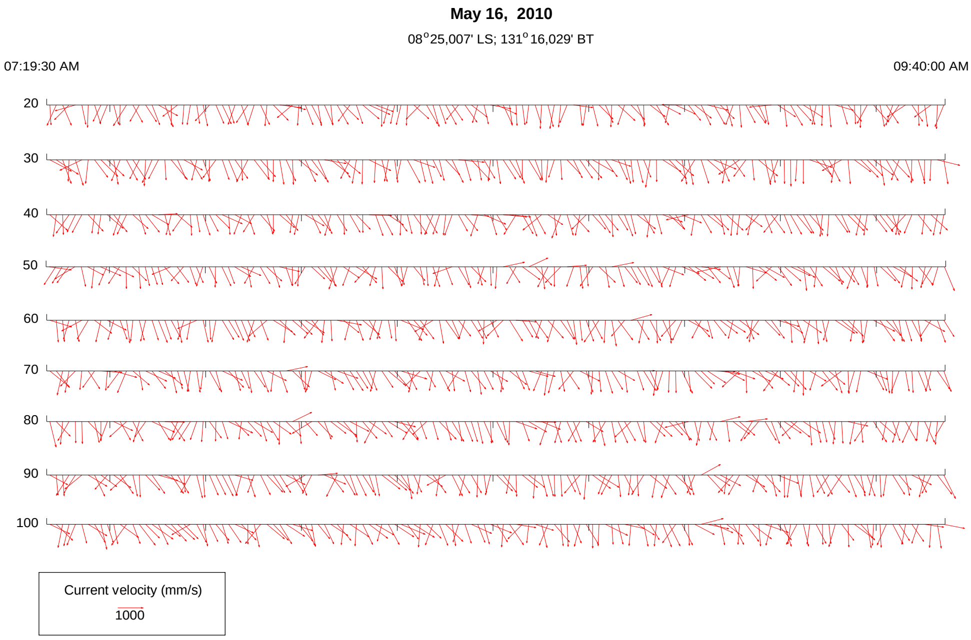



**Figure 2.37.** Current pattern of water layers at different depths at Station 12 (South of Lemola - Tanimbar)

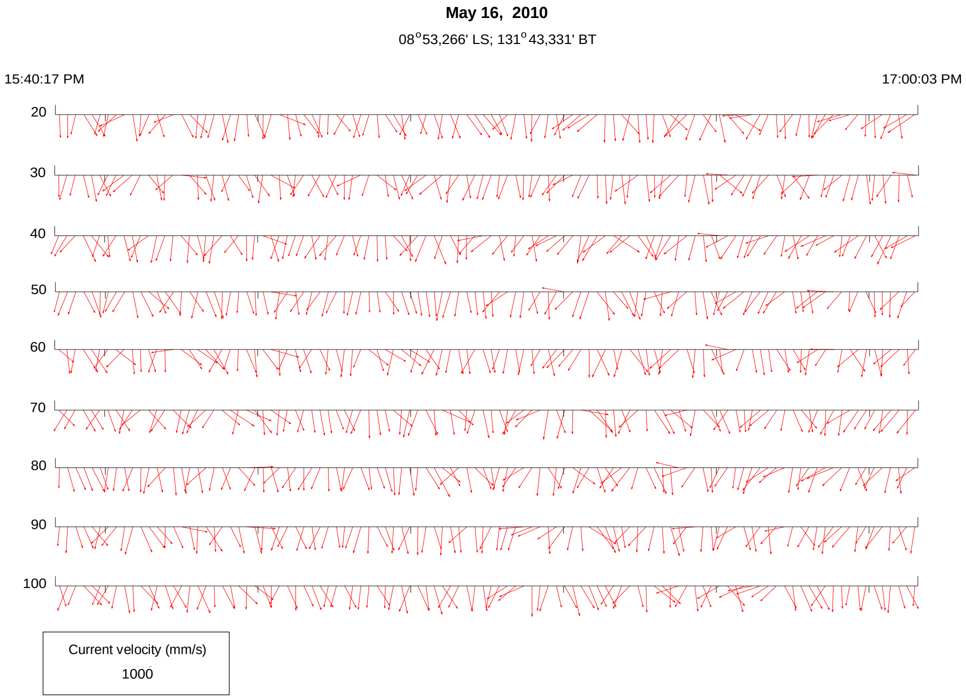



**Figure 2.38.** Current pattern of water layers at different depths at Station 13 (South of Lemola - Tanimbar)

## Arafura Sea

Although current varies somewhat at each station, the general movement of water at Stations 15, 17, 19, 21 and 23 was to the west – southwest. At Stations 16 and 22, the current moved southeastward, but at Stations 18 and 20 the current tended to move southward. The westward movement of the current is due to the wind. Another factor affecting the water mass movement is tide, particularly at stations near the coast. The surface current velocity in Arafura Sea during observation ranged between 326.49 and 674.80 mm/s (Figures 2.39 – 2.47).

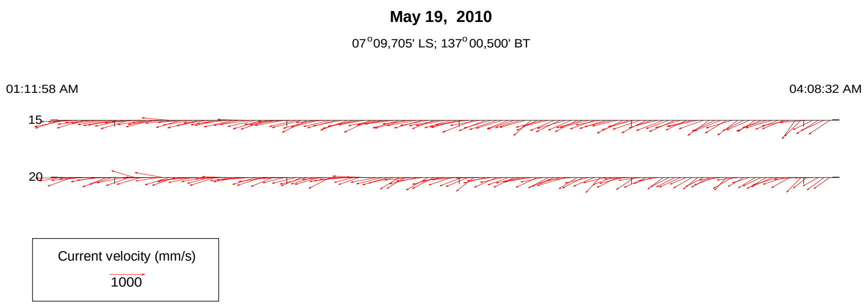



**Figure 2.39.** Current pattern of water layers at different depths at Station 15 (Arafura Sea)

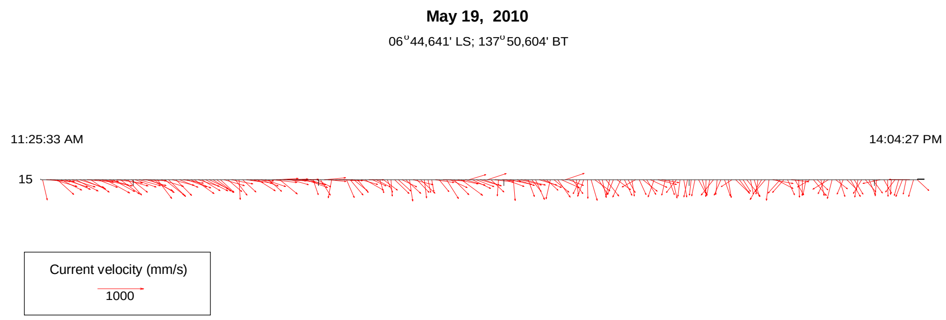



**Figure 2.40.** Current pattern at Station 16 (Arafura Sea)

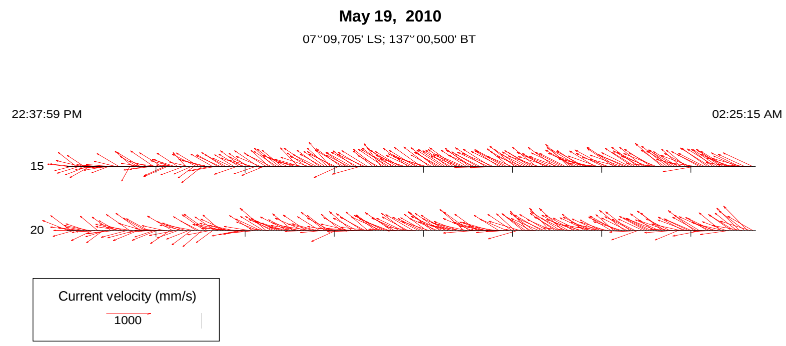



**Figure 2.41.** Current pattern of water layers at different depths at Station 17 (Arafura Sea)

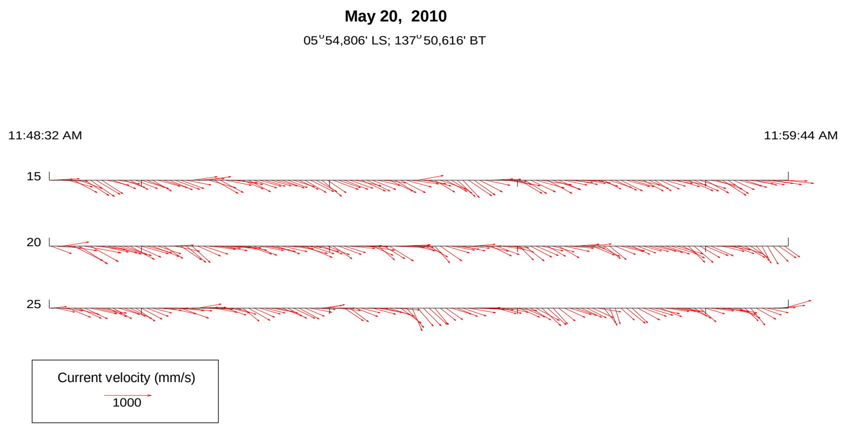



**Figure 2.42.** Current pattern of water layers at different depths at Station 18 (Arafura Sea)

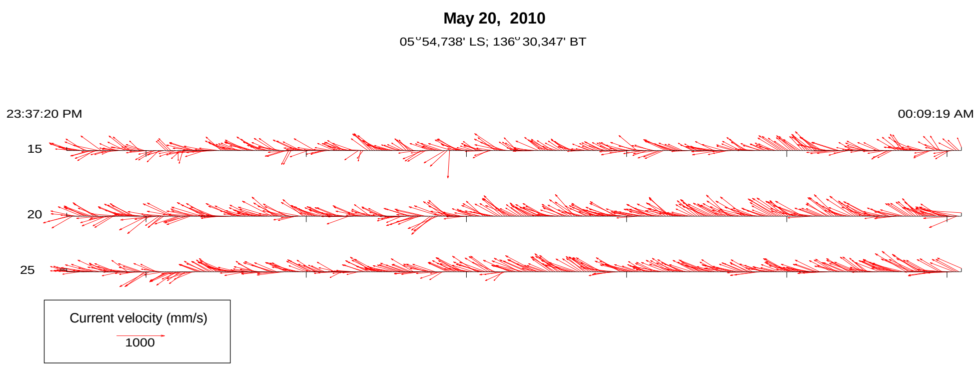



**Figure 2.43.** Current pattern of water layers at different depths at Station 19 (Arafura Sea)

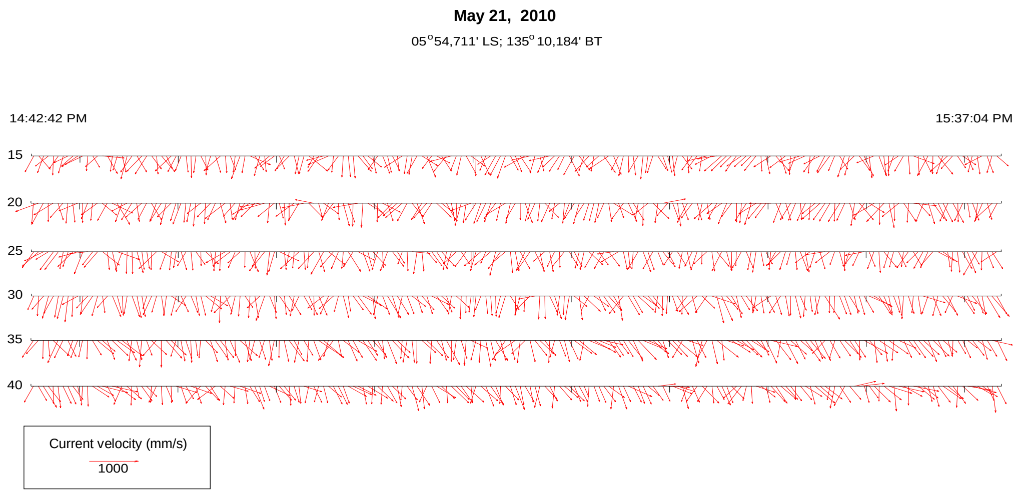



**Figure 2.44.** Current pattern of water layers at different depths at Station 20 (Arafura Sea)

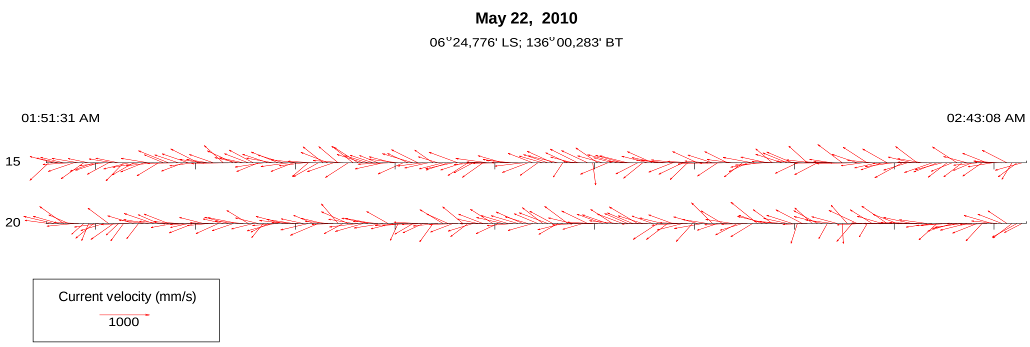



**Figure 2.45.** Current pattern of water layers at different depths at Station 21 (Arafura Sea)

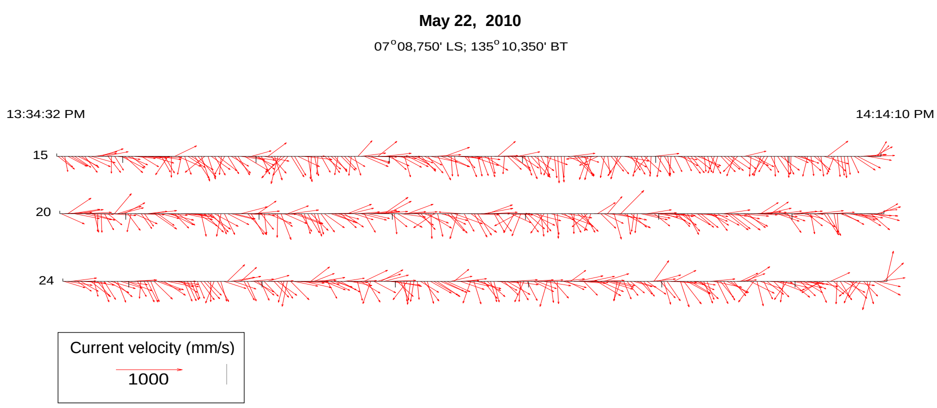



**Figure 2.46.** Current pattern of water layers at different depths at Station 22 (Arafura Sea)

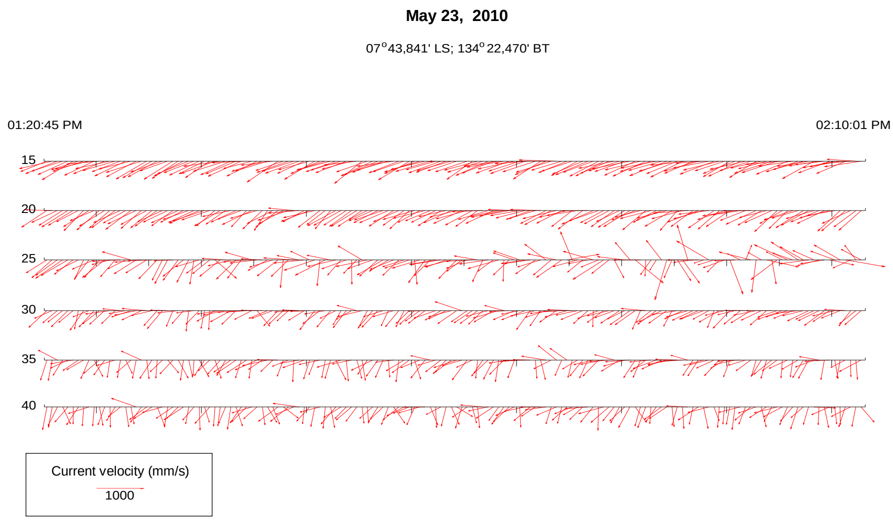



**Figure 2.47.** Current pattern of water layers at different depths at Station 23 (Arafura Sea)

## 2.5. Conclusion

The water mass in the Timor Sea in May was characterized by temperatures that ranged between 27.66 and 29.68$^{o}$ C with an average of 28.75 ± 0.59$^{o}$ C; salinity of 33.15 to 34.11 psu; and sigma-t values between 20.62 and 21.84 kg/m$^3$ with an average of 21.03 ± 0.40 kg/m$^3$. The depth of the mixed layer was 50 m. The waters near the coast had lower temperatures, higher salinity and thus greater density from those of the open sea. The distribution of temperature, salinity and density from 0 to 50 m near the coast, reflected the occurrence of deep water upwelling, particularly at Station 4. Waters flowed to the southwest parallel to the Timor coast.

The waters south of Leti Moa Lakor (The Lemola Islands) – Tanimbar showed different distribution patterns of temperature, salinity and density between the western and the eastern parts. The western portion of the upper layers (depths of 0, 25 and 50 m) were characterized by lower salinity and density. At a depth of 100 m, however, the western water mass had lower temperatures with higher salinity and density. The western water mass characteristics indicate an upward movement of water, probably due to deflection. The thermocline occurred at an average depth of 70 m, and the waters flowed to the south.

Sea surface temperatures in the Arafura Sea ranged from 28.65 to 29.61 $^{o}$C. At 25 m, temperatures were 27.93 to 29.73 $^{o}$C. There was little variation of temperature with increasing water depth. Salinity in the western Arafura Sea was higher than in the eastern Arafura Sea. The sigma-t values of the surface water ranged between 14.05 and 21.15 kg/m$^3$, and between 20.08 and 21.58 kg/m$^3$ at 25 m depth. Waters in the Arafura Sea tended to flow westward in May.

## Chapter III

# BATHYMETRY

**M. Hasanudin[1], Sugiarta Wirasantosa[2]**

[1] Research Centre for Oseanography (RCO) – Indonesian Institute of Science (LIPI), Indonesia
Email: *mhasanudin@lipi.go.id*

[2] Arafura and Timor Seas Ecosystems Action (ATSEA) Program

## 3.1. Introduction

The main purpose of bathymetric mapping is to study the physical contours of the seabed. Seabed morphology reflects natural processes such as tectonic activity, long-term sedimentation and changes in sea level and currents. Sea bottom morphology is also an important element of marine environment. The bathymetry of the Sahul shelf, the Timor Trough and various other bathymetric features are well known.

The bathymetric mapping in the Arafura Sea was conducted using both single beam echosounder SIMRAD EA-500 and multibeam echosounder SIMRAD EM-1002. The focus area for multibeam mapping was the area of the Arafura Sea to the south of Tanimbar Island (Figure 3.1).

The multibeam survey was conducted on May 15th and 16th, 2010 across the bathymetric transition from the edge of the shelf to the trough.

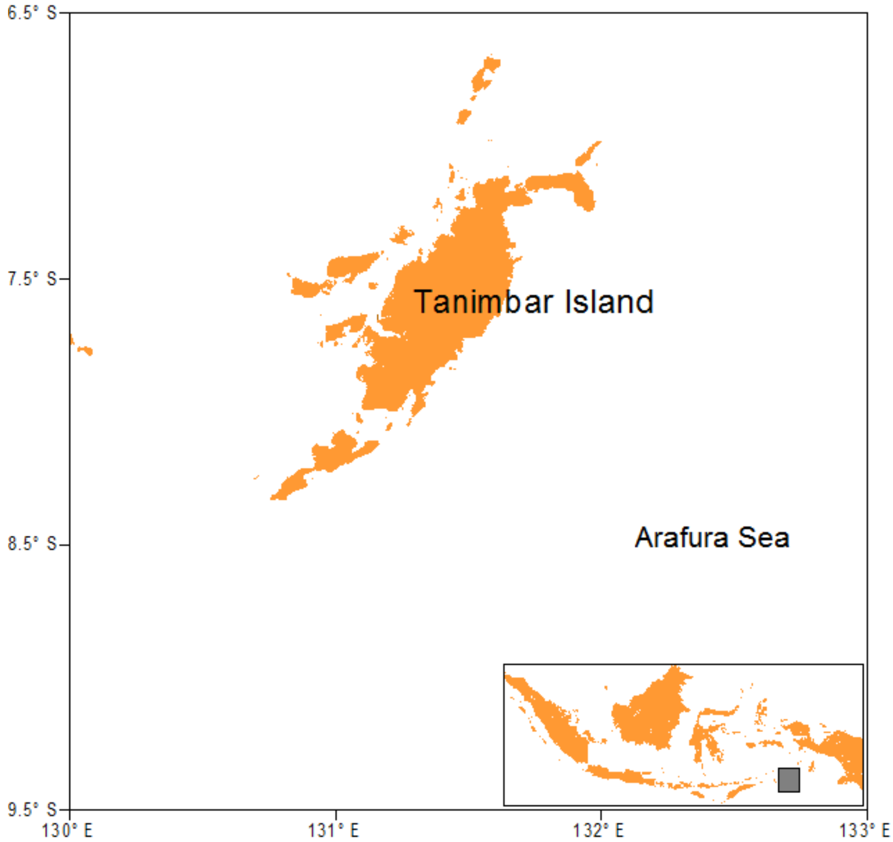



**Figure 3.1.** Area of the bathymetric survey

## 3.2. Methods

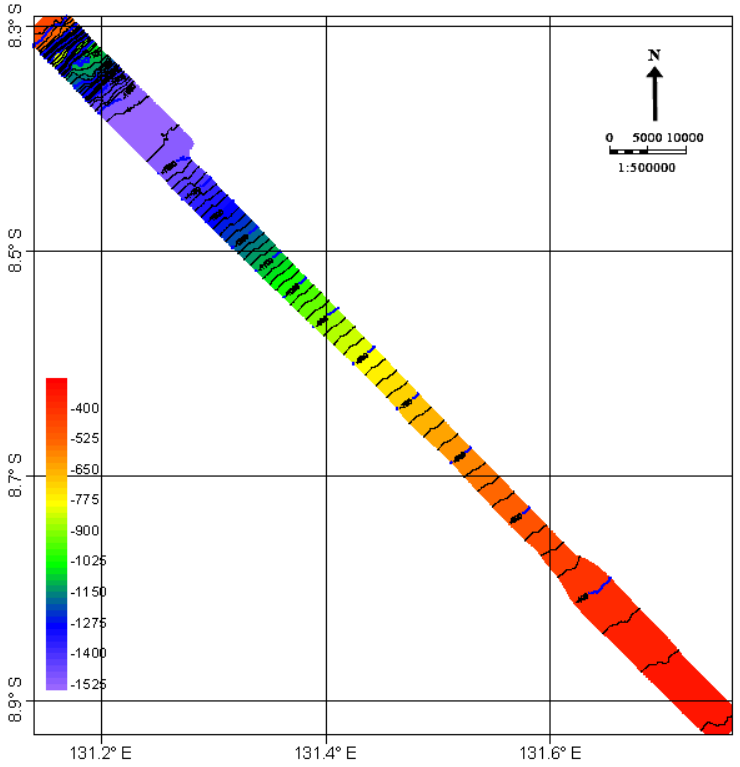
This survey used single beam echosounder SIMRAD EA-500 to acquire bathymetric data in the range of 3 to 11,000 m. EA-500 utilizes 12 kHz frequency and data were recorded using Navipac software.

Multibeam echosounder SIMRAD EM-1002 was utilized to obtain high resolution bathymetry image from depths of < 1,000 m. EM-1002 uses 111 beam with a frequency of 95 kHz for depths ranging from 5 to 1,000 m. The sweeping width of this equipment is 7.4 times the depth.

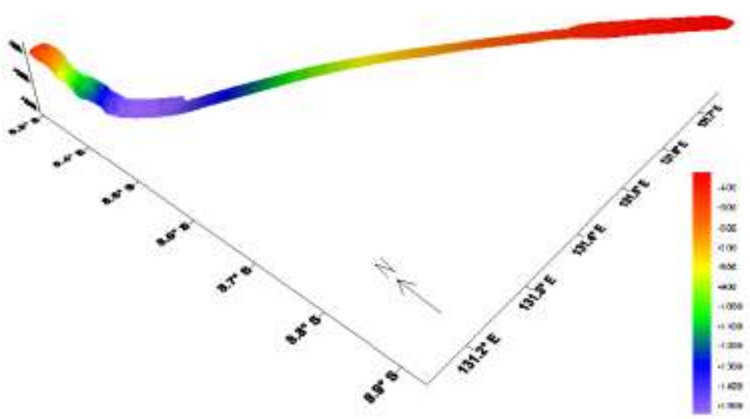
Multi beam data were recorded using Seafloor Information System (SIS) Software and processed with Neptune software. Variation of sound velocity, effect of pitch and roll and direction of the ship are calculated and corrected. Corrections were also done for position, tide and noise effect. Processed data were inputted into CFloor software to create diagram of sea floor morphology.

## 3.3. Results

The bathymetric survey was done in a northwest to southeast direction. Diagrams of sea floor morphology were obtained by using single beam and multi beam data. Figure 3.2 shows the bathymetry of the surveyed area.

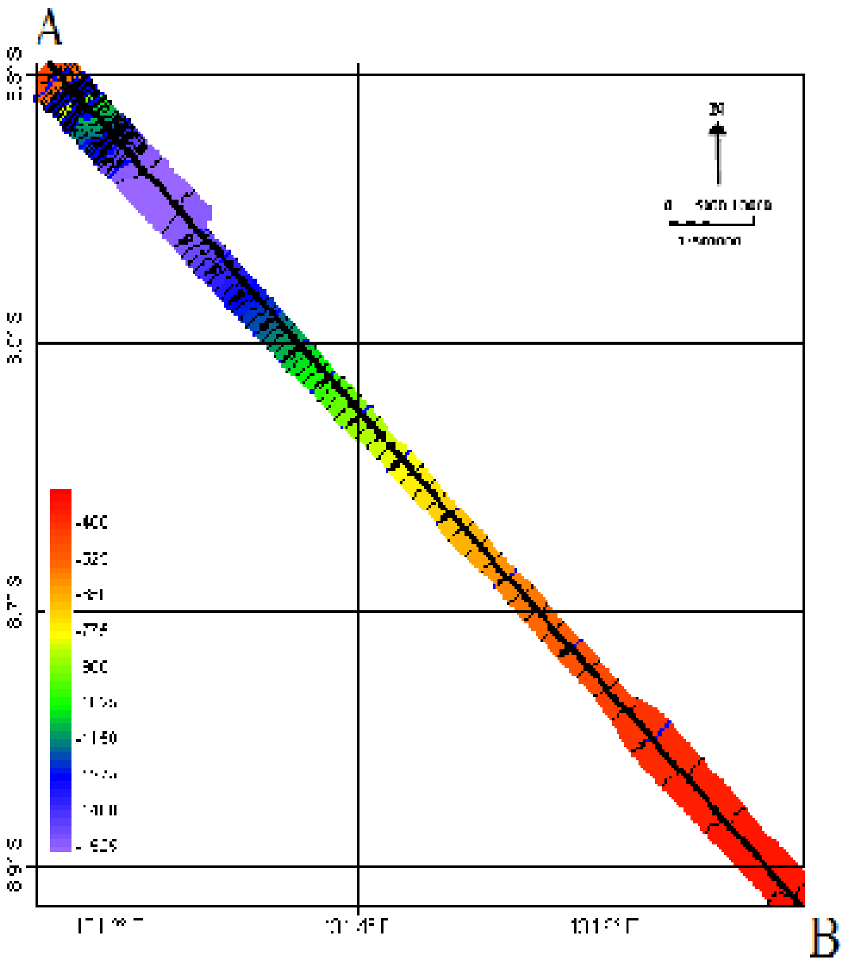



(3.2.a)

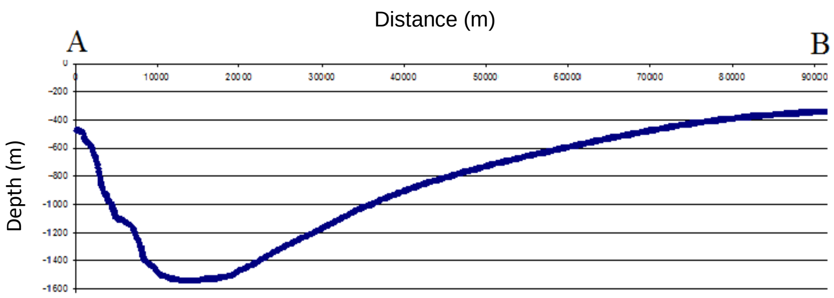


(3.2.b)

**Figure 3.2.** Bathymetry of the Arafura trough in (a) 2D bathymetry and (b) 3D bathymetry



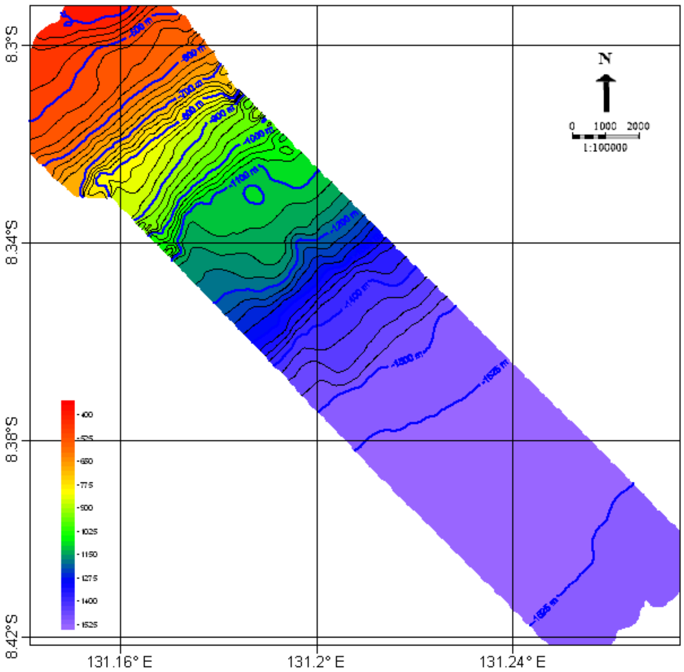

**(3.3.a)**



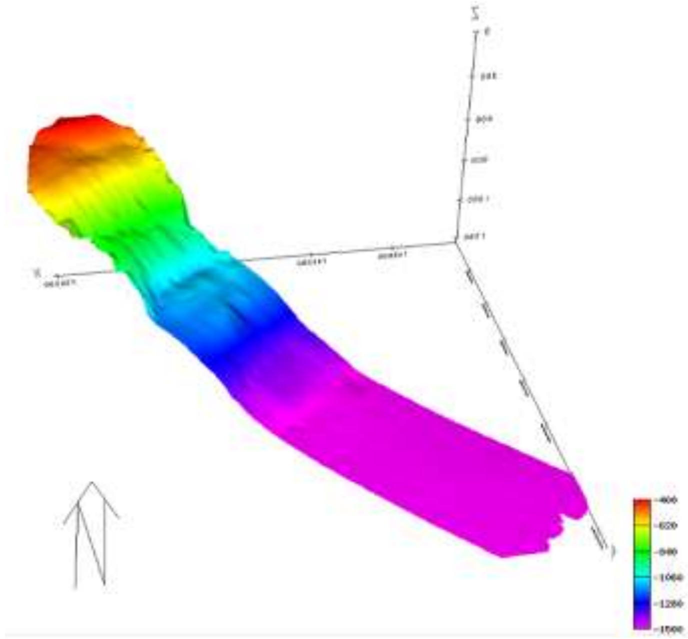

**(3.3.b)**

**Figure 3.3.** Depth profile A-B

Figure 3.3 shows the bathymetric variation from 320 to 1,540 m. The shallowest depth was located at the southeast end of the profile and the deepest part was in the middle. Figure 3.4 indicates different slopes of the Arafura trough; a small slope at the southeast side and a moderate slope at the northwest side.

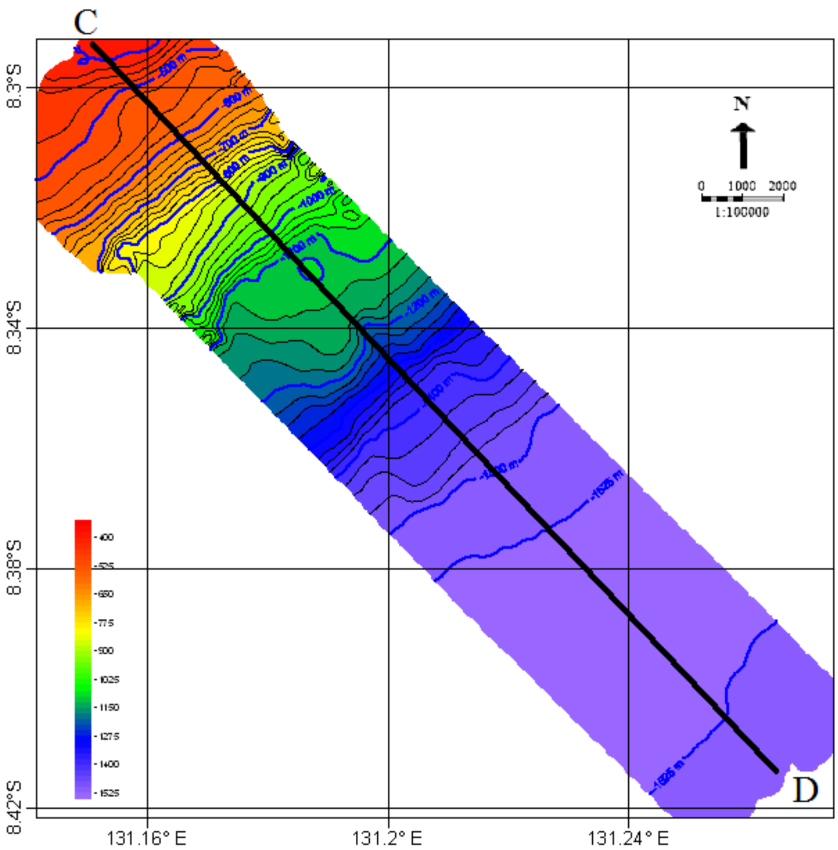



(3.4.a)

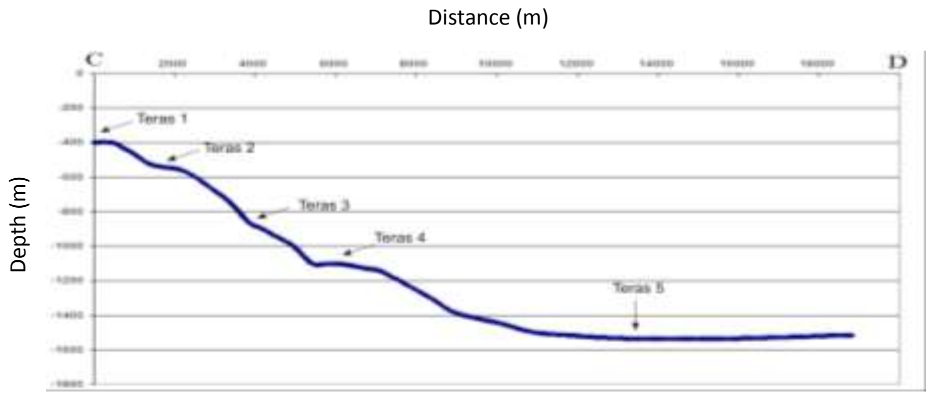


(3.4.b)

**Figure 3.4.** Bathymetry of the northwest side of the surveyed area; (a) - 2D bathymetry and (b) - 3D bathymetry




(3.5.a)

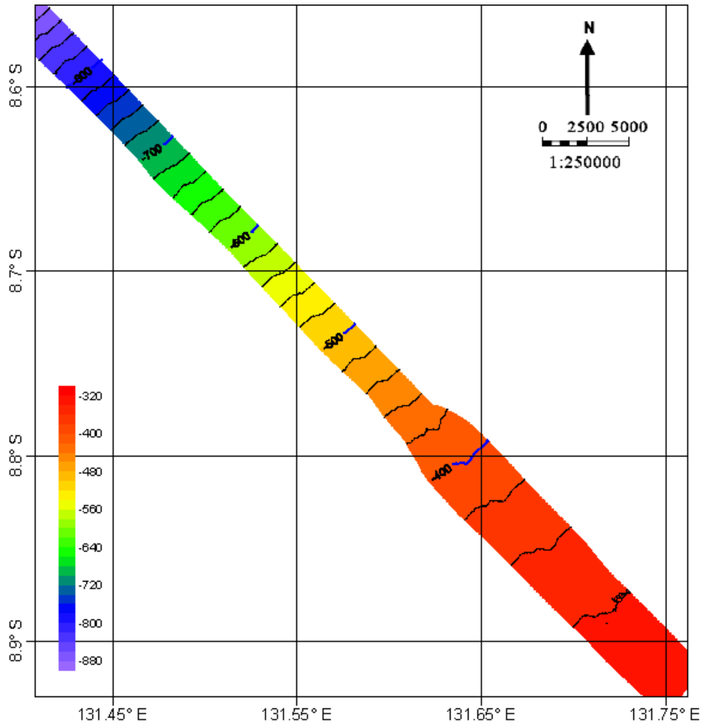



(3.5.a)

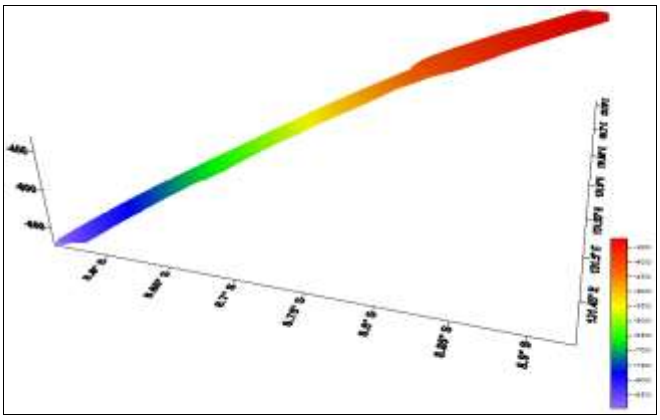
**Figure 3.5.** Bathymetry profile in northwest – southeast direction

Figure 3.5 reflects the moderate slope of the northwest part of the profile. The slope ranges between 10° and 20° at depths of 400 to 1,540 m and indicates five terraces at different levels. These terraces may be part of the accretionary sediments that formed in the subduction zone.

Bathymetry of the southeastern side of the trough indicates a small slope of less than 5° from 325 to 900 m deep (Figures 3.6 and 3.7).

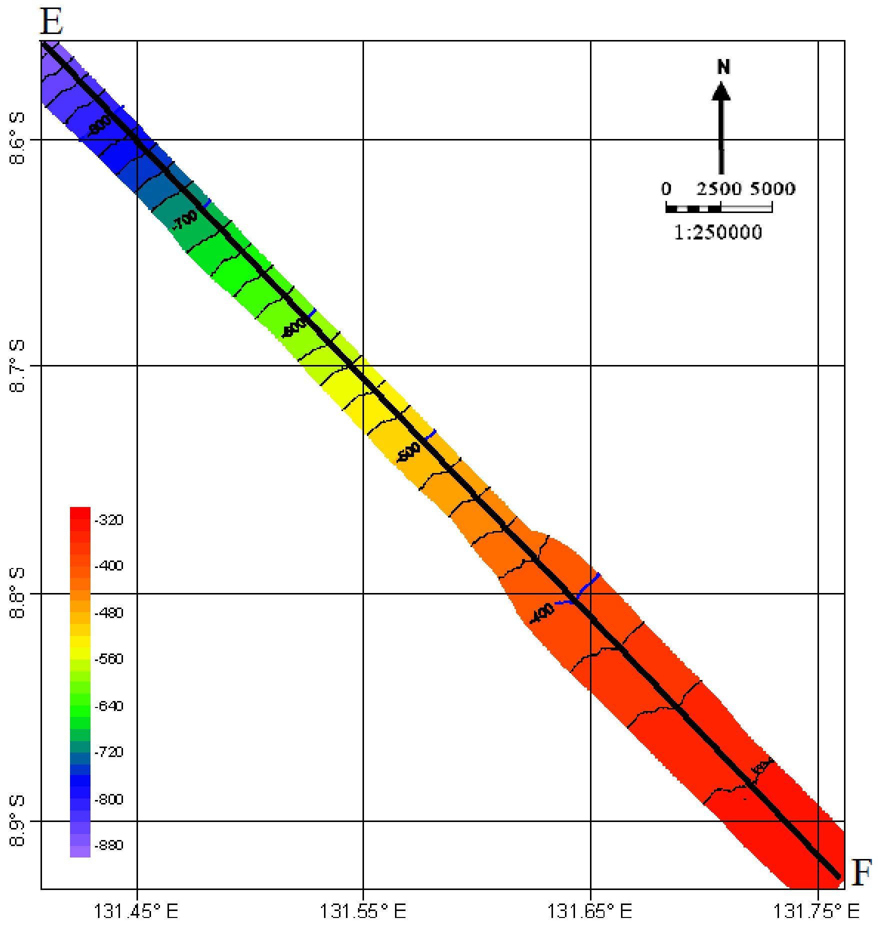



**(3.6.a)**

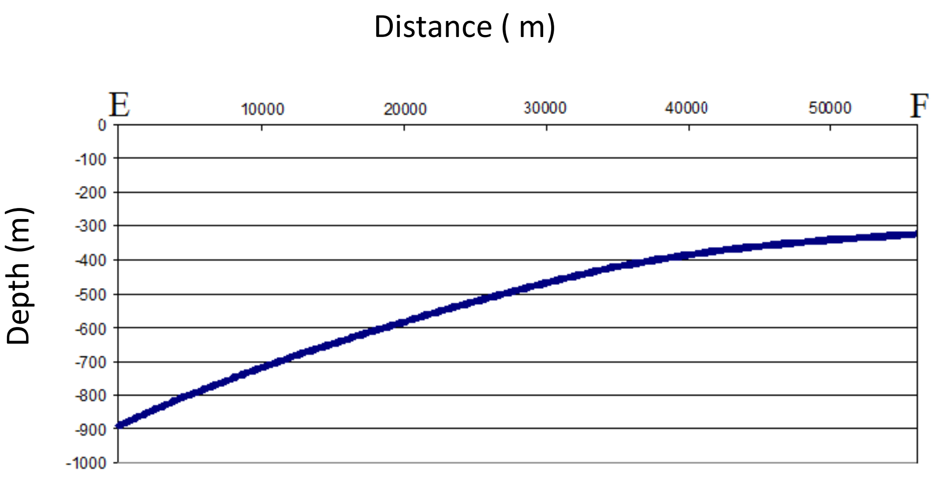


**(3.6.b)**

**Figure 3.6.** Bathymetry profile of the southeastern side of the trough.
(3.6a) – 2D bathymetry; (3.6b) – 3D bathymetry




(3.7.a)

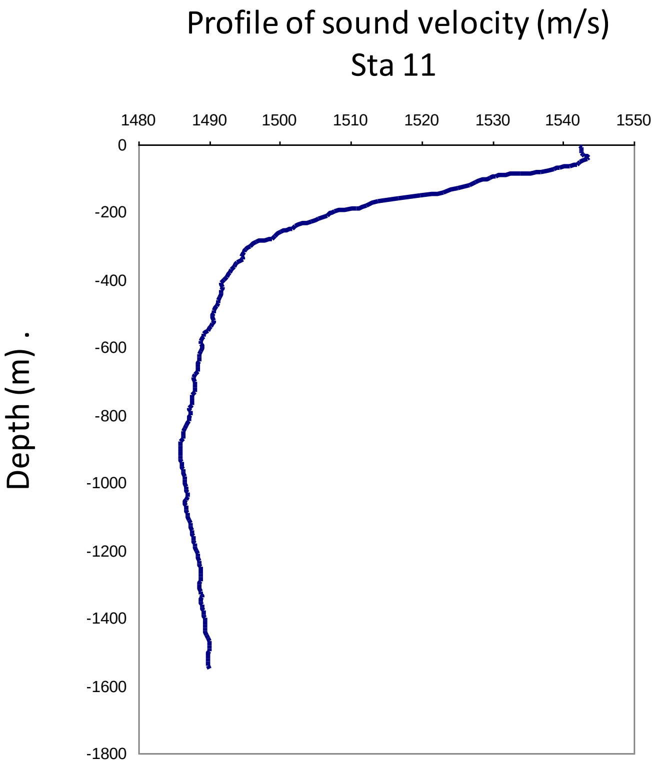



(3.7.b)

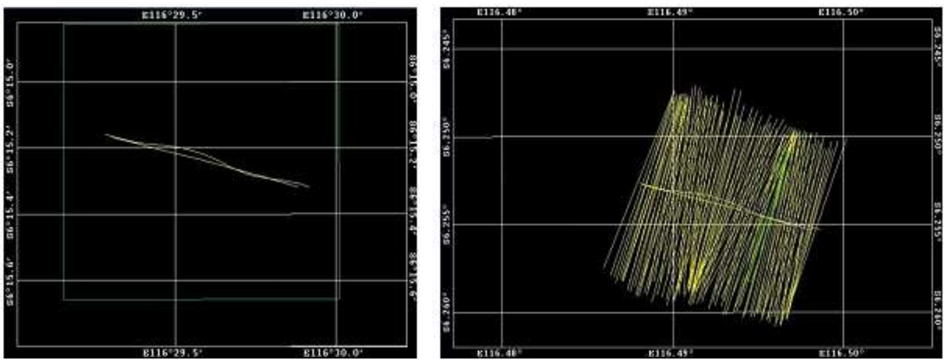
**Figure 3.7.** Bathymetry of the southeastern side of the trough

## Appendix 3.1

# Sound velocity profile used in the survey



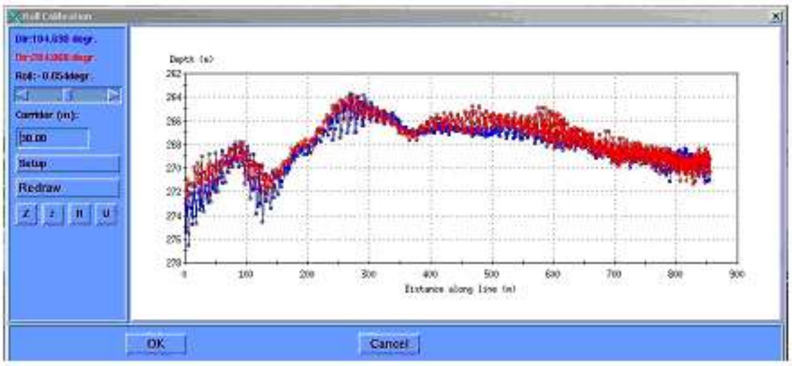

Correction parameters *pitch, roll, time delay* and *heading* for *multibeam echosounder* EM1002.



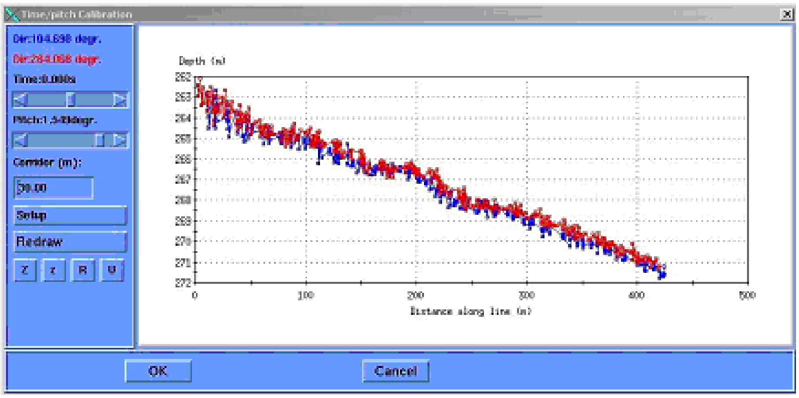
Pitch and roll calibration track

## Appendix 3.2

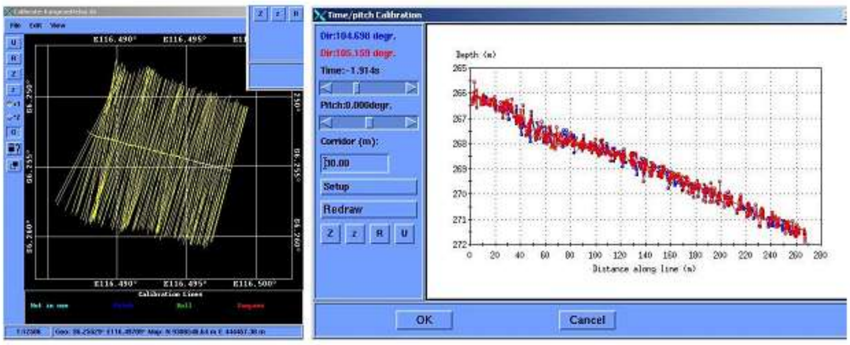
# Time-delay calibration parameter




Roll parameter

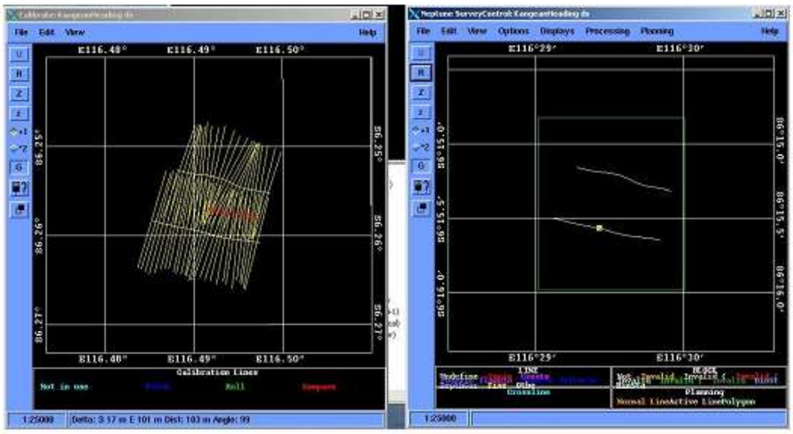



Pitch parameter

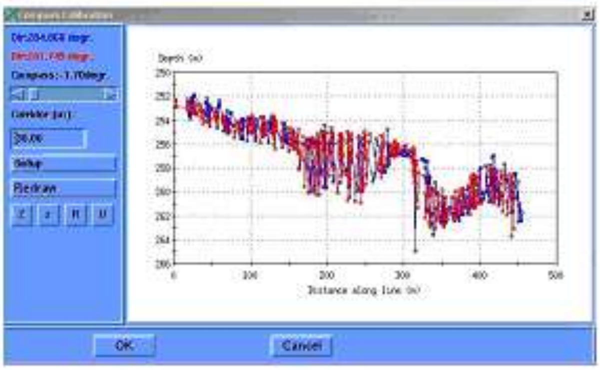


## Appendix 3.3

# Calibration




Calibration for heading



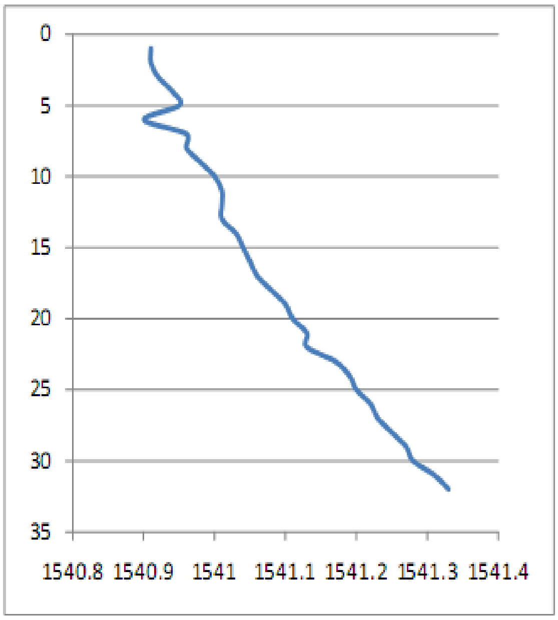

Calibration parameter for heading

**Calibration table**

| | |
|---|---|
| Pitch | 1.549° |
| Roll | -0.054° |
| Delay Time | -1.914 Sec |
| Heading | -1.7 |

**Appendix 3.4**

## Sound velocity applied during calibration:




*Sound Velocity Profile*

Chapter IV

# FISH RESOURCE ASSESSMENT

Contributors to Part A. Pelagic Fish Resources : Moh. Natsir[1], Duto Nugroho[1], Priyadi D.S.[1], Dani Setyawan[1],

Contributors to Part B. Shrimp and Demersal Fish Stock Assessment : Bambang Sumiono[1], Herlisman[1], Suprapto[1], Wedjatmiko[1], M.Rijal[1], Agus Salim[1], Ali Kusnin[1], Constancio dos Santos Silva[2], Fernando da Silva[2], Orlando Halek Kalis[2], Francisco Xavier Luis Pereira[2]

[1]Research Institute for Marine Fisheries
Ministry of Marine Affairs and Fisheries, Indonesia
Email: *naseer.brpl@gmail.com*

[2]National Directory of Aquacultur Fisheries
Ministy of Agriculture and Fisheries,
Republic Democratic of Timor Leste

## A. Pelagic Fish Resources

### 4.1. Introduction

Information on fisheries stock is an important input for policy planning and fisheries management by policy makers (Gulland, 1983). Basic information on stock assessment and the population status of marine organisms, especially fish that inhabit certain waters, supports fisheries development and reflects the effects of development to existing resources (Shevelev *et al.,* 1998). The commonest techniques used in fish stock assessment are trawling and acoustic methods.

The utilization of acoustic and bottom trawling in fisheries research, particularly in fish stock assessment, has been applied by many fisheries research institutions and universities (Kailola and Tarp, 1984). The development of acoustic technology is very progressive in terms of hardware, software and methodology, which significantly improves the accuracy of its assessment.

Assessment of fisheries stock by means of acoustic survey is in general similar to the other fisheries survey methods. The survey only includes data collected on the biota inhabiting a specific area, and analysis of the survey will only produce information on fisheries resources at the time of the survey (MacLennan and Simmonds, 1992).

Fisheries information from a survey will be more benefitial if the survey is conducted periodically. To enable a comparison between one survey and the next, consistency in methodology is required. The consistency includes sampling schemes for data collection, data processing and analysis where even a small variation will affect the results (Shevelev *et al.,* 1998).

Various techniques on stock assessment have been applied in Indonesian waters. Natsir *et al*. (2005) used a combination of survey and biological data from landing stock assessment in Tomini Bay waters. Meanwhile, the technique that was developed mostly by sub-tropical countries, which is a standard in fishery stock assessment, is a trawl-acoustic estimation, using information of biology produced by a trawling operation to support interpretation of echogram obtained from acoustic recordings.

Progress on trawl-acoustic estimation has been made by Bez *et al.* (2007), who compared acoustic data during trawl operation to acoustic data obtained between trawl operations. On the other hand, Tjelmeland (2002) developed a model on biomass data of *Mallotus villosus (muller)* estimated from trawl-acoustic starting from 1972 to 2000 and its relation to biological parameters obtained from trawl operations.

The use of both methods uncovers their benefits and weaknesses (Shevelev *et al*., 1998). Each method complements the other and improves the accuracy and precision of the estimated fish abundances (Bez *et al*., 2007).

## 4.2. Survey area

Acoustic data were gathered continuously from May 10 to May 23, 2010 from the Timor to the Arafura Sea. The acoustic data collection in the Timor Sea was conducted over five days from May 10 to May 15, along the cruise track shown in Figure 4.1. Moving to the Arafura Sea, acoustic data recordings began on May 17 and were completed on May 23, 2010 in the area shown in Figure 4.2.

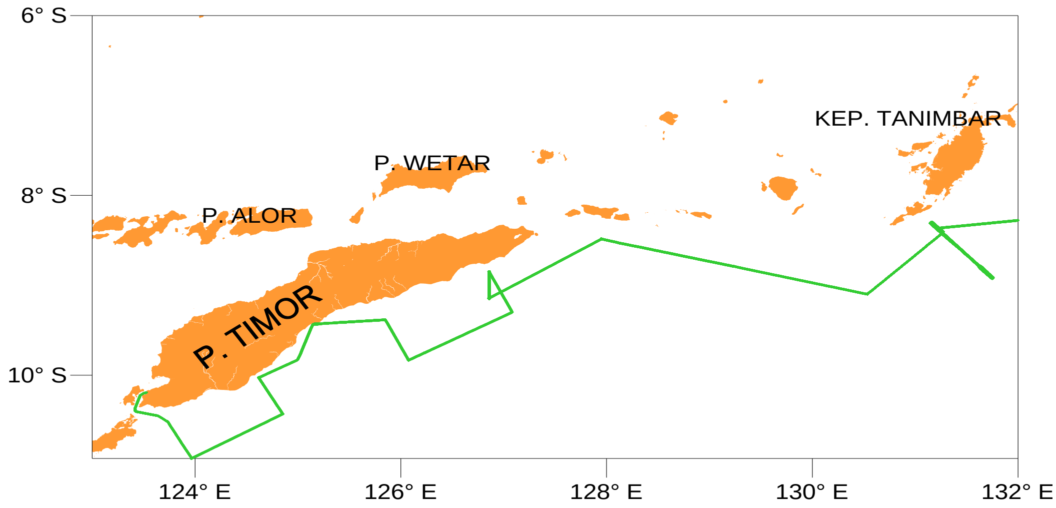



**Figure 4.1.** Ship's track for acoustic data in the Timor Sea

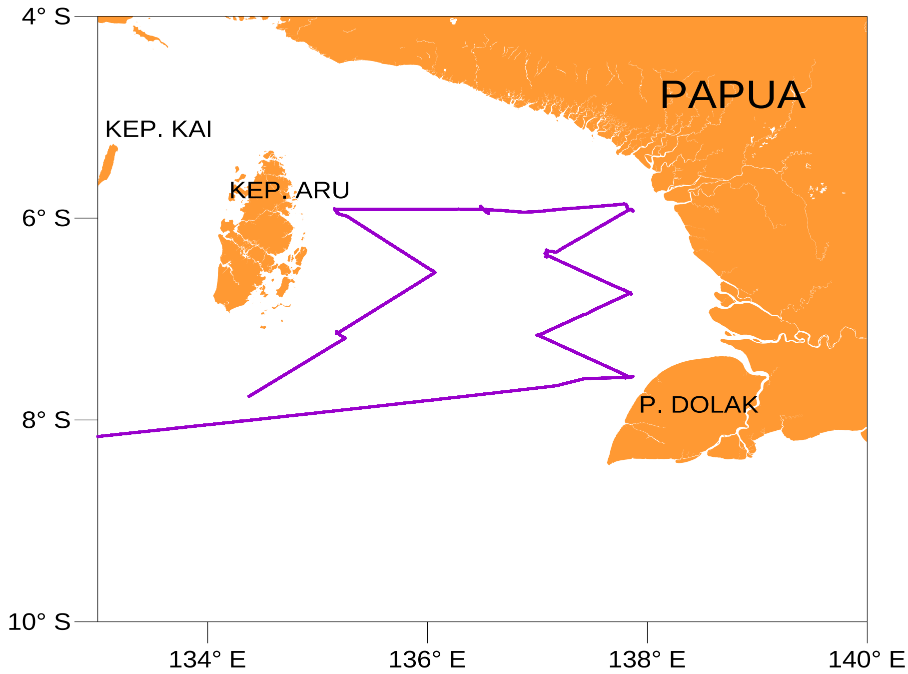



**Figure 4.2.** Ship's track for acoustic data in the Arafura Sea

## 4.3. Method

Acoustic data were gathered by using a SIMRAD EK 500 scientific echosounder and applying frequencies of 38 kHz and 120 kHz. Data acquisition was done by SIMRAD Seri APC 10 computer supported with BI500 software and was connected to SIMRAD EK 500 network system.

Detail of the preliminary analysis refers to the equation applied by Sonar data (2006) which for layer j, the mean area backscattering coefficient was calculated by equation :

$$NASC = 4\pi * 1852 * 10^{SV/10} * T$$

While estimated fish size (cm) was determined by the empirical equations :

- TS = 20 log 10 L - 67.4 (for physoclist; Foote, 1987)
- TS = 20 log 10 L - 71.9 (for physostome)
- TS = 20 log 10 L - 84.9 (for no bladder; Edwards, 1984)
- TS = 20 log 10 L - 75.4 (for squid – like; Arnaya, 1989)

Acoustic data were recorded in the water column to 500 m in the Timor Sea and 150 m in the shallower depth of the Arafura Sea. Two groups of data were collected including acoustic data along the ship's track and acoustic data from trawling operation (Figures 4.1 and 4.2 ).

Data analysis includes integration of echograms to obtain the index of scattering area (SA) for the whole echo. Then, extracting the value of target strength from the single target in the water column to obtain backscattering coefficient ($\sigma_{bs}$), which will be used to estimate the fish abundance in the area. Data processing will be done by using post processing software BI500 and Echoview Version 4.0.1.

## 4.4. Results

Acoustic data in the Timor Sea were recorded in 202 set file within 4 file by using a frequency of 38 kHz and 202 file for 120 kHz. In the Arafura Sea, 207 set file was recorded at a frequency of 38 kHz and 207 set file for 120 kHz. The total length of ship track was 2000 nmi.

Acoustic data recorded simultaneously with trawl operation were from 11 locations, including one in the Timor Sea and ten in the Arafura Sea. Selected echograms and ship's track, where acoustic data were recorded simultaneously with trawl operation, are shown in Figures 4.1 and 4.2.

The number of samples, average back scattering strength (m2/nm) and target strength (in dB) and related acoustics values of the Timor and Arafura Seas is shown in Table 4.1.

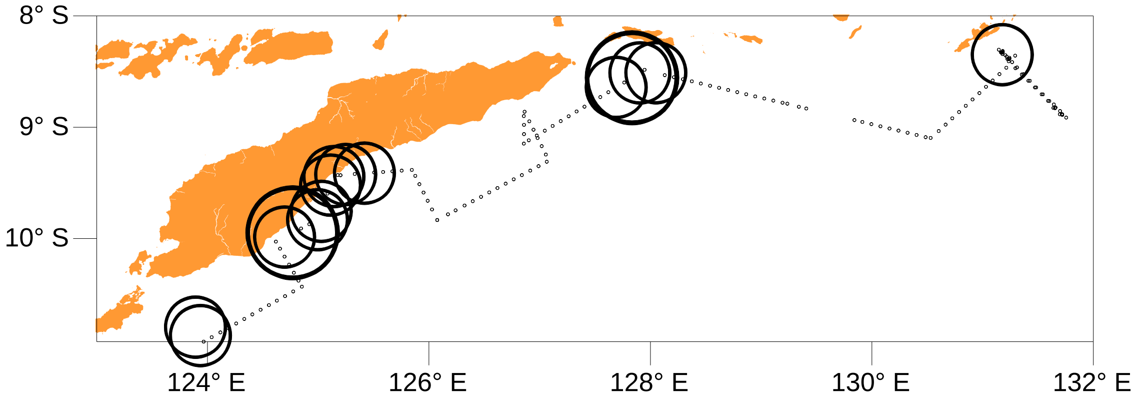
**Table 4.1.** The number of samples, average back scattering strength (m2/nm) and Target Strength (TS = dB) and its related acoustics values by depth ranges

| | Depth | Timor Sea | | | | | Arafura Sea | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (m) | n | avg | stdev | max | min | n | avg | stdev | max | min |
| SA | 2 – 50 | 165 | 839 | 848.0 | 5780 | 22 | 188 | 2242 | 1522.9 | 9661 | 435 |
| | 50 – 100 | 164 | 839 | 867.3 | 5062 | 3 | 66 | 1508 | 1965.8 | 7539 | 2.1 |
| | 100 – 150 | 160 | 123 | 217.0 | 1176 | 1 | 7 | 2330 | 2084.3 | 5389 | 581 |
| | 150 – 200 | 152 | 34 | 94.6 | 727 | 1 | - | - | - | - | - |
| | 200 - 250 | 159 | 28 | 48.0 | 376 | 1 | - | - | - | - | - |
| | 250 - 300 | 162 | 61 | 120.0 | 900 | 1 | - | - | - | - | - |
| TS | 2 – 50 | 155 | - 44.2 | 3.56 | - 35.5 | - 56.35 | 210 | -52.67 | 5.48 | -19.9 | -59.9 |
| | 50 – 100 | 156 | - 43.3 | 2.92 | - 29.4 | - 55.33 | 201 | -51.01 | 4.63 | -30.46 | -59.82 |
| | 100 – 150 | 154 | - 42.2 | 3.48 | - 25.5 | - 55.82 | 11 | - 47.32 | 9.03 | 22.48 | -59.76 |
| | 150 – 200 | 120 | - 41.3 | 3.10 | - 31.0 | - 48.16 | - | - | - | - | - |
| | 200 – 250 | 60 | - 39.9 | 5.19 | - 19.1 | - 48.25 | - | - | - | - | - |
| | 250 - 300 | 13 | - 42.3 | 4.23 | - 37.4 | - 50.30 | - | - | - | - | - |

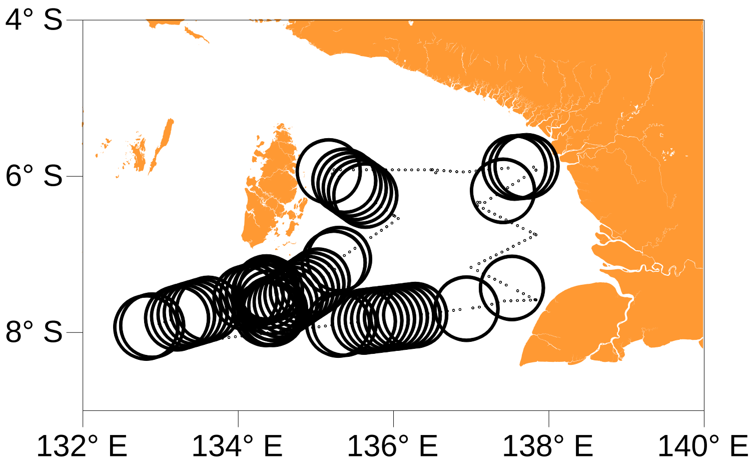
The average relative density in each layer shows that the Arafura Sea gives a higher value than the Timor Sea. The a ratio in the surface layer is 2.67. While the estimate fish length (in dB) shows that at all depth ranges, the Timor Sea gives a higher value than the Arafura Sea.

## Density distribution

The horizontal distribution of relative density of the acoustics population at the surface layer (2 to 50 m), which are assumed to be a small group of pelagic fish, show that the values of the Arafura Sea are higher than the Timor Sea (Figure 4.3). The distribution by depth indicates that all relative densities at all depth ranges in the Arafura Sea are higher than the Timor Sea (Figure 4.4).




(4.3.a)




(4.3.b)

**Figure 4.3.** Distribution of relative density in (a) Timor Sea and (b) Arafura Sea (unit > 3000 $m^2/nm^2$)

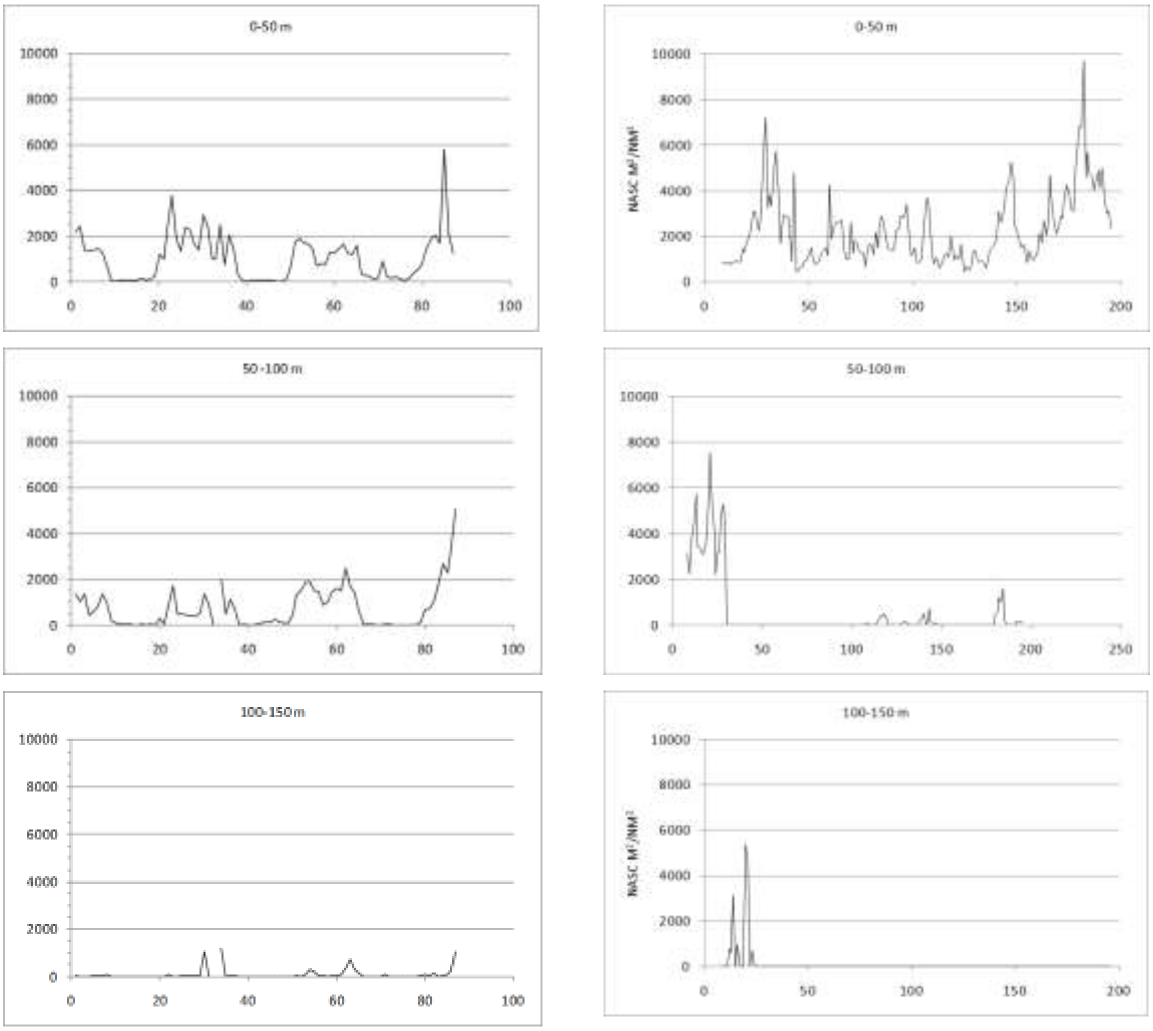
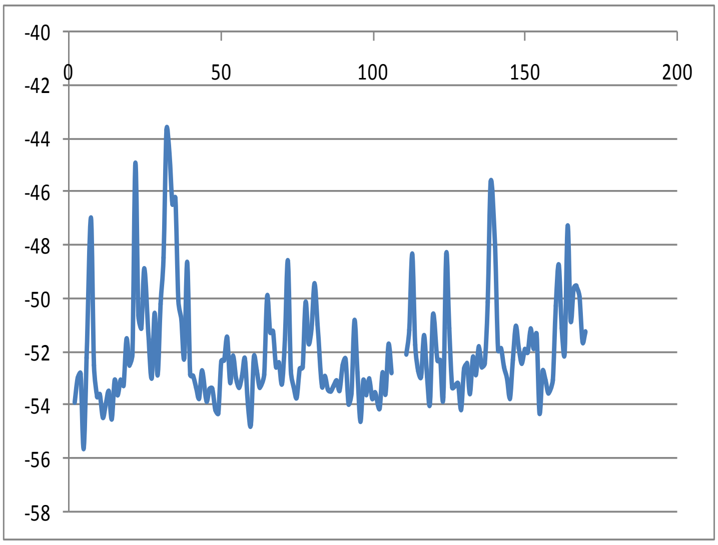


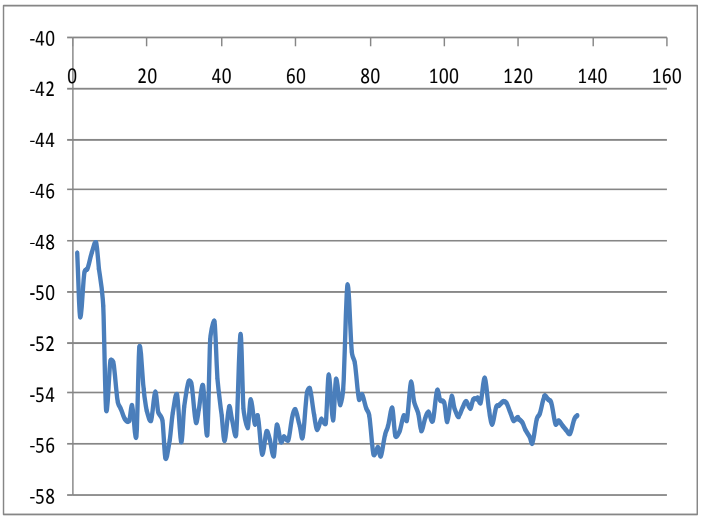

**Figure 4.4.** Profile of horizontal relative density by depth range in the Timor (left) and Arafura (right) Seas.

## Fish Size Estimate

The horizontal distribution of relative fish sizes (TS in dB) in the surface layers (2 to 50 m) show that the average individual fish size in the Timor Sea is bigger (± 2dB) than the Arafura Sea (Figure 4.5). These differences are probably due the pelagic fish in the Arafura Sea, consisting of coastal water species, dominated by small individuals, while the Timor Sea is dominated by large oceanic pelagic species.




**(4.5.a)**




**(4.5.b)**

**Figure 4.5.** The horizontal average fish length (dB) by ESDU in the (a) Timor Sea and (b) Arafura Seas

The TS by depth distribution in the Timor Sea shows that there is of a slightly different median value at each depth range, and bigger sizes tend to occur in deeper water (Figure 4.6).

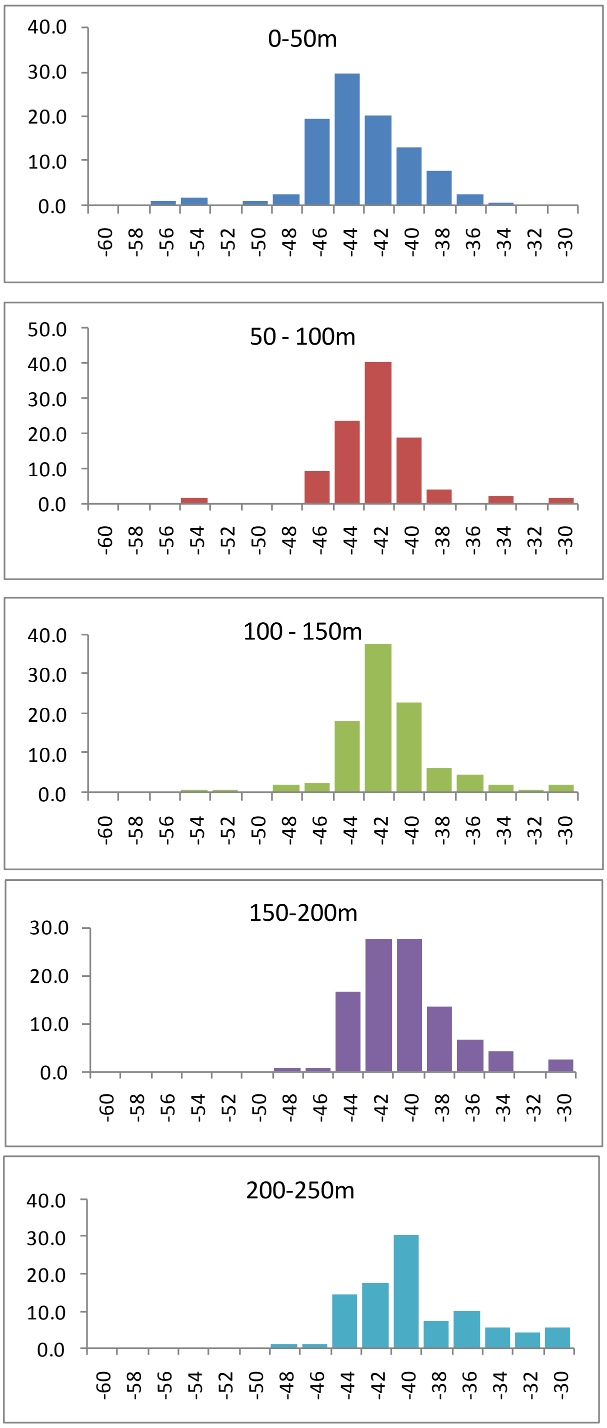
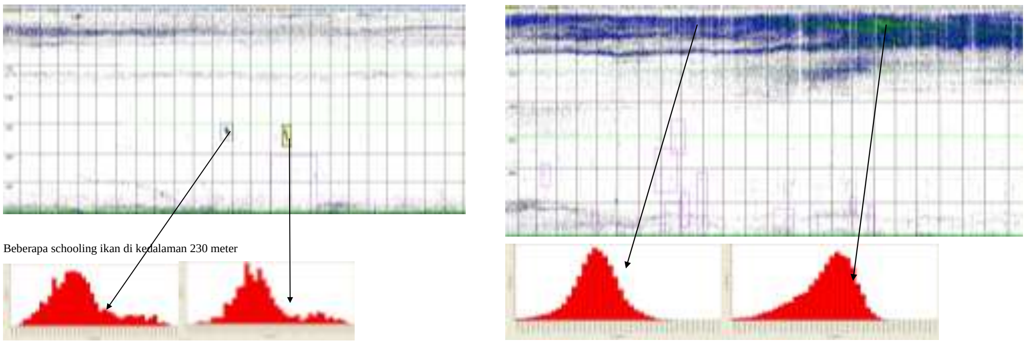



**Figure 4.6.** The TS by depth distribution of single fish in the Timor Sea

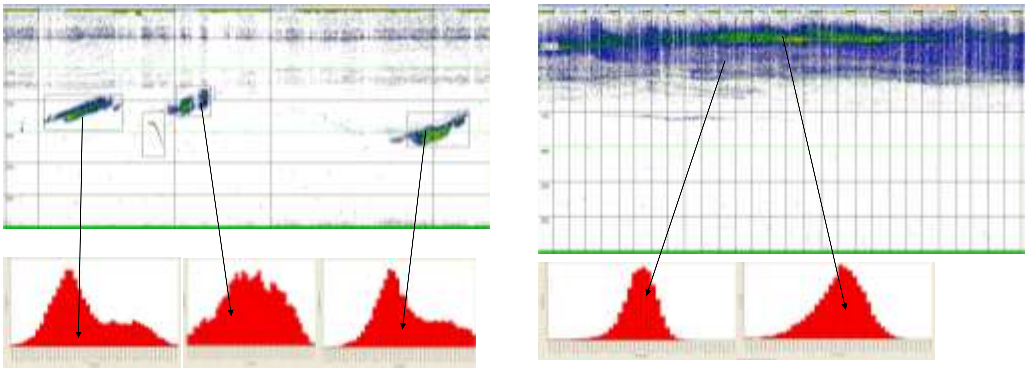
## Fish schools

There are some indications that pelagic and mid water fish school, of greater size occur in the Timor Sea. Some larger fish are also found in the water column in the scattered layer, which vertically migrates in relation to day light. Detailed estimate of density and school distribution in the area is still under observation in the laboratory. Some examples of fish school, in both sub areas, are shown in Figures 4.7 – 4.11.




(4.7.a) (4.7.b)

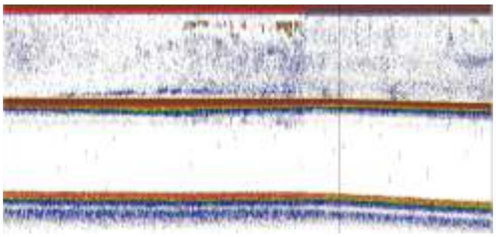
**Figure 4.7.** A number of schooling fish in the Timor Sea to a depth of 230 m (a) and a thick layer of small fish groups mixed with plankton (b) with relative individual size (in dB) distribution.



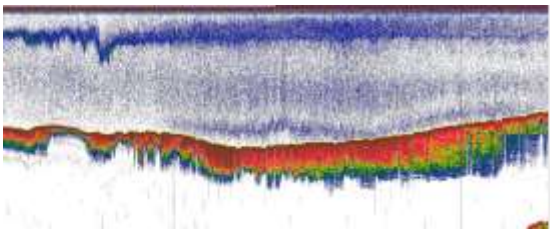
(4.8.a) (4.8.b)

**Figure 4.8.** Some schools of large fish in the Timor Sea at a depth of 230 m (a) and thick layer at the surface of school of small fish mixed with plankton, and a number of individual large fish (b)

## Location: Arafura Sea

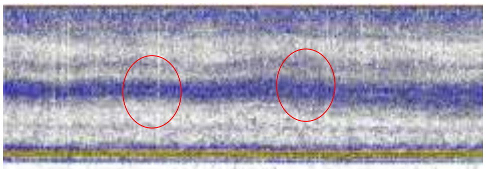


(4.9.a)

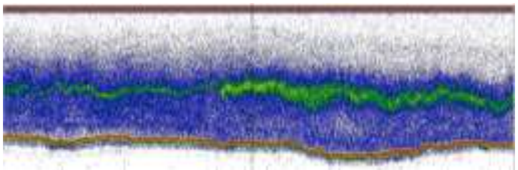


(4.9.b)

**Figure 4.9.** Several small schools of fish at the surface (a) and diurnal migration of layer consisting of plankton and small fish from night time to morning time (more diverse layer) (b)



(4.10.a)



(4.10.b)

**Figure 4.10.** Mixed large and small size single targets (a) and a dense layer in the middle of the water column, consisting of small fish and plankton (b)

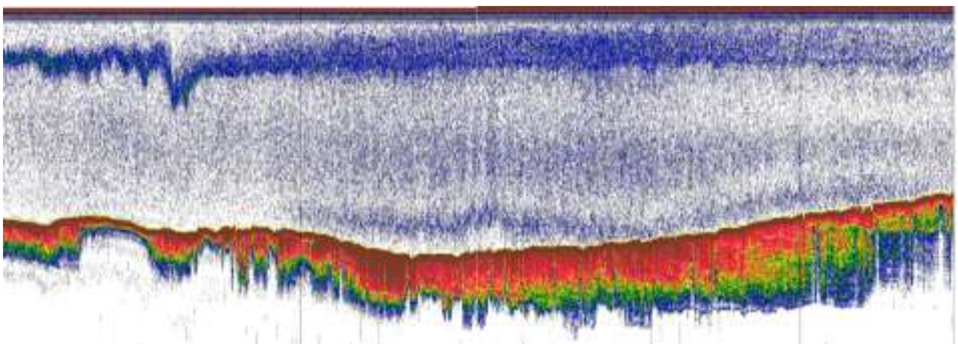


**Figure 4.11.** Diurnal migration of a layer consisting of plankton and small fish from night time (thicker layer) to morning time (more diverse layer)

## 4.5. Preliminary Conclusion

- There are some indications that the population abundance, are higher in the Arafura than the Timor Sea, with an ratio of 2.7 : 1
- The mean fish size (db) in the Timor Sea is higher (±2 dB) than the Arafura Sea. The oceanic pelagic fish which are associated with higher salinity probably dominate in this area.

There are some acoustics shoals occurring in the surface and mid water columns of the deep water in the Timor Sea.

# B. Shrimp and Demersal Fish Stock Assessment

## 4.6. Introduction

Stock assessment of fish and shrimp resources is the main priority for the *Balai Riset Perikanan Laut* (BRPL), which is aimed at obtaining data and updated information on the productivity of fish resources in Indonesian waters, and monitoring the changes due to fishing activity. Assessment of demersal fish and shrimp in the Fisheries Management Area (WPP) of the Arafura Sea was part of the research activities in 2010. This research is expected to produce inputs in terms of proposing alternative policies to fisheries resource management in the central and local governments. The exploitation of the fish and shrimp resources in the Arafura Sea began many years ago, starting in the 1960s and 1970s. At that time, the fish capturing activities were generally a joint venture between Indonesia and Japan. Since then, it has been private companies that capture shrimp in the Arafura Sea. The capture of shrimp in the Arafura Sea is progressing very quickly, and therefore the information required to support the management of this area should be in greater detail.

Ecologically, demersal fish and penaeid shrimp occupy the same habitat at or near the bottom of the ocean, and are therefore frequently captured together. These multi-species resources interact with one another biologically through competition and/or through predator-prey relationships. According to Naamin (1984), the shrimp capturing area of the Arafura Sea is 76,000 $km^2$ which is sub-divided into the main shrimp capturing areas of Dolak, Kaimana, Aru, Bird Head and Bintuni Bay.

Based on the new Fisheries Management Area (WPP), as issued through the Ministerial Decree No.1/2009 concerning Fisheries Management Area, WPP 718 includes the Aru Sea, the Arafura Sea and the eastern part of the Timor Sea. The main fishing areas in the Arafura Sea are the Dolak and Aru sub-areas. Stock assessment on demersal fish and shrimp in the Arafura Sea is badly needed considering that the Arafura Sea is one of the potential fishing areas for demersal fish and shrimp, and current shrimp capturing is very intensive. This is why stock assessment on demersal fish and shrimp was done by the 1230 GT of *RV Baruna Jaya VIII* owned by the Research Centre of Oceanology – Indonesian Institute of Sciences. The vessel is equipped with bottom trawl, acoustic equipment and CTD.

### Objectives

1. To study the composition and distribution of demersal fish and shrimp;
2. To determine the catch rate and stock abundance of demersal fish and shrimp.

### Time and location

The survey was conducted in the Timor and Arafura Seas from May 8 to May 27, 2010. The distribution of the trawling stations are shown in Figure 4.12.

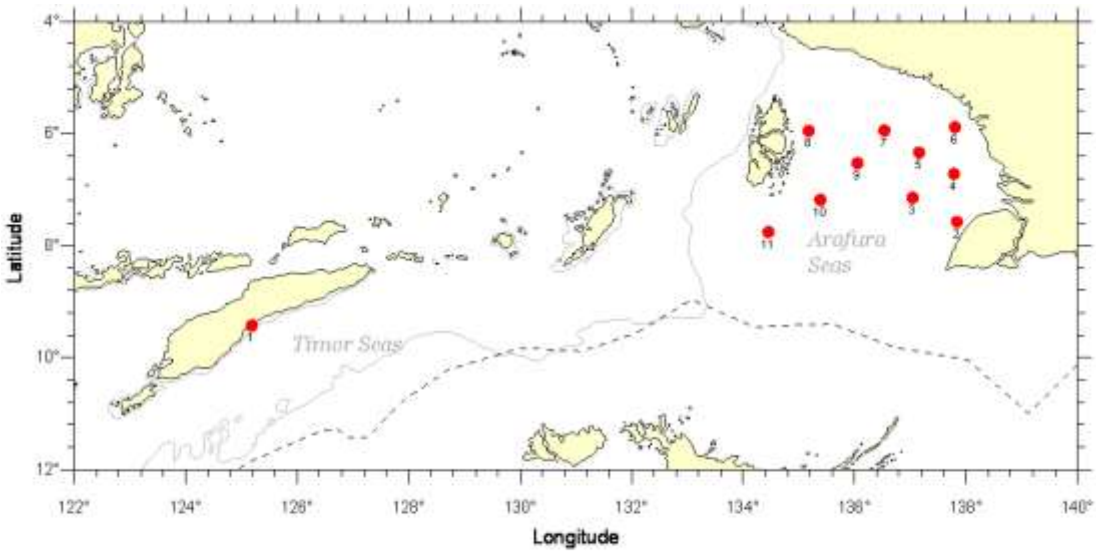



**Figure 4.12.** Distribution of trawling stations in the Timor and Arafura Seas

## 4.7. Methods

### Data collecting

Sampling locations for bottom trawling was arranged based on a systematic track. The trawling net used in the survey had a head rope of 36 m and ground rope of 42 m, and an otter board of 140 cm length and 76 cm width. The sampling stations included one station in the Timor Sea (Suai sub-area) and ten stations in the Arafura Sea (Dolak and Aru sub-areas). Towing time was in the range of 0.5 to 1.5 hours with an average towing speed of 3 knots.  The captured fish were sorted into family (species), weighted and counted. Individual length was measured and gonad maturity of dominant species was assessed. The record of operational aspects (Captain Bridge Sheet) contains information concerning the date, geographical position, depth of collection, ship direction, time of trawling, ship speed during trawling and other matters. The operational aspects of trawling is shown in Appendix 4.1.

## Data Analysis

Assuming that catch rate is proportional with demersal fish biomass, the ratio can be used as an index of relative abundance; this is one of the best indices of abundance to estimate stock. Catch rate is weight of catch (kg) in a certain time period (hour) obtained from according to the Sparre & Venema (1999) equation:

$$C/R = \left(\frac{Cw}{t}\right) \text{ kg/hour} \qquad (1)$$

Where,

C/R = catch rate
$C_w$ = weight of catch (kg)
t = trawling time (hour)

Stock density is estimated by the following calculation:

$$a = S \times E \qquad (2)$$

Where:

S = $v \times t \times 1.85 \times 10^{-3}$
a = swept area per hour ($km^2$)
E = width of net mouth (m)
S = swept distance (km)
v = ship speed during towing (nm/hr)
t = towing time
1. 85 = conversion from mile to km
$10^{-3}$ = conversion from meter to km.

Swept distance (S) is counted from the position from which the net starts to be pulled, to the position the net begins to be taken out of the water. Position is determined by GPS. Stock density is estimated by applying formula (2):

$$D = \frac{Cw/a}{ef} \ kg/km^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

| | | |
|---|---|---|
| D | = | stock density |
| $C_w$ | = | weight of catch (kg) |
| a | = | swept area ($km^2$) |
| ef | = | catch factor, is the ratio of fish catch to fish stock in the waters. |

According to Shindo (1973), the catch factor commonly used in Southeast Asian waters is 0.5

Fish biomass is the weight of fish catch in a certain area and can be estimated by the following formula:

$$B = \{(Cw/a) \times A\}/ef \ \text{ton} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where:

| | | |
|---|---|---|
| B | = | total biomass in survey area (ton) |
| Cw/a | = | average of catch weight per unit area of all sampling ($kg/km^2$) |
| A | = | area of survey ($km^2$) |
| ef | = | escapement factor (=0.5) |

### Species Identification

Fish were identified into species, genus or family aboard the ship, immediately after the fish were caught. Gloefer-Tarp and Kailola (1985) and Nakabo (2000) were referred to for fish identification, Grey *et al*. (1983) was referred to for shrimp identification.

## 4.8. Results

Trawling activity was done in waters with a relatively flat seabed, at depths of < 100 m. There were a total of 11 sampling stations, one of which was to the south of Suai, Timor Leste, five stations to the west of southwest Papua (Dolak and Kokonao sub-areas) and five stations to the east of Aru (Figure 4.12). The sea floor at the different sites varied: sandy with coral debris in the south of Suai, muddy in the Dolak sub-area, and muddy sand in the Aru sub-area.

### 4.8.1. Timor Sea

### General condition of the waters

The trawable shelf area was not large, being limited the rivermouths of the south coast of Belu and Kovalima. Morgan and Valencia (1986) stated that the continental shelf in the Timor Sea was 200 to 4000 m deep, in the form of the Timor Trench (a continental slope and ridge) with a flat area at the coast and in the middle and bordering Australia.

Mangrove areas, and those affected by fresh water from rivers, are areas containing shrimp and demersal fish (mainly located around Rote Island and part of Kupang Bay). According to Naamin *et al*. (1992), the distribution area of penaeid shrimp is mainly located in waters adjacent to mangrove forests, rivermouths or waters with sandy mud bases. Moreover, Unar (1978), supported by the result of an exploration survey aboard the *RV Baruna Jaya I* (1991, 1993), stated that the location of demersal fish and penaeid shrimp in south Timor does not exceed 40 m depth, especially along the south coast of Belu (NTT) to the south of Kovalima Timor Leste. According to Badrudin and Barus (1991), the fishing area for shrimp and demersal fish is in the south coast of Belu are the Abudenok waters, Motodikin, Namfalus and Natarboek, especially at the Babulu and Benanai rivermouths. The important fishing area for shrimp is Natar Boek, particularly at depths of 10 to 20 m. Another area containing shrimp is the south coast of Kabupaten Timor Tengah Selatan (TTS), in the rivermouth of the Noilmina River. A fishing area for demersal fish is in the deep waters of the Timor Sea, located close to the Australian border, where coral reefs are found. The catch from bottom longlines is dominated by deep sea bass of the genera *Pristipomoides* and *Etelis*, and by groupers, which prefer coral reef areas. The red snapper stock in the Arafura and Timor Seas is considered a shared stock between Indonesia and Australia. According to Ramm (1996), red snappers in the waters of the Northern Territory and West Australia are fishing targets of trawls, fishing line and *bubus*. Fishing for red snapper with proper fishing licenses issued in Darwin, has occurred for some time; but since 1988 the production has been declining drastically, causing a moratorium on fishing permits.

### Catch composition

To learn about species and catch composition of the bottom waters in Suai, Kovalima District, Timor Leste, trawling was conducted with a towing time of 30 min at depths of 23 to 25 m in geographical position between $9^{o}25.840$'and

9°25.716’S and 125°09.540’and 125°11.527’ E. Total catch was 42.84 kg/30 min (or 85.68 kg/hr). Catch rate composition (kg/hr) consisted of demersal fish of 61.4 kg (71.7% from total catch), followed by 20.8 kg (23.3%) sea urchin, 2.6 kg (3.0%) penaeid shrimp and 0.8 kg (1.0%) other crustacea (non edible crab). Demersal fish catch by trawling is shown in Table 4.2.

**Table 4.2.** Demersal fish group caught by trawl in the waters of Suai, Kovalima District, Timor Leste, May 2010

| No. | Family | (Kg WW/hr) | (%) |
|---|---|---|---|
| 1 | Pomadasyidae | 21.04 | 34.27 |
| 2 | Nemipteridae | 18.40 | 29.97 |
| 3 | Triacanthidae | 3.60 | 5.86 |
| 4 | Leiognathidae | 3.22 | 5.24 |
| 5 | Priacanthidae | 3.00 | 4.89 |
| 6 | Apogonidae | 2.06 | 3.36 |
| 7 | Sciaenidae | 1.78 | 2.90 |
| 8 | Mullidae | 1.70 | 2.77 |
| 9 | Platycephalidae | 1.34 | 2.18 |
| 10 | Harpadontidae | 1.08 | 1.76 |
| 11 | Ariidae | 1.00 | 1.63 |
| 12 | Polynemidae | 1.00 | 1.63 |
| 13 | Lactariidae | 0.70 | 1.14 |
| 14 | Paralichthyidae | 0.60 | 0.98 |
| 15 | Priacanthidae | 0.40 | 0.65 |
| 16 | Teraponidae | 0.24 | 0.39 |
| 17 | Paralichthyidae | 0.08 | 0.13 |
| 18 | Gerridae | 0.08 | 0.13 |
| 19 | Uranoscopidae | 0.04 | 0.07 |
| 20 | Engraulidae | 0.02 | 0.03 |
| 21 | Lutjanidae | 0.02 | 0.03 |
| | **Total** | **61.40** | **100** |

## Fish species

The ten dominant fish families caught are sweet lips, with the main species being *Pomadasys argyreus* and *P. kaakan*, followed by threadfin breams of the family Nemipteridae and fish of the family Triacanthidae. Of the Nemipteridae family, the dominant species are *Nemiperus tolu* and *N. japonicus*. The fourth dominant fish group is ponyfish of the Leiognathidae family, followed by the big-eye of the Priacanthidae family and polka dot fish of Apogonidae family. The ponyfish are dominated by the species *Leiognathus daura*, the big eye group by *Priacanthus tayenus* and the polka dot fish group by *Apogon septemstriarus* and *A. poeciloptherus*. The next dominant fish group are the Sciaenidae family (the bearded croakers), the Mullidae family, the Platycephalidae family and lizard fishes of the family Harpadontidae. The Sciaenidae were dominated by the species *Penahia macrocephalus*, *Upeneus vittatus*, *U. sulphureus*, and *Coeciella crocodila*; the lizard fish are dominated by the species *Saurida micropectoralis* and *S. undusquamis*.

During the trawling, some juvenile red snappers (*Lutjanus malabaricus*) of 10 cm long were captured together with the small pelagic anchovy *Stolephorus indicus*. Non-fish biota found include the sea urchin. Penaeid shrimps were only caught at a rate of 2.6 kg/hr, dominated by the endeavor shrimp (*Metapenaeus ensis)* and *Trachypenaeus fulvus*. The most captured crustacea is the non-edible crab *Charybdis* spp.

## Measured length of fish

Measured biological parameters include the capture frequency and indentification of the dominant fish and shrimp types (Table 4.3, Figures 4.13 - 4.17).

**Table 4.3.** Range of length of fish and penaeid shrimp captured in Suai, Timor Leste, May 2010.

| No. | Species | Range of length | n |
|---|---|---|---|
| | FISH | | |
| 1 | *Pomadsys argyreus* | 12.5 – 31.0 cm TL | 90 |
| 2 | *Leiognathus daura* | 8.0 – 12.0 cm TL | 57 |
| 3 | *Nemipterus tolu* | 5.5 – 21.0 cm FL | 206 |
| 4 | *Polydactylus microstoma* | 10.5 – 13.5 cm FL | 13 |
| 5 | *Pennahia macrocephalus* | 16.5 – 21.0 cm FL | 10 |
| | SHRIMP | | |
| 1 | *Metapenaeus ensis* | 14.5 – 42.0 mm CL | 44 |
| 2 | *Trachypenaeus fulvus* | 13.0 – 22.0 mm CL | 42 |

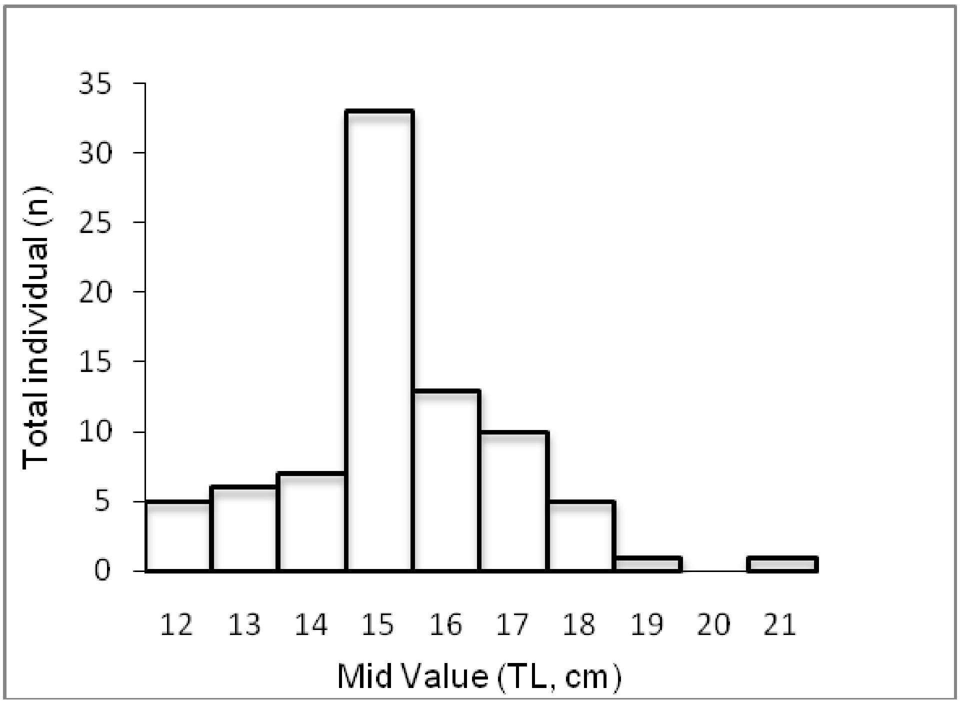



**Figure 4.13.** Frequency and total length (TL) of sweet lips (*Pomadasys argyreus)*

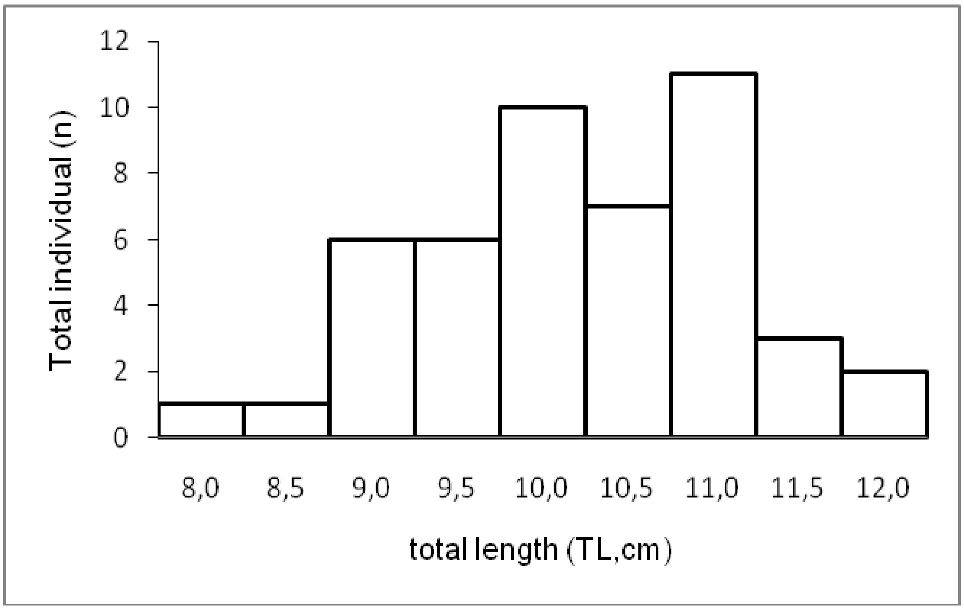



**Figure 4.14.** Frequency and the total length of ponyfish (*Leiognathus daura*)

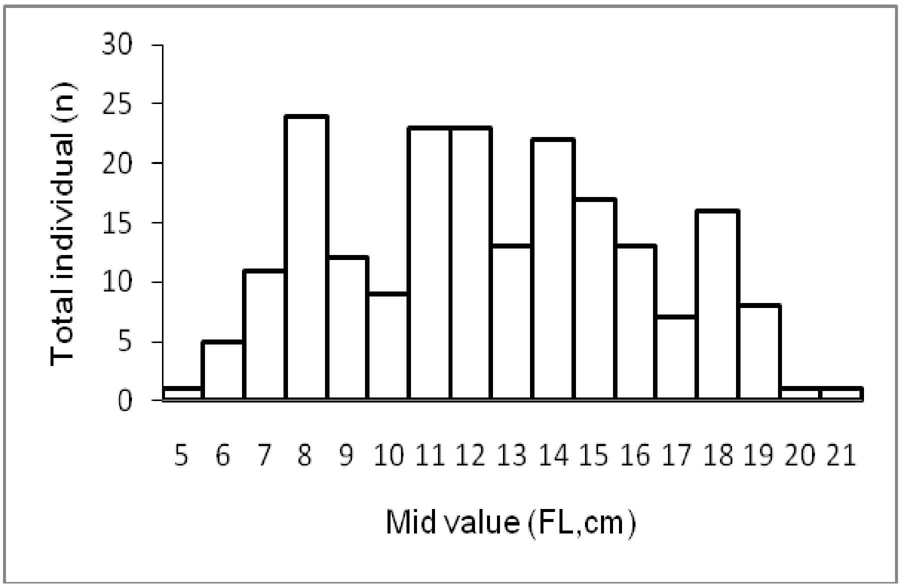



**Figure 4.15.** Frequency of the total length of threadfin breams (*Nemipetrus tolu*)

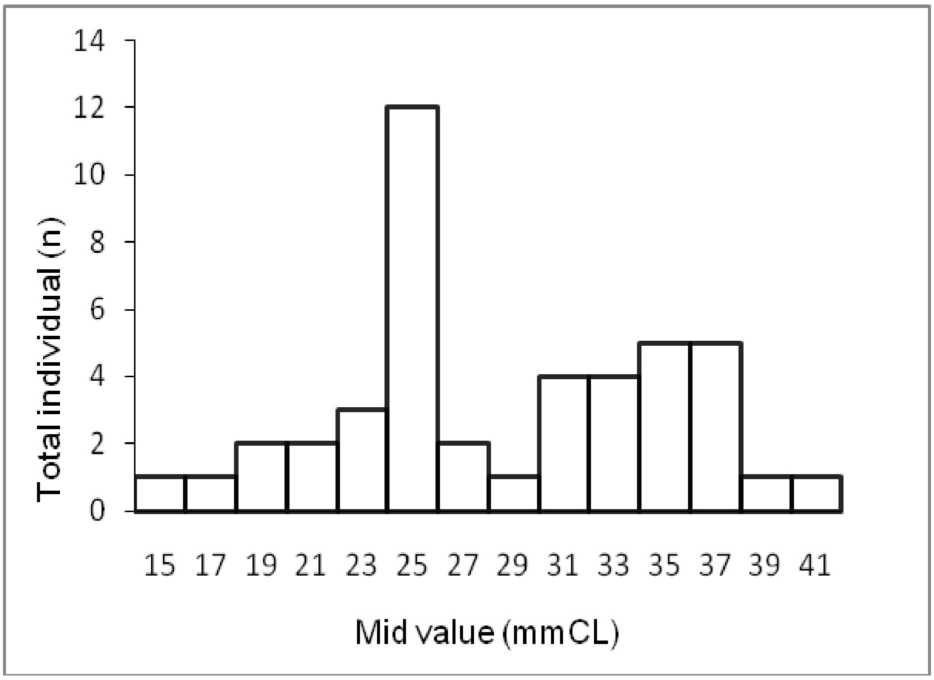



**Figure 4.16.** Frequency and carapace length (CL) of the Endeavour shrimp (*Metapenaeus ensis)*

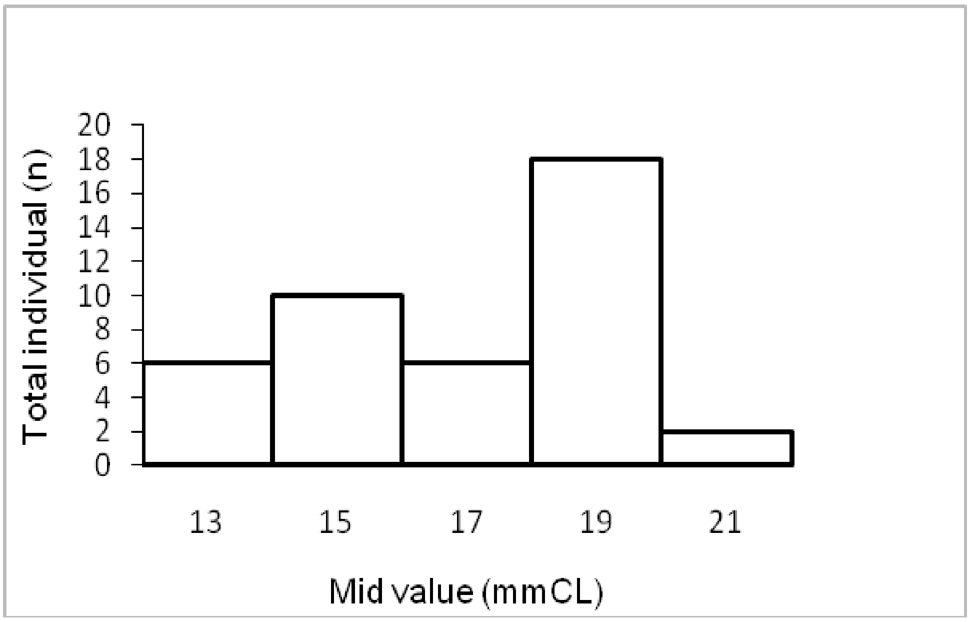



**Figure 4.17.** Frequency and carapace length of *krosok* shrimp (*Trachypenaeus fulvus*)

### 4.8.2. Arafura Sea

#### General condition of the waters

The Arafura Sea includes the Sahul shelf, which connects Papua and Australia at 5 to 60m, and consists of a coastal length of more than 1100 nmi (including Bintuni Bay). The average depth is less than 50 m, and within 12 miles (19.3 km) from the coastline, the area is regulated by local authorities, and the relatively shallow waters are affected by the orographic variation of the land. The sea floor is covered with mud and a small amount of sand, present in almost 70% of the water area. Mangrove forests, on the southwest coast of Papua, are a main contributer to primary production, and also function as a support zone for fish resources, especially shrimp.

The fishing area for shrimp in the Arafura Sea can be divided into three areas: the Bird Head area consisting of Sele waters, Bintuni Bay and Kaimana (sub-areas II and III); the Dolak area (sub-areas IV and V); and Aru (sub-area VI). According to Naamin (1984), the Arafura Sea area is 150,000 $km^2$ with an intensive commercial fishing area for shrimp and demersal fish of 73,500 $km^2$. Fishing activity for capturing shrimp is mainly done at depths of 10 to 50m.

A previous study aboard the *RV Baruna Jaya I* in 1992 indicated that 70,000$km^2$ of the Exclusive Economic Zone (EEZ) Arafura Sea, located between the south of Papua and the border of Australia, was used for demersal and shrimp fisheries. The waters are 30 – 250 m deep, and the eastern waters (south of Dolak) are shallower than the western waters of the Arafura Sea (Budihardjo *et al*., 1993).

#### Catch rate and stock density

Applied extensively, fish surveys with bottom trawls have been conducted to obtain the index of stock abundance for demersal fish. During the survey aboard the *RV Baruna Jaya VIII*, the lowest catch rate of 11.17kg/hr was observed at Station 11 to the south of Aru at 58 m depth; the highest catch rate was 193.14 kg/hr and was found at Station 3 in Dolak waters at 30 m. Summary of the catch rate is shown in Table 4.4 and catch rate distribution is shown in Figure 4.18.

**Table 4.4.** Summary of trawling catch rates in the Arafura Sea, May 2010

| Item | Quantity |
|---|---|
| Total catch stations | 10 |
| Minimum catch rate (kg/hr) | 11.19 |
| Maxsimum catch rate (kg/hr) | 193.14 |
| Average catch rate (kg/hr) | 125.75 |
| Standard deviation | 52.14 |
| Variation coeffisient (%) | 41.47 |

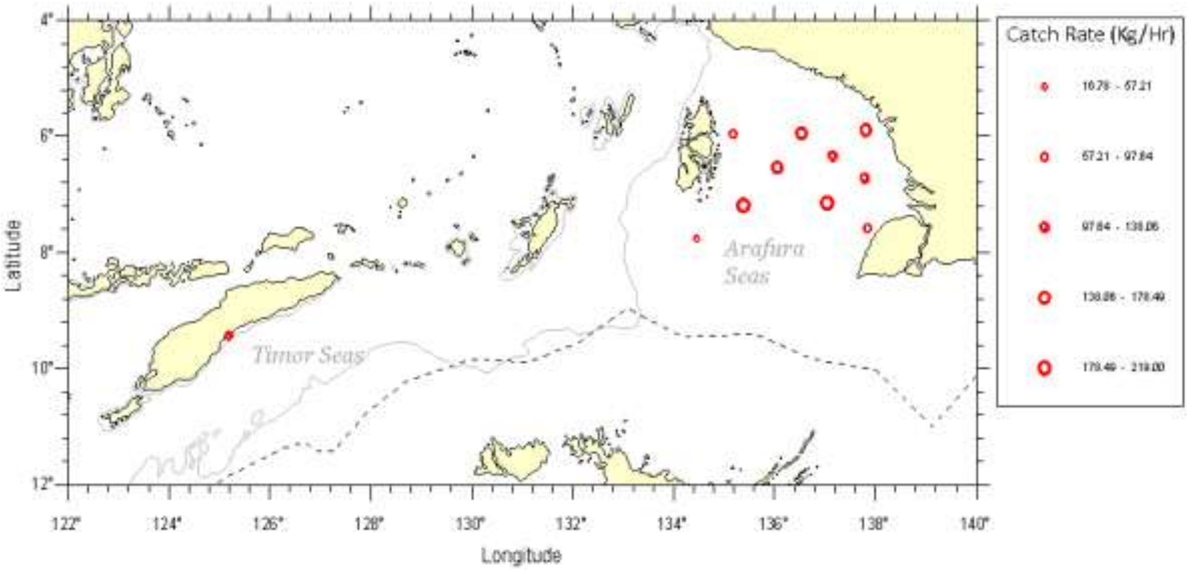



**Figure 4.18.** Distribution of trawl catch rates in the Timor and Arafura Seas, May 2010

A fishing survey in the Arafura Sea was conducted by using ten stations at depths of 18 to 60 m. The average catch rate during the survey was 125.8 kg/hr. Catch composition was dominated by demersal fish (87.91% of the total catch), followed by penaeid shrimp (4.19%). Other crustacea (lobster, squilla shrimp, swimming crab and non-edible crab) occurred at 3.13%, small pelagic fish at 3.07%, mollusca at 1.23% and others (gastropod and other avertebrata) at 0.48%.

Swept area analysis indicates that the average catch rate of the dominant catch in the Arafura Sea (demersal fishes) was 110.54 kg/hr, followed by penaeid shrimp at 5.27 kg/hr and other crustacea at 3.93 kg/hr. Considering the towing speed of 2.9 knots and towing time of on average one hour, the stock density of demersal fish is 1.8 ton/km$^2$, the stock density of penaeid shrimp is 0.09 ton/km$^2$ and the stock density of other crustacea is 0.06 ton/km$^2$. According to Naamin (1984) the trawlable area in the waters of Dolak and Aru are 80,000 km$^2$. Therefore, the biomass of demersal fish in the waters is estimated to be 144,000 ton, that of penaeid shrimp is 7,200 ton and other crustacea biomass is 4,800 ton. Composition of the catch rate and stock density is shown in Table 4.5.

**Table 4.5.** Average catch rate, stock density and biomass by fish groups in the Dolak and Aru sub-areas, May 2010.

| Fish group | Average catch rate (kg/hr) | Stock density (ton/km$^2$) | Biomass (ton) |
|---|---|---|---|
| Demersal fish | 110.54 | 1.80 | 144,000 |
| Penaeid shrimp | 5.27 | 0.09 | 7,200 |
| Other crustacea | 3.93 | 0.06 | 4,800 |
| Small pelagic | 3.86 | 0.05 | 4,800 |
| Others | 2.15 | 0.03 | 2,400 |
| **Total** | **125.75** | **2.00** | **160,000** |

## Catch composition

Referring to Gloefer-Tarp and Kailola (1985) and Nakabo (2000) for fish identification, 147 demersal fish species, 16 species of penaeid shrimp, 13 species of other crustacea (swimming crab, non edible crab, squilla, lobster), three species of squid and 21 species of small pelagics were catagorized. The dominant captured fish groups are shown in Table 4.6.

**Table 4.6.** Dominant demersal fish groups captured by trawl in the Arafura Sea, May 2010

| Family | Catch rate (kg/hour) | (%) |
|---|---|---|
| Dasyiatididae | 154.76 | 13.0 |
| Sciaenidae | 143.57 | 12.1 |
| Pomadasyidae | 114.94 | 9.7 |
| Mullidae | 90.79 | 7.6 |
| Harpadontidae | 61.73 | 5.2 |
| Platycephalidae | 59.98 | 5.1 |
| Teraponidae | 48.39 | 4.1 |
| Nemipteridae | 40.24 | 3.4 |
| Rhynchobatidae | 35.57 | 3.0 |
| Apogonidae | 34.18 | 2.9 |

Trawl catch was dominated by rays of Dasyatididae family, with the main species being *Dasyatis kuhlii* and *Urolophus* sp, followed by bearded croakers of Sciaenidae family and sweet lips of Pomadasydae family. Sciaenidae family consists of *Atrobucca nibe*, *Otolithes ruber* and *Johnius amblycephalus* as dominant fish, while Pomadasydae family is dominated by *Pomadasys maculatus* and *P. argyreus.*

The fourth dominant group was goat fish of the Mullidae family, followed by lizard fish of the Harpadontidae family and the Platycephalidae family. Goat fish were dominated mainly by *Upeneus sulphureus* and *U. bensasi*, lizard fish were dominated by *Saurida micropectoralis* and *S. undusquamis*, and the Platycephalidae by *Cociella crocodila* and *Suggrundus macracanthus*. The next dominant groups were *Terapon jarbua* of the Teraponidae family, threadfin breams of Nemipteridae, sharks of Rhynchobatidae and polka dot fish of Apogonidae. The main species of these groups are: *Terapon terap* and *Pelates* *quadrilineatus* of the Teraponidae, *Nemipterus hexodon* and *N. peronii* of the threadfin breams, *Rhynchobatus* sp. of the sharks, and *Apogon septemstriatus* and *A. poecilopterus* of the polka dot fish.

A small number of small pelagic fish from the Carangidae family, mostly *Decapterus macrosoma* and *Alepes djedaba*, were captured during the trawling. Furthermore, *Ilisha elongata* and *Sardinela gibbosa* of the Clupeidae family were also captured.

The penaeid shrimp group of the Penaeidae family was dominated by tiger shrimp (*Penaeus semisulcatus*), captured in Aru, Endeavour shrimp (*Metapenaeus ensis*, *M. endeavouri*) and other shrimps such as *Solenocera australiana*, *Trachypenaeus asper* and *T. fulvus*. However, white shrimp (*Penaeus merguiensis*) were only captured in small numbers. Other crustacea groups include the genera *Charybdis* and *Squilla*.

### Length of fish

Biological parameters, such as the length of fish and dominant fish captured, are shown in Table 4.7.

**Table 4.7.** Length of 10 dominant species in Arafura Sea, May 2010

| No. | Fish species | n | FL/TL | Min. Length (cm) | Max length (cm) |
|---|---|---|---|---|---|
| 1 | *Otolithes rubber* | 210 | TL | 7.5 | 41.4 |
| 2 | *Cociella crocodila* | 87 | TL | 11.0 | 29.5 |
| 3 | *Nemipterus hexodon* | 104 | TL | 9.0 | 24.5 |
| 4 | *Cynoglossus arel* | 89 | TL | 9.0 | 31.5 |
| 5 | *Polydactylus sextarius* | 15 | FL | 14.5 | 16.5 |
| 6 | *Dactyloptena macracanthus* | 39 | TL | 11.5 | 16.0 |
| 7 | *Pomadasys maculatus* | 91 | TL | 11.5 | 19.0 |
| 8 | *Johnius amblycephalus* | 137 | TL | 11.0 | 40.0 |
| 9 | *Atrobucca nibe* | 44 | TL | 21.5 | 27.5 |
| 10 | *Apogon septemstriatus* | 84 | TL | 6.5 | 11.5 |
| 11 | *Upeneus sulphureus* | 128 | TL | 9.5 | 18.0 |
| 12 | *Polynemus macracanthus* | 51 | TL | 14.5 | 19.5 |
| 13 | *Cynophrenes pentanomus* | 51 | FL | 16.5 | 19.5 |
| 14 | *Terapon terap* | 66 | FL | 11.5 | 20.5 |
| 15 | *Upeneus bensasi* | 34 | FL | 10.0 | 13.5 |
| 16 | *Saurida micropectoralis* | 94 | TL | 21.5 | 31.0 |
| 17 | *Saurida undusquamis* | 37 | TL | 12.0 | 22.5 |
| 18 | *Leiognathus equulus* | 16 | FL | 21.0 | 25.0 |
| 19 | *Pelatus quadrilineatus* | 27 | FL | 13.5 | 18.5 |
| 20 | *Silago sihama* | 18 | TL | 14.5 | 18.0 |
| 21 | *Ariomma indica* | 18 | FL | 18.0 | 22.0 |

## 4.9. Conclusion

### Timor Sea

(1) The trawlable area in the Timor Sea is relatively narrow, particularly to the south of Belu and Suai (Kovalima), with a seafloor consisting of muddy sand and coral debris.

(2) Catch rate composition of the trawl in Suai consists of demersal fish at 61.4 kg/hr (71.7% of total catch), followed by sea urchin at 20.8 kg/hr (23.3%), penaeid shrimp at 2.6 kg/hr (3.0%) and other crustacea (non edible crab) at 0.8 kg/hr.

(3) The ten dominant species of demersal fish were sweet lips (Pomadasydae family), threadfin breams (Nemipteridae), Triacanthidae, ponyfish (Leiognathidae), purple spotted fish (Priacanthidae), polka dot fish

(Apogonidae), bearded croakers (Sciaenidae), Mullidae, Platycephalidae and lizard fish (Harpadontidae).

## Arafura Sea

(1) The waters of Dolak and Aru are good trawling areas. The difference in seafloor sediment composition is the cause for the difference in dominant fish catch.

(2) The minimum total catch rate of 11.2 kg/hr was observed to the south of Aru at 58 m, and the highest catch rate of 193.1 kg/hr was found in the waters of Dolak at 30 m. Average catch rate was 125.8 kg/hr.

(3) Average catch rate of demersal fish was 110.5 kg/hr, followed by penaeid shrimp at 5.3 kg/hr and other crustacea of 3.9 kg/hr. Stock density of demersal fish was 1.8 ton/km$^2$, penaeid shrimp 0.1 ton/km$^2$ and other crustacea, 0.1 ton/km$^2$.

(4) The top ten dominant demersal fish species captured include:
rays (Dasyatididae), bearded croakers (Sciaenidae), sweet lips (pamadasydae), Mullidae, lizard fish (Harpadontidae), Platycephalidae, *Terapon jarbua* (Teraponidae), threadfin breams (Nemipetridae), sharks (Rhynchobatidae) and polka dot fish (Apogonidae).

## Appendix 4.1

# Operational aspect of trawling in the Timor and Arafura Seas, May 2010

| Stations | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 13/05/2010 | 18/05/2010 | 19/05/2010 | 19/05/2010 | 20/05/2010 | 20/05/2010 | 21/05/2010 | 21/05/2010 | 22/05/2010 | 22/05/2010 | 23/05/2010 |
| Area | | Timor Sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea | Arafura sea |
| Sub area | | Suai, T. Leste | Dolak | Dolak | Dolak | Kokonao | Kokonao | Aru | East Aru | East Aru | South east Aru | South Aru |
| Water depth (m) | Start | 25 | 18 | 30 | 30 | 35 | 37 | 47 | 50 | 35 | 38 | 58 |
| | Stop | 23 | 18.5 | 30.8 | 29.7 | 35 | 38 | 46 | 50 | 35 | 40 | 58.5 |
| Fishing time | Start | 1:30 | 17.22 | 4:26 | 14:50 | 2:25 | 12:50 | 3:15 | 18:10 | 5:00 | 17:00 | 4:45 |
| | Stop | 2:00 | 18:22 | 5:26 | 15:50 | 3:25 | 13:56 | 4:15 | 18:45 | 6:00 | 18:15 | 6:15 |
| Position start | Lat | 09° - 25.840' | 07° - 35.153' | 07° - 09°.834' | 06° - 45°.086' | 06° - 19.928' | 05° - 55.599' | 05 ° - 53.881' | 05 ° - 55.210' | 06 ° - 30.096' | 07 ° - 08.183' | 07 ° - 45.733' |
| | Long | 125° - 09.540' | 137° - 18.364' | 136° - 59.745' | 137° - 50.005' | 137° - 20.500' | 137° - 51.334' | 136 ° - 29.224' | 135 ° - 09.293' | 136 ° - 00.249' | 135 ° - 10.502' | 134 ° - 21.961' |
| Position stop | Lat | 09° - 25.716' | 07° - 34.686' | 07° - 08.841' | 06° - 43°.264' | 06° - 20.500' | 05° - 53.325' | 05 ° - 56.779' | 05 ° - 57.284' | 06 ° - 31.959' | 07 ° - 11.153' | 07 ° - 45.596' |
| | Long | 125° - 11.527' | 137° - 50.34' | 137° - 02.499' | 137° -47°.011' | 137° - 09°.039' | 137° - 48.267' | 136 ° - 31.997' | 135 ° - 10.642' | 136 ° -03.011 | 135 ° - 14.003' | 134 ° - 27.017' |
| Wire out (m) | | 150 | 125 | 200 | 210 | 250 | 275 | 350 | 400 | 275 | 300 | 400 |
| Towing dir (°) | | 85 | 76 | 74 | 305 | 97 | 330 | 140 | 152 | 125 | 46 | 95 |
| Speed (knot) | | 2.9 | 2.7 | 2.9 | 3 | 3 | 3 | 3 | 3 | 3 | 3,0 | 3 |
| Wind (dir) | | SEE | SEE | E | SEE | E | E | E | E | E | SE | SE |
| Sea condition | | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Bottom type | | Sand | Mud | Sand-mud | Mud | Mud | Sand | Sand | Sand | Sand | Sand | Sand |
| Catch (kg/hr) | | 42.84 | 66.98 | 193.14 | 127.66 | 127.49 | 144.08 | 144.09 | 126.80 | 140.97 | 175.14 | 11.19 |
| Remarks | | | | | | | | | | | Sponge | Sponge |

## Appendix 4.2.

# Trawl catch rate at Station 1 in the Timor Sea, May 2010

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Echinoidea | | 20.80 |
| | Holothuridae | *Holothuria* sp. | 1.02 |
| | Muricidae | *Murex pecten* | 0.40 |
| | Olividae | *Oliva* sp. | 0.20 |
| | Pectiniidae | *Amusium japonicum* | 1.40 |
| | Portunidae | *Charybdis feriatus* | 0.70 |
| | | *Padolpthalmus vigil* | 0.10 |
| | | *Portunus pelagicus* | 0.08 |
| **Demersal** | Apogonidae | *Apogon albimaculosus* | 0.10 |
| | | *Apogon poecilopterus* | 0.66 |
| | | *Apogon septemstriatus* | 0.50 |
| | | *Apogon* sp | 0.80 |
| | | *Arius venosus* | 1.00 |
| | Gerreidae | *Gerres filamentosus* | 0.08 |
| | | *Saurida micropectoralis* | 1.06 |
| | | *Saurida undosquamis* | 0.02 |
| | Lactaridae | *Lactarius lactarius* | 0.70 |
| | Leiognathidae | *Gazza minuta* | 0.06 |
| | | *Leiognathus bindus* | 0.02 |
| | | *Leiognathus daura* | 2.60 |
| | | *Leiognathus elongatus* | 0.20 |
| | | *Leiognathus equlus* | 0.20 |
| | | *Secutor insidiator* | 0.14 |
| | | *Lutjanus malabaricus* | 0.02 |
| | | *Upeneus sulphureus* | 0.70 |
| | | *Upeneus vittatus* | 1.00 |
| | | *Nemipterus japonicus* | 1.20 |
| | | *Nemipterus peroni* | 17.20 |
| | | *Pseudorhombus* sp. | 0.68 |
| | Pectiniidae | *Amusium japonicum* | 0.40 |
| | Platycephalidae | *Coeciella crocodila* | 0.80 |
| | | *Platycephalus indicus* | 0.54 |
| | | *Polydactylus microstoma* | 1.00 |
| | Pomadasyidae | *Pomadasys argyreus* | 14.44 |
| | | *Pomadasys kaakan* | 6.60 |
| | | *Priacanthus tayenus* | 3.40 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | | *Pennahia macrocephalus* | 1.78 |
| | | *Terapon jarbua* | 0.06 |
| | | *Terapon theraps* | 0.18 |
| | | *Triacanthus* sp. | 3.60 |
| | Uranoscopidae | *Uranoscopus cognatus* | 0.04 |
| | | *Stolephorus* sp. | 0.02 |
| | | *Metapenaeus ensis* | 1.40 |
| | | *Trachypenaeus asper* | 0.60 |
| | | *Trachypenaeus fulvus* | 0.60 |
| | Squillidae | *Squilla* sp | 0.30 |
| | | **TOTAL** | **89.40** |

## Appendix 4.3.

# Trawl catch rate at Station 2 in the Arafura Sea, May 2010

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Echinoidea | | 0.02 |
| | Holothuridae | *Holothuria* sp. | 1.70 |
| | Sea star | | 0.02 |
| **Crabs** | Calappidae | *Calappa philargius* | 0.10 |
| | Portunidae | *Charybdis natator* | 0.10 |
| **Demersal** | Ariidae | *Arius maculatus* | 7.25 |
| | Cynoglossidae | *Cynoglossus arel* | 1.00 |
| | Diodontidae | *Diodon histrix* | 1.80 |
| | Harpadontidae | *Harpadon nehereus* | 4.00 |
| | Platycephalidae | *Coeciella crocodila* | 3.40 |
| | Plotosidae | *Euristhmus nudicep* | 0.20 |
| | Polynemidae | *Polydactylus microstoma* | 2.30 |
| | Rhinoprenidae | *Rhinoprenes pentanemus* | 0.20 |
| | Scianidae | *Atrobucca nibe* | 1.20 |
| | | *Johnius amblycephalus* | 1.00 |
| | | *Otolithes ruber* | 19.50 |
| | Trichiuridae | *Trichiurus lepturus* | 0.40 |
| **Pelagic** | Carangidae | *Formio niger* | 0.50 |
| | Clupeidae | *Ophistopterus tardoore* | 0.70 |
| | Engraulididae | *Thryssa hamiltonii* | 0.21 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 15.40 |
| | | *Himantura uarnak* | 4.60 |
| | Rhinobatidae | *Rhinobatos* sp | 0.40 |
| **Shellfish** | Volutidae | *Melo amphora* | 0.05 |
| **Shrimp** | Penaeidae | *Atypopenaeus stenodactylus* | 0.10 |
| | | *Parapenaeopsis sculptilis* | 0.19 |
| | | *Penaeus merguiensis* | 0.02 |
| | | *Trachypenaeus asper* | 0.02 |
| | | *Trachypenaeus fulvus* | 0.10 |
| | Squillidae | *Squilla* sp | 0.50 |
| | | **TOTAL** | **66.98** |

**Appendix 4.4.**

# Trawl catch rate at Station 3 in the Arafura Sea

| Group | Family | *Species* | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Echinoidea | | 0.6 |
| | Holothuridae | *Holothuria* sp. | 0.6 |
| | Sepiidae | *Sepia* sp. | 1.32 |
| **Cephalopods** | Octopodidae | *Octopus* sp. | 0.12 |
| **Crabs** | Portunidae | *Charybdis* sp | 1.8 |
| **Demersal** | Apogonidae | *Apogon albimaculosus* | 0.04 |
| | | *Apogon poecilopterus* | 1.6 |
| | | *Apogon septemstriatus* | 4.84 |
| | Ariidae | *Arius maculatus* | 0.4 |
| | Batrachoidae | *Batrachomoeus occidentalis* | 0.2 |
| | Bothidae | *Arnoglossus dalgleishi* | 0.5 |
| | Cynoglossidae | *Cynoglossus arel* | 10.6 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 8.5 |
| | Diodontidae | *Diodon histrix* | 1.66 |
| | Harpadontidae | *Saurida micropectoralis* | 1.18 |
| | Labridae | *Choerodon vitta* | 0.2 |
| | Lactaridae | *Lactoria diaphana* | 0.24 |
| | Lethrinidae | *Lethrinus lentjam* | 1 |
| | Loliginidae | *Loligo edulis* | 0.08 |
| | Monacanthidae | *Aluterus monoceros* | 0.62 |
| | Mullidae | *Upeneus sulphureus* | 1.04 |
| | Muraenesocidae | *Oxyconger leptognathus* | 2.4 |
| | Nemipteridae | *Nemipterus hexodon* | 10.8 |
| | | *Scolopsis taeniopterus* | 0.2 |
| | Orectolobidae | *Orectolobus maculatus* | 0.6 |
| | Platycephalidae | *Coeciella crocodila* | 15.4 |
| | Plotosidae | *Euristhmus lepturus* | 2.88 |
| | Polynemidae | *Polydactylus nigripinnis* | 4 |
| | Pomadasyidae | *Pomadasys maculatus* | 27.8 |
| | Psettodidae | *Psettodes erumei* | 0.6 |
| | Rachycentridae | *Rachycentron canadus* | 0.6 |
| | Scianidae | *Atrobucca nibe* | 5.6 |
| | | *Johnius amblycephalus* | 5 |
| | | *Otolithes ruber* | 0.8 |
| | Scorpaenidae | *Pterois russelli* | 0.1 |
| | | *Synanceia* sp | 0.4 |
| | Serranidae | *Cephalopholis boenak* | 0.68 |

| Group | Family | Species | Catch Rate (Kg/hr) |
| --- | --- | --- | --- |
| | | *Epinephelus areolatus* | 0.56 |
| | Soleidae | *Aesopia cornuta* | 0.08 |
| | | *Zebrias guagga* | 0.16 |
| | Solenoceridae | *Solenocera australiana* | 0.6 |
| | Teraponidae | *Pelates quadrilineatus* | 0.36 |
| | Tetraodontidae | *Arothron immaculatus* | 0.12 |
| | Triacanthidae | *Triacanthus biaculetus* | 0.06 |
| | Triglidae | *Lepidotrigla grandis* | 0.42 |
| **Mantis shrimp** | Harpiosquilidae | *Harpiosquilla harpax* | 4.2 |
| | Squillidae | *Arctides regalis* | 0.16 |
| **Pelagic** | Clupeidae | *Pellona ditchela* | 0.1 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 69 |
| **Shrimp** | Penaeidae | *Metapenaeus ensis* | 0.18 |
| | | *Penaeus semisulcatus* | 0.52 |
| | | *Trachypenaeus asper* | 0.38 |
| | | *Trachypenaeus fulvus* | 0.02 |
| | Solenoceridae | *Solenocera australiana* | 1.22 |
| | | **TOTAL** | **193.14** |

## Appendix 4.5.

# Trawl catch rate at Station 4 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Cephalopoda** | Loliginidae | *Loligo edulis* | 0.2 |
| | Sepiidae | *Sepia* sp. | 2.8 |
| **Crabs** | Portunidae | *Charybdis feriatus* | 2.5 |
| | | *Charybdis natator* | 0.4 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 3.5 |
| | | *Apogon septemstriatus* | 1.0 |
| | Ariidae | *Arius maculatus* | 4.0 |
| | Ariommatidae | *Ariomma indica* | 0.4 |
| | Cynoglossidae | *Cynoglossus arel* | 6.9 |
| | Leiognathidae | *Leiognathus bindus* | 0.4 |
| | | *Leiognathus decorus* | 0.5 |
| | Monacanthidae | *Monacanthus* sp. | 0.2 |
| | Mullidae | *Upeneus sulphureus* | 0.9 |
| | Muraenesocidae | *Oxyconger leptognathus* | 0.6 |
| | Nemipteridae | *Nemipterus hexodon* | 0.5 |
| | Platycephalidae | *Coeciella crocodila* | 9.0 |
| | Plotosidae | *Plotosus caninus* | 0.1 |
| | Polynemidae | *Polydactilus sextarius* | 0.3 |
| | | *Polydactylus microstoma* | 4.5 |
| | | *Polydactylus nigripinnis* | 5.1 |
| | Pomadasyidae | *Pomadasys maculatus* | 2.2 |
| | Priacanthidae | *Priacanthus macracanthus* | 0.2 |
| | Psettodidae | *Psettodes erumei* | 3.0 |
| | Rhinoprenidae | *Rhinoprenes pentanemus* | 5.0 |
| | Scianidae | *Atrobucca nibe* | 4.9 |
| | | *Johnius amblycephalus* | 1.5 |
| | | *Otolithes ruber* | 8.3 |
| | Scorpaenidae | *Scorpaenopsis cirrosa* | 0.2 |
| | Soleidae | *Aesopia* sp | 0.2 |
| | Teraponidae | *Terapon theraps* | 1.0 |
| | Triacanthidae | *Triacanthus macracanthus* | 0.9 |
| **Mantis shrimp** | Harpiosquilidae | *Harpiosquilla harpax* | 2.5 |
| | Squillidae | *Squilla* sp | 9.1 |
| **Pelagic** | Carangidae | *Alepes djedaba* | 0.3 |
| | Clupeidae | *Ilisha elongate* | 5.6 |
| | Engraulididae | *Thryssa hamiltonii* | 2.3 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | | *Thryssa mystax* | 0.3 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 34.5 |
| **Gastropoda** | Volutidae | *Melo amphora* | 0.7 |
| **Shrimp** | Penaeidae | *Metapenaeus ensis* | 0.0 |
| | | *Parapenaeus* sp. | 0.2 |
| | | *Penaeus semisulcatus* | 0.1 |
| | | *Trachypenaeus asper* | 0.0 |
| | | *Trachypenaeus fulvus* | 0.0 |
| | Solenoceridae | *Solenocera australiana* | 0.8 |
| | | **TOTAL** | **127.7** |

## Appendix 4.6.

# Trawl catch rate at Station 5 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Sea star | | 0.31 |
| **Cephalopods** | Sepiidae | *Sepia* sp. | 0.19 |
| **Crabs** | Portunidae | *Charybdis feriatus* | 1.40 |
| | | *Charybdis natator* | 0.31 |
| | | *Charybdis* sp | 0.03 |
| | | *Portunus pelagicus* | 4.81 |
| **Demersal** | Apogonidae | *Apogon albimaculosus* | 0.08 |
| | | *Apogon poecilopterus* | 0.16 |
| | | *Apogon septemstriatus* | 3.61 |
| | Bothidae | *Arnoglossus dalgleishi* | 0.16 |
| | | *Pseudorhombus* sp. | 0.06 |
| | Carcharinidae | *Carcharhinus sealei* | 1.24 |
| | Cynoglossidae | *Cynoglossus arel* | 0.51 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 9.56 |
| | Diodontidae | *Diodon histrix* | 0.08 |
| | Harpadontidae | *Saurida micropectoralis* | 7.44 |
| | Labridae | *Choerodon vitta* | 0.16 |
| | Lagocephalidae | *Lagocephalus innermis* | 0.93 |
| | Leiognathidae | *Leiognathus bindus* | 0.08 |
| | | *Leiognathus decorus* | 0.29 |
| | | *Leiognathus equlus* | 0.05 |
| | | *Secutor ruconius* | 0.03 |
| | Monacanthidae | *Aluterus monoceros* | 0.74 |
| | | *Paramonacanthus japonicus* | 0.14 |
| | Mullidae | *Upeneus bensasi* | 0.78 |
| | | *Upeneus sulphureus* | 10.60 |
| | | *Upeneus tragula* | 0.08 |
| | Nemipteridae | *Nemipterus hexodon* | 3.10 |
| | | *Nemipterus mesoprion* | 0.47 |
| | | *Nemipterus nematophorus* | 0.36 |
| | Ostraciidae | *Lactoria diaphana* | 0.31 |
| | Platycephalidae | *Coeciella crocodila* | 5.89 |
| | | *Suggrundus macracantus* | 1.32 |
| | Plotosidae | *Plotosus lineatus* | 1.71 |
| | Polynemidae | *Polydactylus sextarius* | 0.47 |
| | Pomadasyidae | *Pomadasys argyreus* | 0.08 |
| | | *Pomadasys maculatus* | 4.42 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Psettodidae | *Psettodides erumei* | 2.17 |
| | Scianidae | *Atrobucca nibe* | 0.31 |
| | | *Otolithes ruber* | 12.40 |
| | Scorpaenidae | *Scorpaenopsis oxycephalus* | 0.31 |
| | Serranidae | *Epinephelus areolatus* | 2.33 |
| | | *Epinephelus* sp | 0.06 |
| | Siganidae | *Siganus canaliculatus* | 0.47 |
| | Squillidae | *Squilla* sp | 2.17 |
| | Teraponidae | *Pelates quadrilineatus* | 0.14 |
| | | *Terapon theraps* | 11.89 |
| | Triacanthidae | *Triacanthus nieuhofi* | 2.53 |
| | | *Triacanthus* sp. | 2.70 |
| | Trichiuridae | *Trichiurus lepturus* | 1.24 |
| | Triglidae | *Lepidotrigla grandis* | 0.78 |
| | Uranoscopidae | *Uranoscopus cognatus* | 0.12 |
| **Lobster** | Scyllaridae | *Thennus orientalis* | 0.23 |
| **Mantis shrimp** | Squillidae | *Harpiosquilla harpax* | 0.08 |
| | | *Squilla* sp | 1.55 |
| **Pelagic** | Carangidae | *Alepes djedaba* | 0.16 |
| | | *Carangoides malabaricus* | 0.76 |
| | Clupeidae | *Ilisha elongata* | 1.24 |
| | | *Sardinella gibbosa* | 6.22 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 7.21 |
| | Gymnuridae | *Gymnuria australis* | 1.40 |
| **Sharks** | Carcharinidae | *Carcharhinus sealei* | 1.71 |
| **Shrimp** | Penaeidae | *Metapenaeus ensis* | 1.07 |
| | | *Penaeus longistylus* | 0.39 |
| | | *Penaeus semisulcatus* | 2.87 |
| | | *Solenocera australiana* | 0.05 |
| | | *Trachipenaeus asper* | 0.14 |
| | | *Trachipenaeus fulvus* | 0.70 |
| | Solenoceridae | *Solenocera australiana* | 0.23 |
| | | **TOTAL** | **127.49** |

## Appendix 4.7.

# Trawl catch rate at Station 6 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Cephalopods** | Sepiidae | *Sepia* sp. | 0.55 |
| **Crabs** | Penaeidae | *Parapenaeus* sp | 0.14 |
| | | *Solenocera australiana* | 0.09 |
| | Portunidae | *Charybdis feriatus* | 5.01 |
| | | *Charybdis* sp | 0.55 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 2.73 |
| | | *Apogon septemstriatus* | 1.27 |
| | Ariidae | *Arius maculatus* | 3.55 |
| | Ariommatidae | *Ariomma indica* | 0.27 |
| | Cynoglossidae | *Cynoglossus arel* | 2.00 |
| | Ephippididae | *Drepane punctata* | 5.27 |
| | Harpadontidae | *Harpadon nehereus* | 4.64 |
| | | *Saurida micropectoralis* | 0.45 |
| | Leiognathidae | *Leiognathus decorus* | 0.02 |
| | | *Secutor ruconius* | 0.01 |
| | Lutjanidae | *Lutjanus areolatus* | 0.05 |
| | | *Lutjanus johni* | 1.91 |
| | | *Lutjanus malabaricus* | 0.36 |
| | Mugillidae | *Mugil cephalus* | 0.14 |
| | Mullidae | *Upeneus sulphureus* | 9.64 |
| | Muraenesocidae | *Oxyconger leptognathus* | 1.45 |
| | Platycephalidae | *Coeciella crocodila* | 2.36 |
| | Polynemidae | *Polydactylus microstoma* | 0.73 |
| | | *Polydactylus nigripinnis* | 0.09 |
| | | *Polydactylus sextarius* | 0.45 |
| | Pomadasyidae | *Pomadasys argyreus* | 0.23 |
| | | *Pomadasys maculatus* | 0.14 |
| | Psettodidae | *Psettodes erumei* | 0.91 |
| | Rhinoprenidae | *Rhinoprenes pentanemus* | 0.82 |
| | Rhynchobatidae | *Rhynchobatus* sp | 18.86 |
| | Scianidae | *Johnius amblycephalus* | 5.64 |
| | | *Johnius macropterus* | 0.45 |
| | | *Otolithes ruber* | 27.91 |
| | Scorpaenidae | *Scorpaenopsis neglecta* | 0.01 |
| | Serranidae | *Epinephelus areolatus* | 0.73 |
| | | *Epinephelus tauvina* | 10.00 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Teraponidae | *Terapon theraps* | 4.09 |
| | Trichiuridae | *Trichiurus lepturus* | 0.91 |
| **Mantis shrimp** | Squillidae | *Squilla* sp | 4.36 |
| **Pelagic** | Clupeidae | *Hilsa kelee* | 0.27 |
| | | *Ilisha elongata* | 0.18 |
| | | *Sardinella fimbriata* | 0.09 |
| | Engraulididae | *Thryssa hamiltonii* | 0.18 |
| | | *Thryssa mystax* | 0.45 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 9.82 |
| | | *Hymantura uarnak* | 1.64 |
| | Gymnuridae | *Gymnuria australis* | 2.64 |
| **Sharks** | Carcharinidae | *Carcharhinus sealei* | 7.18 |
| **Shrimp** | Penaeidae | *Metapenaeus ensis* | 0.13 |
| | | *Penaeus monodon* | 0.36 |
| | | *Penaeus semisulcatus* | 0.18 |
| | | *Trachipenaeus asper* | 0.09 |
| | | *Trachipenaeus fulvus* | 0.09 |
| | Solenoceridae | *Solenocera australiana* | 2.00 |
| | | **TOTAL** | **144.09** |

## Appendix 4.8.

# Trawl catch rate at Station 7 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Echinoidea | | 0.2 |
| | Holothuridae | *Holothuria* sp. | 0.6 |
| | Sea star | *Sea star* | 0.3 |
| **Cephalopods** | Loliginidae | *Loligo edulis* | 0.05 |
| | Octopodidae | *Octopus* sp. | 0.25 |
| | Sepiidae | *Sepia sp.* | 1.3 |
| **Crabs** | Portunidae | *Charybdis* sp | 3 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 1.1 |
| | | *Apogon septemstriatus* | 1.7 |
| | Ariidae | *Arius maculatus* | 0.15 |
| | Ariommatidae | *Arioma indica* | 0.3 |
| | Bothidae | *Arnoglossus dalgleishi* | 0.32 |
| | | *Crosorhombus azureus* | 0.2 |
| | Cynoglossidae | *Cynoglossus arel* | 0.12 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 0.2 |
| | Gerreidae | *Pentaprion longimanus* | 2.2 |
| | Haemulidae | *Diagramma pictum* | 6 |
| | Harpadontidae | *Nemipterus hexodon* | 3 |
| | | *Saurida micropectoralis* | 16.8 |
| | | *Saurida undosquamis* | 3.4 |
| | Leiognathidae | *Leiognathus bindus* | 0.16 |
| | | *Leiognathus decorus* | 0.55 |
| | | *Leiognathus elongatus* | 0.5 |
| | | *Leiognathus equlus* | 0.15 |
| | Lethrinidae | *Lethrinus lentjam* | 4.3 |
| | Lutjanidae | *Lutjanus malabaricus* | 6.1 |
| | Menidae | *Mene maculata* | 0.2 |
| | Monacanthidae | *Monacanthus* sp. | 0.15 |
| | | *Paramonacanthus japonicus* | 0.45 |
| | Mullidae | *Upeneus bensasi* | 2.4 |
| | | *Upeneus sulphureus* | 18.5 |
| | Muraenesocidae | *Oxyconger leptognathus* | 0.6 |
| | Nemipteridae | *Nemipterus hexodon* | 2.75 |
| | | *Nemipterus mesoprion* | 0.2 |
| | Ophidiidae | *Sirembo imberbis* | 0.45 |
| | Paralichthyidae | *Pseudorhombus argus* | 0.7 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | | *Pseudorhombus diplospilus* | 0.3 |
| | Platycephalidae | *Coeciella crocodila* | 4.2 |
| | | *Elates ransonneti* | 0.1 |
| | | *Onigocia pedimacula* | 0.65 |
| | | *Suggrundus macracantus* | 2.3 |
| | Plotosidae | *Euristhmus nudiceps* | 3.5 |
| | Polynemidae | *Polydactylus nigripinnis* | 0.15 |
| | Scianidae | *Atrobucca nibe* | 17.5 |
| | Squillidae | *Squilla* sp | 2.4 |
| | Synodontidae | *Synodus indicus* | 0.1 |
| | Teraponidae | *Terapon theraps* | 0.6 |
| | Tetraodontidae | *Arothron immaculatus* | 0.4 |
| | Triacanthidae | *Triacanthus nieuhofi* | 0.01 |
| | Trichiuridae | *Trichiurus lepturus* | 0.5 |
| | Triglidae | *Lepidotrigla grandis* | 4.5 |
| **Gastropoda** | Facidae | *Ficus* sp | 0.4 |
| **Pelagic** | Carangidae | *Carangoides malabaricus* | 0.35 |
| | Clupeidae | *Ilisha elongata* | 0.3 |
| | Engraulididae | *Ilisha elongata* | 0.1 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 0.25 |
| | Gymnuridae | *Gymnuria australis* | 4.9 |
| **Sharks** | Carcharinidae | *Carcharhinus sealei* | 2.5 |
| **Shellfish** | Pectiniidae | *Amusium japonicum* | 2.65 |
| **Shrimp** | Penaeidae | *Metapenaeus endevouri* | 0.05 |
| | | *Metapenaeus ensis* | 0.5 |
| | | *Penaeus longistylus* | 0.05 |
| | | *Penaeus semisulcatus* | 2.8 |
| | Solenoceridae | *Solenocera australiana* | 0.03 |
| | Penaeidae | *Trachypenaeus asper* | 0.65 |
| | | *Trachypenaeus fulvus* | 0.61 |
| | | **TOTAL** | **132.7** |

## Appendix 4.9.

# Trawl catch rate at Station 8 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Sea star | | 0.67 |
| **Cephalopods** | Loliginidae | *Loligo edulis* | 0.13 |
| | Sepiidae | *Sepia* sp. | 1.36 |
| **Crabs** | Calappidae | *Calappa* sp | 0.03 |
| | Portunidae | *Charybdis feriatus* | 0.40 |
| | | *Charybdis* sp | 4.67 |
| | | *Portunus pelagicus* | 0.60 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 1.07 |
| | | *Apogon septemstriatus* | 5.33 |
| | Ariommatidae | *Arioma indica* | 0.93 |
| | Bothidae | *Arnoglossus dalgleishi* | 0.15 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 0.20 |
| | Gerreidae | *Gerres filamentosus* | 0.07 |
| | | *Pentaprion longimanus* | 0.03 |
| | Harpadontidae | *Saurida micropectoralis* | 6.00 |
| | | *Saurida undosquamis* | 2.67 |
| | Labridae | *Choerodon vitta* | 0.40 |
| | Lagocephalidae | *Lagocephalus innermis* | 0.13 |
| | Leiognathidae | *Gazza minuta* | 0.19 |
| | | *Leiognathus bindus* | 0.20 |
| | | *Leiognathus decorus* | 0.04 |
| | | *Leiognathus elongatus* | 1.87 |
| | | *Leiognathus equlus* | 0.04 |
| | | *Secutor insidiator* | 0.07 |
| | Lutjanidae | *Lutjanus fulviflammus* | 0.67 |
| | Monacanthidae | *Aluterus monoceros* | 0.19 |
| | Mullidae | *Upeneus sulphureus* | 3.33 |
| | Muraenesocidae | *Oxyconger leptognathus* | 1.33 |
| | Nemipteridae | *Nemipterus hexodon* | 6.13 |
| | | *Scolopsis taeniopterus* | 0.13 |
| | Ophidiidae | *Sirembo imberbis* | 0.27 |
| | Paralichthyidae | *Cynoglossus arel* | 0.27 |
| | | *Pseudorhombus argus* | 1.87 |
| | | *Pseudorhombus elevatus* | 2.00 |
| | Platycephalidae | *Coeciella crocodila* | 6.67 |
| | | *Elates ransonneti* | 0.13 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Plotosidae | *Euristhmus nudiceps* | 0.40 |
| | Pomadasyidae | *Pomadasys argyreus* | 0.13 |
| | Psettodidae | *Psettodides erumei* | 6.40 |
| | Scianidae | *Atrobucca nibe* | 1.53 |
| | Serranidae | *Epinephelus areolatus* | 0.20 |
| | Soleidae | *Aesopia cornuta* | 0.27 |
| | Teraponidae | *Terapon theraps* | 0.80 |
| | Triacanthidae | *Triacanthus macracanthus* | 0.27 |
| | | *Triacanthus* sp. | 0.53 |
| | Trichiuridae | *Trichiurus lepturus* | 0.13 |
| | Triglidae | *Lepidotrigla grandis* | 3.07 |
| | Uranoscopidae | *Uranoscopus cognatus* | 0.91 |
| **Eels** | Congridae | *Oxyconger* sp | 0.13 |
| **Mantis shrimp** | Squillidae | *Squilla* sp | 0.40 |
| **Pelagic** | Carangidae | *Atule mate* | 0.13 |
| | | *Carangoides malabaricus* | 0.13 |
| | | *Carangoides* sp | 0.67 |
| | | *Decapterus macrosoma* | 0.27 |
| | Clupeidae | *Ilisha elongata* | 2.13 |
| | | *Sardinella fimbriata* | 0.11 |
| **Rays** | Dasyiatididae | *Dasyiatis kuhlii* | 2.93 |
| | Rajidae | *Raja* sp. | 3.80 |
| **Shellfish** | Pectiniidae | *Amusium japonicum* | 1.33 |
| **Shrimp** | Penaeidae | *Metapenaeus endevouri* | 1.47 |
| | | *Metapenaeus ensis* | 4.40 |
| | | *Penaeus longistylus* | 0.13 |
| | | *Penaeus semisulcatus* | 4.67 |
| | Solenoceridae | *Solenocera australiana* | 0.80 |
| | Penaeidae | *Trachypenaeus asper* | 2.93 |
| | | *Trachypenaeus fulvus* | 6.00 |
| | | *Trachypenaeus fulvus* | 1.60 |
| | | **TOTAL** | **98.89** |

## Appendix 4.10.

# Trawl catch rate at Station 9 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Cephalopods** | Loliginidae | *Loligo edulis* | 0.1 |
| | Sepiidae | *Sepia* sp. | 4.7 |
| **Crabs** | Portunidae | *Charybdis feriatus* | 0.4 |
| | | *Charybdis* sp | 4.5 |
| | | *Portunus pelagicus* | 0.3 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 1.3 |
| | | *Apogon septemstriatus* | 1.7 |
| | Ariommatidae | *Arioma indica* | 0.3 |
| | Bothidae | *Arnoglossus dalgleishi* | 1.2 |
| | Cynoglossidae | *Cynoglossus arel* | 2.2 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 2.5 |
| | Gerreidae | *Gerres kapas* | 0.8 |
| | Haemulidae | *Diagramma pictum* | 4.2 |
| | Harpadontidae | *Saurida micropectoralis* | 2.5 |
| | | *Saurida undosquamis* | 0.4 |
| | Lagocephalidae | *Lagocephalus innermis* | 0.6 |
| | Leiognathidae | *Leiognathus bindus* | 0.5 |
| | | *Leiognathus elongatus* | 1 |
| | | *Leiognathus equlus* | 4.6 |
| | | *Secutor ruconius* | 0.02 |
| | Lutjanidae | *Lutjanus fulviflammus* | 0.3 |
| | Monacanthidae | *Paramonacanthus japonicus* | 0.9 |
| | Mullidae | *Upeneus sulphureus* | 23.1 |
| | Muraenesocidae | *Oxyconger leptognathus* | 0.7 |
| | Nemipteridae | *Nemipterus hexodon* | 5.86 |
| | Paralichthyidae | *Pseudorhombus argus* | 0.15 |
| | | *Pseudorhombus arsius* | 0.1 |
| | | *Psudorhombus malayanus* | 0.1 |
| | Platycephalidae | *Coeciella crocodila* | 2.5 |
| | | *Elates ransonneti* | 2.1 |
| | Plotosidae | *Euristhmus nudiceps* | 1.7 |
| | Polynemidae | *Polydactylus nigripinnis* | 0.1 |
| | Psettodidae | *Psettodes erumei* | 12 |
| | Scianidae | *Atrobucca nibe* | 0.3 |
| | Scorpaenidae | *Minous trachycephalus* | 0.3 |
| | Serranidae | *Epinephelus areolatus* | 1.1 |
| | Siganidae | *Siganus canaliculatus* | 0.1 |
| | Soleidae | *Aesopia cornuta* | 0.2 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Teraponidae | *Pelates quadrilineatus* | 0.34 |
| | | *Terapon theraps* | 9.9 |
| | Trichiuridae | *Trichiurus lepturus* | 1.1 |
| | Triglidae | *Lepidotrigla grandis* | 3.1 |
| | Uranoscopidae | *Uranoscopus cognatus* | 1.2 |
| | Urolophidae | *Urolophus* sp | 16 |
| **Eels** | Muraenesocidae | *Muraenosox bagio* | 13 |
| **Mantis shrimp** | Squillidae | *Squilla* sp | 5.1 |
| **Pelagic** | Carangidae | *Alepes djedaba* | 0.1 |
| | | *Atule mate* | 0.35 |
| | | *Carangoides malabaricus* | |
| | Clupeidae | *Amblygaster sirm* | 0.2 |
| | | *Ilisha elongata* | 0.3 |
| | | *Ilisha* sp | 2.5 |
| **Sharks** | Carcharinidae | *Carcharhinus sealei* | 0.5 |
| **Shellfish** | Pectiniidae | *Amusium japonicum* | 0.1 |
| **Shrimp** | Penaeidae | *Metapenaeus endeavouri* | 0.1 |
| | | *Metapenaeus ensis* | 0.1 |
| | | *Penaeus semisulcatus* | 1 |
| | Solenoceridae | *Solenocera australiana* | 0.3 |
| | Penaeidae | *Trachypenaeus asper* | 0.15 |
| | | *Trachypenaeus fulvus* | 0.1 |
| | | **TOTAL** | **140.97** |

## Appendix 4.11.

# Trawl catch rate at Station 10 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Echinoidea | | 0.62 |
| | Sea star | | 0.21 |
| **Cephalopods** | Loliginidae | *Loligo edulis* | 0.42 |
| | Sepiidae | *Sepia* sp. | 0.62 |
| **Crabs** | Calappidae | *Calappa* sp | 0.83 |
| | Portunidae | *Charybdis feriatus* | 0.83 |
| | | *Charybdis* sp | 0.42 |
| | | *Matuta victor* | 0.83 |
| | | *Portunus pelagicus* | 4.37 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 1.14 |
| | Ariommatidae | *Ariomma indica* | 4.37 |
| | Bothidae | *Arnoglossus dalgleishi* | 1.35 |
| | Centricidae | *Centriscus scutatus* | 2.50 |
| | Chaetodontidae | *Chaetodon* sp | 0.21 |
| | Cynoglossidae | *Cynoglossus arel* | 0.42 |
| | Dactylopteridae | *Dactyloptena grandis* | 1.66 |
| | | *Dactyloptena macracanthus* | 0.62 |
| | Gerreidae | *Gerres kapas* | 2.08 |
| | | *Pentaprion longimanus* | 0.94 |
| | Haemulidae | *Diagramma pictum* | 2.50 |
| | Harpadontidae | *Saurida micropectoralis* | 0.21 |
| | | *Saurida undosquamis* | 6.24 |
| | Labridae | *Chaerodon vitta* | 0.46 |
| | Lagocephalidae | *Lagocephalus innermis* | 1.35 |
| | Leiognathidae | *Leiognathus bindus* | 0.83 |
| | | *Leiognathus elongatus* | 2.70 |
| | Lutjanidae | *Lutjanus fulviflammus* | 5.49 |
| | | *Lutjanus vitta* | 0.83 |
| | Mullidae | *Upeneus bensasi* | 1.02 |
| | | *Upeneus sulphureus* | 8.11 |
| | | *Upeneus tragula* | 1.46 |
| | Nemipteridae | *Nemipterus hexodon* | 1.87 |
| | | *Nemipterus mesoprion* | 2.29 |
| | | *Nemipterus peronii* | 2.29 |
| | | *Pentapodus porosus* | 0.21 |
| | | *Scolopsis taeniopterus* | 1.46 |
| | Ophichthididae | *Ophictus urolopus* | 0.21 |
| | Ostraciidae | *Rhynchostracion nasus* | 0.12 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Paralichthyidae | *Pseudorhombus diplospilus* | 0.42 |
| | Platycephalidae | *Coeciella crocodila* | 3.54 |
| | Plotosidae | *Euristhmus nudiceps* | 0.83 |
| | Pomadasyidae | *Pomadasys maculatus* | 79.66 |
| | Priacanthidae | *Priacanthus tayenus* | 0.35 |
| | Psettodidae | *Psettodes erumei* | 0.06 |
| | Scaridae | *Scarus* sp. | 0.62 |
| | Scorpaenidae | *Tetraroge leucogatser* | 0.42 |
| | Serranidae | *Epinephelus areolatus* | 1.35 |
| | Siganidae | *Siganus canaliculatus* | 0.21 |
| | Silaginidae | *Silago sihama* | 1.66 |
| | Soleidae | *Aesopia cornuta* | 0.21 |
| | Synodontidae | *Synodus indicus* | 0.42 |
| | Teraponidae | *Pelates quadrilineatus* | 3.95 |
| | | *Terapon theraps* | 11.23 |
| | Triacanthidae | *Triacanthus nieuhofi* | 0.21 |
| | Trichiuridae | *Trichiurus lepturus* | 13.31 |
| | Uranoscopidae | *Uranoscopus cognatus* | 0.08 |
| **Lobster** | Scyllaridae | *Thennus orientalis* | 0.15 |
| **Mantis shrimp** | Squillidae | *Squilla* sp | 0.62 |
| **Pelagic** | Carangidae | *Alepes djedaba* | 1.87 |
| | | *Atule mate* | 0.62 |
| | | *Decapterus macrosoma* | 4.16 |
| | | *Decapterus russelli* | 0.21 |
| | Clupeidae | *Herklotsichthys koningsbergi* | 0.42 |
| | | *Sardinella fimbriata* | 0.10 |
| | Engraulididae | *Ilisha elongata* | 0.94 |
| | Scombridae | *Rastrelliger kanagurta* | 0.42 |
| **Rays** | Urolophidae | *Urolophus* sp | 17.47 |
| **Sharks** | Carcharinidae | *Carcharhinus sealei* | 4.16 |
| **Shrimp** | Penaeidae | *Metapenaeus endeavouri* | 0.08 |
| | | *Penaeus longistylus* | 0.08 |
| | | *Penaeus semisulcatus* | 4.99 |
| | | **TOTAL** | **218.92** |

**Appendix 4.12.**

## Trawl catch rate at Station 11 in the Arafura Sea

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| **Avertebrata** | Holothuridae | *Holothuria* sp. | 1.20 |
| | Sea star | *Sea star* | 0.20 |
| **Cephalopods** | Loliginidae | *Loligo edulis* | 0.40 |
| | Octopodidae | *Octopus* sp. | 0.07 |
| | Sepiidae | *Sepia* sp. | 0.47 |
| **Crabs** | Majidae | *Schizophryes dama* | 0.03 |
| | Portunidae | *Charybdis* sp | 0.13 |
| | | *Matuta victor* | 0.03 |
| **Demersal** | Apogonidae | *Apogon poecilopterus* | 0.04 |
| | | *Apogon septemstriatus* | 0.03 |
| | Bothidae | *Arnoglossus dalgleishi* | 0.13 |
| | Caesionidae | *Plerochaesio chrysazona* | 0.47 |
| | Cynoglossidae | *Cynoglossus arel* | 0.01 |
| | Dactylopteridae | *Dactyloptena macracanthus* | 0.07 |
| | | *Dactyloptena papilio* | 0.27 |
| | Gerreidae | *Pentaprion longimanus* | 0.07 |
| | Haemulidae | *Diagramma pictum* | 0.13 |
| | Harpadontidae | *Saurida undosquamis* | 0.47 |
| | Labridae | *Choerodon monostigma* | 0.03 |
| | | *Choerodon vitta* | 0.05 |
| | Lagocephalidae | *Lagocephalus innermis* | 0.03 |
| | Leiognathidae | *Leiognathus elongatus* | 0.02 |
| | Lutjanidae | *Lutjanus sebae* | 0.07 |
| | Monacanthidae | *Monacanthus* sp. | 0.03 |
| | Mullidae | *Parupeneus chrysopleuron* | 0.60 |
| | | *Upeneus bensasi* | 0.53 |
| | | *Upeneus moluccensis* | 1.00 |
| | Nemipteridae | *Nemipterus marginatus* | 3.20 |
| | Ostraciidae | *Rhynchostracion nasus* | 0.40 |
| | Paralichthyidae | *Pseudorhombus diplospilus* | 0.17 |
| | | *Pseudorhombus malayanus* | 0.01 |
| | Platycephalidae | *Coeciella crocodila* | 0.03 |
| | Priacanthidae | *Priacanthus macracanthus* | 0.27 |
| | Psettodidae | *Psettodes erumei* | 0.20 |
| | Scorpaenidae | *Minous trachycephalus* | 0.01 |
| | | *Pterois russelli* | 0.08 |

| Group | Family | Species | Catch Rate (Kg/hr) |
|---|---|---|---|
| | Serranidae | *Epinephelus areolatus* | 0.01 |
| | Synodontidae | *Trachynocephalus myops* | 1.27 |
| | Teraponidae | *Terapon theraps* | 0.67 |
| | Triacanthidae | *Triacanthus nieuhofi* | 0.20 |
| **Eels** | Muraenidae | *Gymnothorax* sp | 0.07 |
| | Nettastomatidae | *Surenchelys* sp | 0.01 |
| **Lobster** | Scyllaridae | *Thennus orientalis* | 0.40 |
| **Mantis shrimp** | Harpiosquilidae | *Harpiosquilla harpax* | 0.20 |
| | Squillidae | *Squilla* sp | 0.13 |
| **Pelagic** | Carangidae | *Atule mate* | 0.03 |
| | | *Decapterus macrosoma* | 1.67 |
| **Rays** | Gymnuridae | *Gymnuria australis* | 0.27 |
| **Shellfish** | Pectiniidae | *Amusium japonicum* | 0.33 |
| | | *Volachlamys* sp | 0.01 |
| **Shrimp** | Penaeidae | *Metapenaeus endeavouri* | 0.01 |
| | | *Penaeus longistylus* | 0.03 |
| | | *Trachypenaeus asper* | 0.27 |
| | | *Trachypenaeus fulvus* | 0.20 |
| | Solenoceridae | *Solenocera subnuda* | 0.07 |
| | | **TOTAL** | **16.78** |

**Appendix 4.13**

## Dominant fish species in total individual catch in the Arafura Sea

## Appendix 4.14

# Demersal fish species dominating the catch in the Arafura Sea





**Appendix 4.15.**

## Dominant species captured in Suai, Kovalima District, Timor Leste


Pomadasys argyreus (POMADASYIDAE)


Upeneus sulphureus (MULLIDAE)


Apogon septemstriatus (APOGONIDAE)


Apogon poecilopterus (APOGONIDAE)


Leiognathus daura (LEIOGNATHIDAE)


Priacanthus tayenus (PRIACANTHIDAE)


Pennahia macrocephalus (SCIAENIDAE)


Upeneus vittatus (MULLIDAE)


Saurida micropectoralis (HARPADONTIDAE)


Saurida undosquamis (HARPADONTIDAE)


Cociella crocodila (PLATYCEPHALIDAE)

**Appendix 4.16.**

# Dominant shrimp species captured in the Arafura Sea

*Parapenaeus sculptylis*

*Solenosera australis*

*Atypopenaeus stenodactylus*

*Penaeus monodon*

*Penaus semisulcatus*

*Penaeus longistylus*

*Metapenaeus ensis*

*Trachypenaeus vulfus*

*Trachypenaeus asper*

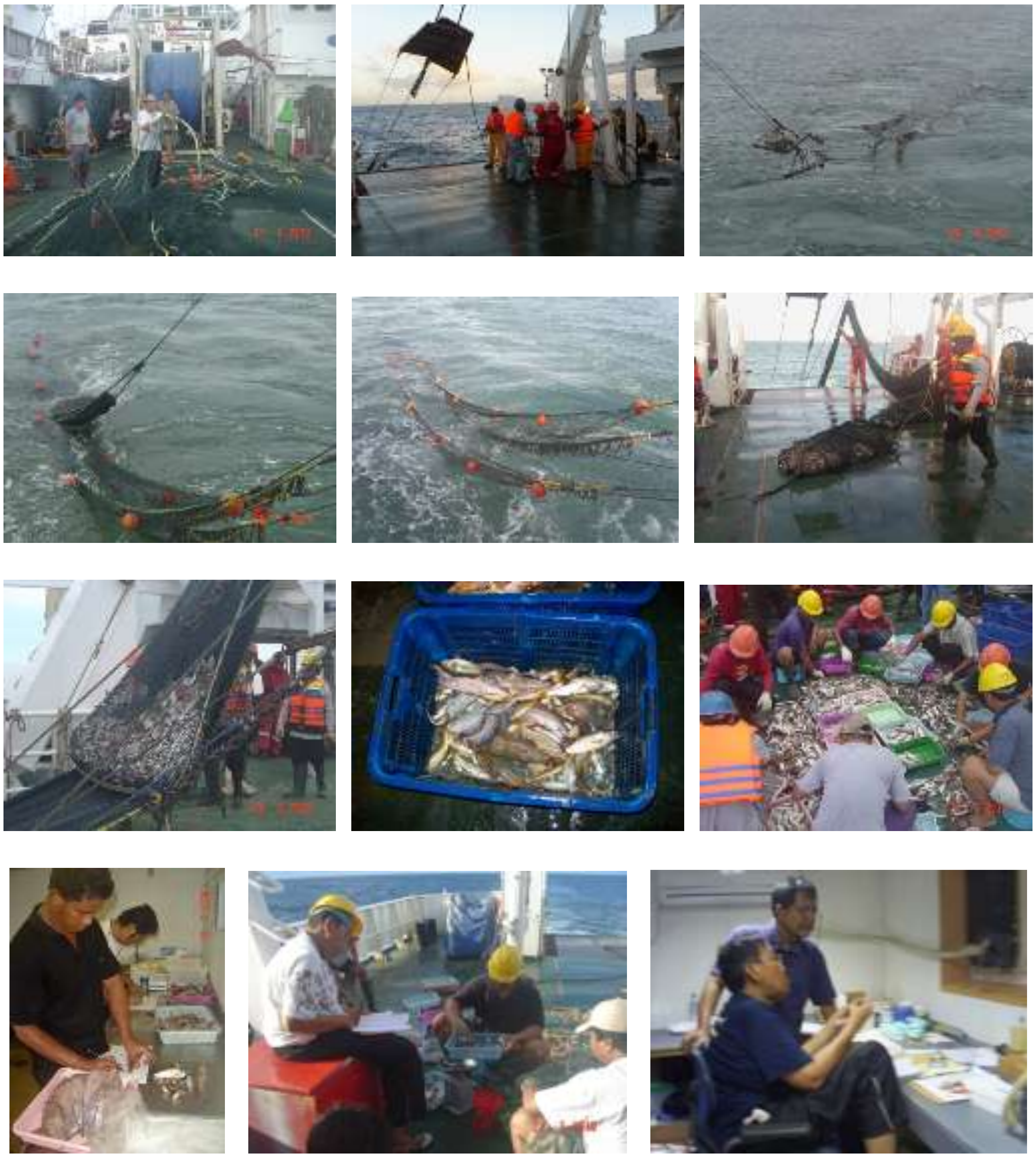
*Harpiosquilla harpax*

*Squilla sp1.*

*Squilla sp2.*

**Appendix 4.17.**

## Fishing activity onboard the *RV. Baruna Jaya VIII* in the Timor and Arafura Seas



Chapter V

# CETACEA AND MARINE MAMMALS

**Jotham Ninef**

Faculty of Agriculture, University of Nusa Cendana, Kupang, Indonesia
Email: *joninef@gmail.com*

## 5.1. Introduction

Indonesian waters are unique, containing 30 species of Cetacea, more than one-third of all whale and dolphin species known, including those that are rare and endangered (Klinowska, 1991). The eastern Indonesian waters, particularly the deep waters around the small islands, are habitats and migration paths of Cetacea. The Sawu, Banda, and Timor Seas, as well as the waters around the small islands of southern Maluku, are Cetacea migration paths connecting the Banda Sea to the Indian Ocean.

Observations by Indonesian researchers on species, habitat and migration path of Cetacea in Indonesian waters is still limited. However, much research on Cetacea in Indonesian waters has been conducted by foreign researchers, mainly in the Sawu Sea and surrounding waters.  Information on Cetacea is required to provide support for the management and conservation of Cetacea in Indonesia. This cruise provides a good opportunity to observe Cetacea in the Arafura and Timor Seas, in relation to a larger framework of marine management and conservation of biodiversity in this area.

## 5.2. Objective

The goal of Cetacea observation was:

1. To visually observation Cetacea, including whales and dolphins, in the Arafura and Timor Seas.
2. To create an inventory of the abundance and distribution of various species of Cetacea in the Arafura and Timor Seas.
3. To observe Cetacea behaviour on the sea surface.
4. To observe sea bird populations in the Arafura and Timor Seas.

## 5.3. Benefit

These observations produce specific information on Cetacea and sea birds in the Timor and Arafura Seas for the benefit of resource management and conservation of biodiversity in the area.

## 5.4. Survey method

### Time and location

Observation on Cetacea and sea birds were conducted onboard the *RV Baruna Jaya VIII* for 17 days from May 10$^{th}$ to May 27$^{th}$, 2010.

### Tools used in the survey

Tools used in Cetacea observation include:

(i) Camera and Handycam
(ii) Binoculers
(iii) GPS
(iv) Data sheet
(v) Data board
(vi) Watch to indicate time of appearance
(vii) Compass to indicate direction of Cetacea movement
(viii) Hydrographic map of the Arafura and Timor Seas
(ix) Manual of Cetacea identification

## 5.5. Data collection

Data recorded during the observation include the date and hour of the Cetacea appearance, GPS position, the Cetacea species, number of Cetacea that appear, the distance between the Cetacea and the observer, direction of Cetacea movement and their behavior during appearance such as resting, feeding, playing and the behavior of any juvenile Cetacea.  The records were supported by photos of the Cetacea for further identification.

Other than Cetacea observation, the survey also conducted bird observation. Cetacea observation and bird sightings were usually conducted during the day time from 6.30 am to 05.00 pm, from a deck position that enables the observer to have a clear line of sight.(Figure 5.1).

**Figure 5.1.** Cetacea watch from the main deck, fore and aft.

## 5.6. Data analysis

Data analysis includes analysis of the abundance and ecological distribution by means of Microsoft Excel and ARCVIEW. Observations were conducted over 16 days, from May 11 to May 26, totalling 151.5 watch hours. Average observation time per day was 9.5 hours. Total observable length was 1,027.5 nmi (1,936.3 km) with an average of 64.2 nmi (118.9 km) per day. Total Cetacea appearances were ten, including nine in the Arafura Sea and one in the Timor Sea (Table 5.1).

**Table 5.1.** Summary of Cetacea observations in the Timor and Arafura Seas

| SurveyID | Date (May, 2010) | Position | | Duration of observation (hours) | Distance covered (nmi) | Number of Sightings |
|---|---|---|---|---|---|---|
| | | begin | End | | | |
| ATSEA1 | 11 | 10°34.639 lat 124°35.484 long | 09°59.300 lat 124°41.627 lonh | 9.5 | 63 | 0 |
| ATSEA2 | 12 | 09°23.640 lat 125°41.331 long | 09°46.277 lat 126°11.625 long | 10 | 45.5 | 0 |
| ATSEA3 | 13 | 08°50.889 lat 126°51.702 long | 08°50.584 lat 127°21.540 long | 10 | 49 | 0 |
| ATSEA4 | 14 | 08°41.046 lat 128°46.977 long | 08°55.551 lat 129°48.146 long | 10 | 67.5 | 0 |
| ATSEA5 | 15 | 08°33.375 lat 131°06.886 long | 08°53.343 lat 131°43.189 long | 10 | 60 | 0 |
| ATSEA6 | 16 | 08°19.750 lat 131°10.683 long | 08°18.582 lat 131°43.430 long | 10 | 75 | 0 |
| ATSEA7 | 17 | 08°05.705 lat 133°36.586 long | 07°56.483 lat 134°55.111 long | 10 | 80 | 0 |
| ATSEA8 | 18 | 07°43.507 lat 136°41.940 long | 07°35.002 lat 137°50.039 long | 10 | 68 | 0 |
| ATSEA9 | 19 | 07°09.807 lat 136°59.834 long | 06°45.126 lat 137°50.069 long | 10 | 63.75 | 0 |
| ATSEA10 | 20 | 06°04.637 lat 137°34.730 long | 05°53.272 lat 137°32.947 long | 9 | 37.5 | 4 |
| ATSEA11 | 21 | 05°55.018 lat 136°23.778 long | 05°54.670 lat 135°08.962 long | 10 | 60 | 1 |
| ATSEA12 | 22 | 06°38.126 lat 135°55.530 long | 07°10.620 lat 135°13.257 long | 10.5 | 63.75 | 3 |
| ATSEA13 | 23 | 07°45.424 lat 134°37.413 long | 07°44.467 lat 133°28.120 long | 10.5 | 99.75 | 1 |
| ATSEA14 | 24 | 08°22.409 lat 131°19.193 long | 08°48.247 lat 129°41.607 long | 10.5 | 99.75 | 0 |
| ATSEA15 | 25 | 09°18.626 lat 127°25.913 long | 09°46.471 lat 125°58.539 long | 9.5 | 75 | 0 |
| ATSEA16 | 26 | 10°26.108 lat 123°32.673 long | 10°27.151 lat 123°21.175 long | 2 | 20 | 1 |
| **Total** | | | | **151.5** | **1,027.5** | **10** |

The observations of Cetacea appearances during the cruise shows that only dolphins were observed, and no whales. The dolphins observed consisted of 57 individuals from two species, including 51 Spinner Dolphins (*Stenella* sp) and six bottlenose dolphins (*Tursiops* sp). In the Arafura Sea, nine Cetacea appeared involving 51 individuals, mainly Spinner Dolphins (*Stenella* sp) (Figure 5.2); the Timor Sea had one appearance of bottlenose dolphins (*Tursiops* sp) consisting of six individuals (Table 5.2). Figure 5.3 shows the appearance of sea birds in the Arafura Sea.

**Table 5.2.** Summary of Cetacea observations in the Timor and Arafura Seas

| Date (May 2010) | Eastern Indonesia Time | Position | | Number of Species | Number of Individuals |
|---|---|---|---|---|---|
| | | Latitude | Longitude | | |
| 20-05-10 | 15.18 | 05°22.215 | 137°44.204 | 1 | 2 |
| | 16.35 | 05°52.971 | 137°35.699 | 1 | 2 |
| | 16.45 | 05°53.081 | 137°34.779 | 1 | 2 |
| | 16.55 | 05°53.272 | 137°32.947 | 1 | 8 |
| 21-05-10 | 07.41 | 05°54.499 | 136°15.866 | 1 | 2 |
| 22-05-10 | 16.19 | 07°08.706 | 135°10.467 | 1 | 10 |
| | 16.54 | 07°08.400 | 135°10.656 | 1 | 6 |
| | 17.17 | 07°09.293 | 135°11.449 | 1 | 15 |
| 23-05-10 | 10.45 | 07°26.766 | 134°24.602 | 1 | 4 |
| 26-05-10 | 8,00 | 10°26.120 | 123°33.385 | 1 | 6 |
| **Total** | | | | **2** | **57** |

**Figure 5.2.** Spinner Dolphins (*Stenella* sp) in the Arafura Sea

**Figure 5.3.** Sea birds in the Arafura Sea

Chapter VI

# MARINE PRODUCTIVITY OF THE ARAFURA AND TIMOR SEAS

**Restu Nur Afi Ati[1], Jemmy Manan[2], Fernando da Silva[3],**

[1] Research and Development Center for Ocean and Coastal Resources,
Ministry of Marine Affairs and Fisheries, Indonesia
Email: *restu.noviansyah@gmail.com*

[2] Faculty of Animal Husbandry, Fisheries and Marine Science,
University of Papua, Manokwari, Indonesia

[3] Ministry of Agriculture and Fisheries
National Directorate of Fisheries and Aquaculture
Democratic Republic of Timor Leste

## 6.1. Introduction

Primary productivity is generally represented by the abundance and composition of plankton, chlorophyll-a and nutrient content. Phytoplankton is one of the biological parameters that can be used as an indicator of aquatic quality and fertility. Phytoplankton is also the largest contributor of oxygen to the marine realm.

The content of chlorophyll-a and nutrients (mainly nitrate and phosphate) can be used as indicators of phytoplankton standing stock and aquatic productivity. Distribution of chlorophyll-a and nutrients in an aquatic system is related to the hydrologic condition and their sources from land. Furthermore, a number of physicochemical parameters affect the distribution of chlorophyll-a and nutrients. These parameters include light, temperature and salinity. According to Tisch *et al*. (1992), the changing conditions of water masses can be detected by observing water mass characteristics such as temperature, salinity, dissolved oxygen and nutrient content. Variation in physicochemical parameters is directly related to the variation of primary productivity in the sea.

The Arafura and Timor Seas have high biodiversity and fish resources. The resources are supported by high productivity due to the through flow of the

Pacific water mass, bringing nutrients to the Timor Sea. On the other hand, the Arafura Sea is a well-mixed system affected by nutrient supply from coastal zones and river systems. Both of the seas are categorized as having high fertility. However, data and scientific assessments concerning the factors that support high diversity of fisheries resources in both seas are minimal, it is therefore important to conduct an assessment of chlorophyll-a, plankton and nutrient distributions in both seas.

The ATSEA cruise was intended to study the supporting factors of the high biodiversity and fisheries resources in Timor and Arafura Seas through the assessment of chlorophyll-a, nutrient and plankton distributions. It is expected that the data and information obtained from this study can be used to support sustainable management of fisheries resources in the Timor and Arafura Seas.

## 6.2. Objective of the research

This research was aimed at conducting an assessment on the condition of the Arafura and Timor Seas in horizontal and vertical dimensions of marine productivity, such as the distribution of chlorophyll-a, phytoplankton, zooplankton and nutrient content (nitrate, phosphate, ammonium and silicate).

## 6.3. Method

The study of marine productivity in this area is based on a laboratory analysis of samples collected using a Rosette Sampler, together with CTD casts at every station during the ATSEA cruise. The analysis focused on the distribution and concentration of chlorophyll-a and nutrients, as well as the identification of plankton. The data were analyzed by using PCA (Principal Component Analysis) and spatial distribution for each parameter. Nutrient analysis was done onboard the ship, but analysis for other parameters was conducted in the laboratory.

Samples in the Timor Sea were collected at 1 m, 25 m, 50 m and 100 m depth for chlorophyll-a and nutrients. Considering that the Timor Sea is a deep-sea habitat, additional samples from 300 m, 1,500 m, 2,000 m and 2,500 m were taken for plankton analysis, and the composition and distribution of plankton were determined for each depth. Samples in the Arafura Sea, however, were obtained from depths which were different from that of the Timor Sea due to their differing depth characteristics. In the Arafura Sea, water samples were collected from depths of 1 m, 17 m, 25 m, 35 m, 50 m and 300 m. The largest depth of 300 m was taken at the station adjacent to the deep sea. Sampling depths in the Arafura and Timor Seas were considered as representative of the upper, middle and bottom layers of the photic zone. Water samples were collected from 13 stations in Timor Sea and 10 stations in the Arafura Sea. Station distribution in both seas is shown in Figure 6.1.

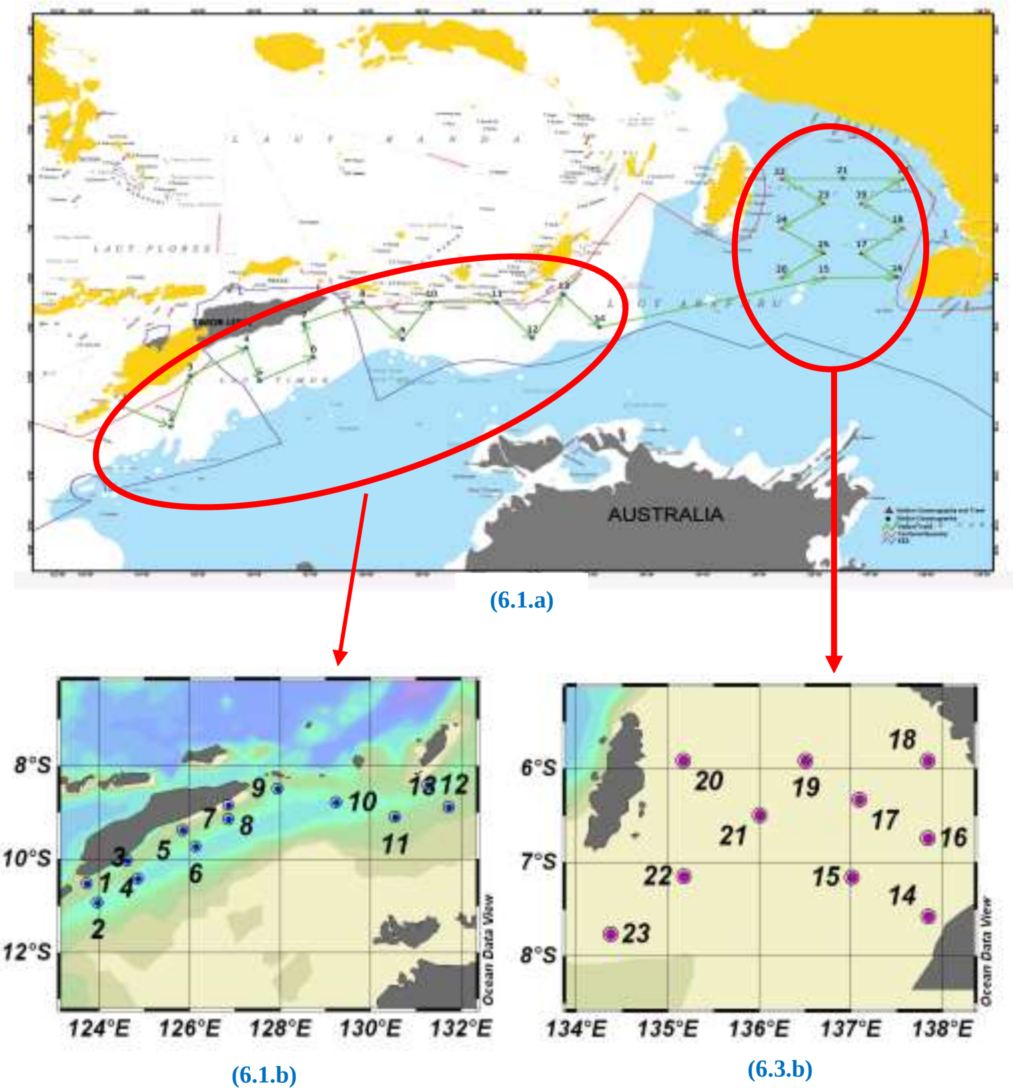



**Figure 6.1.** (a) ATSEA cruise track in the Arafura and Timor Seas; (b) Sampling stations in the Timor Sea; (c) Sampling stations in the Arafura Sea

## 6.4. Result and Discussion

### 6.4.1. Timor Sea

#### Lateral distribution of Chlorophyll-a

Chlorophyll-a at the sea surface in the Timor Sea was quite low. Figure 6.2 shows that the chlorophyll-a content at the sea surface ranges between 0.2 and 0.45 mg/m$^3$. The low content of chlorophyll-a may reflect low fertility, at least at the time of the survey.

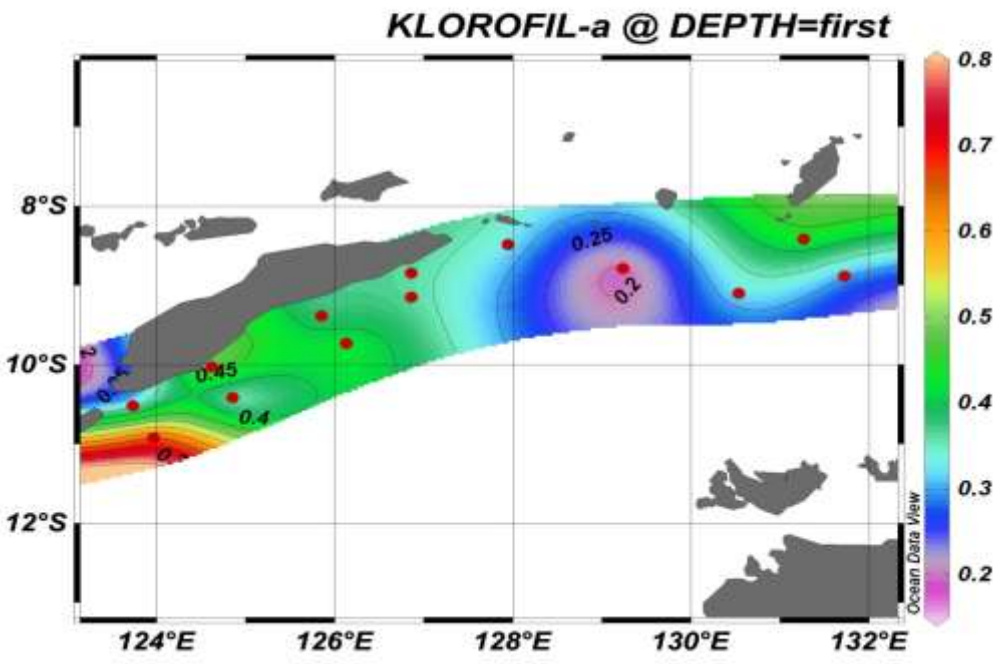



**Figure 6.2.** Distribution of chlorophyll-a at sea surface in the Timor Sea

Chlorophyll-a contentration at a depth of 25 m ranges between 0.4 and 0.5 mg/m$^3$, increasing from that of the surface layer (Figure 6.3). Lateral distribution of chlorophyll-a at 25 m is quite homogeneous, except at the southwest corner. The increase of chlorophyll-a content in this depth may be due to the effect of water mass mixing.

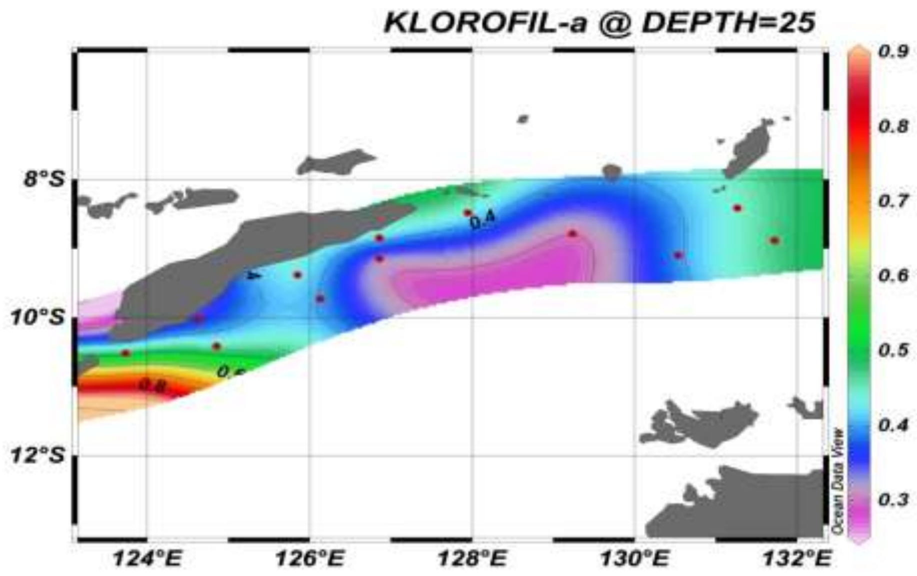



**Figure 6.3.** Distribution of chlorophyll-a at a depth of 25 m

The chlorophyll-a concentration at 50 m ranges between 0.5 and 0.9 mg/m$^3$ (Figure 6.4), increasing from 25 m. The increase of chlorophyll-a concentration at 50 m indicates that the mixing of water mass occurs at this depth. Furthermore, chlorophyll-a concentration is expected to be related to the penetration of sunlight in the area. During the time of maximum sunlight intensity, the chlorophyll-a layer goes deeper; during low light intensity, the maximum chlorophyll layer moves upward towards the surface layer (Raymond, 1980).

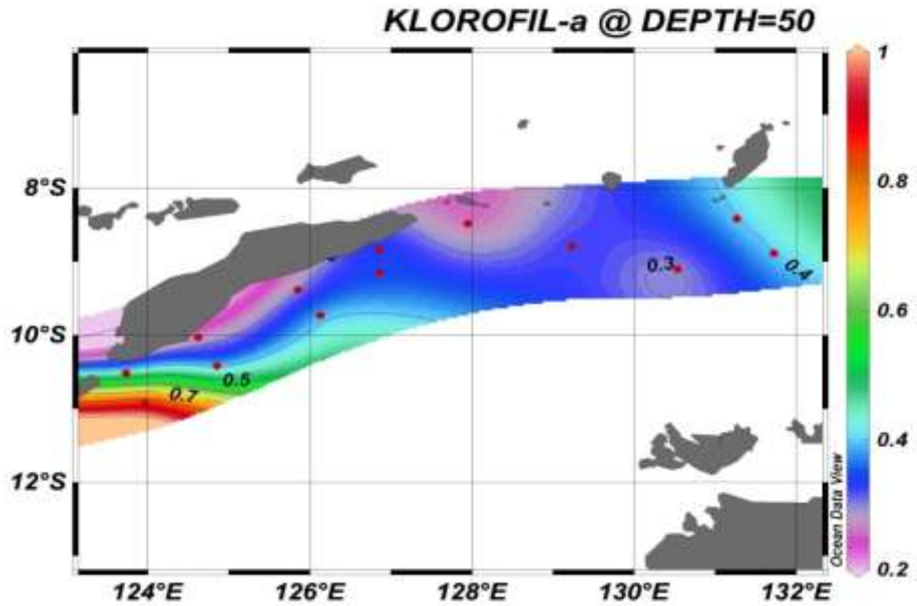



**Figure 6.4.** Distribution of chlorophyll-a at depth of 50 m

Figure 6.5 shows that the vertical distribution of chlorophyll-a is at a maximum between 25 m and 50 m. Therefore, the maximum level of fertility in Timor Sea may occur in the water layer within these depths.

### Vertical distribution of chlorophyll-a in Timor Sea

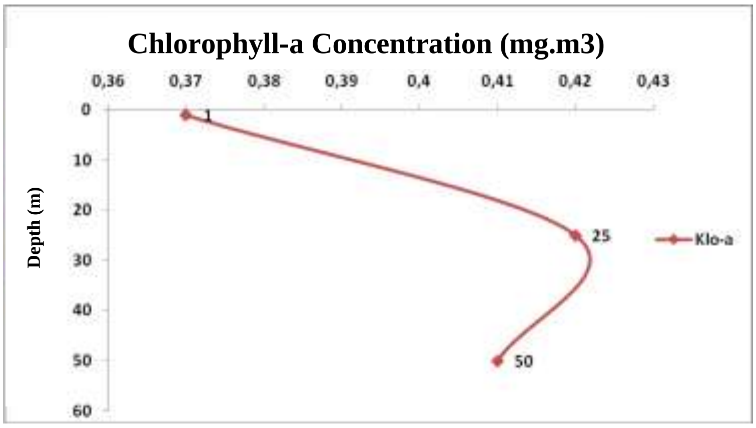



**Figure 6.5.** Vertical distribution of chlorophyll-a in the Timor Sea

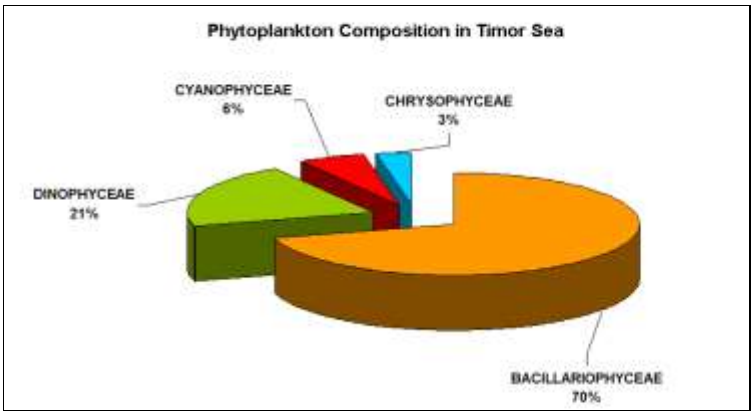
### Plankton

In this report, plankton observation includes phytoplankton and zooplankton. Phytoplankton are autotrophic plant organisms that consist of chlorophyll containing chloroplasts in which photosynthesis occurs, producing their own energy. Phytoplankton are consumed by heterotrophic zooplankton and other organisms at higher trophic levels. Heterotrophs are unable to produce their own food, and therefore consume phytoplankton; for this reason, phytoplankton abundance is related to the primary productivity of the sea and is one of the parameters for determining aquatic ecological conditions.

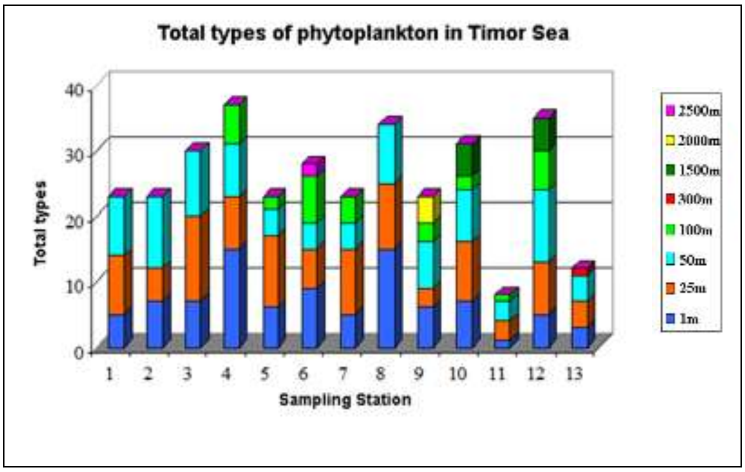
### Lateral distribution of phytoplankton in the Timor Sea

In general, phytoplankton composition in the Timor Sea from the surface to the deep bottom consists of 24 genera of Bacillariophyceae (70%), 7 genera of Dinophyceae (21%), 2 genera of Cyanophyceae (6%) and 1 genus of Chrysophyceae (3%). Phytoplankton is capable of producing large biomass, even though the group is only represented by a small number of phyla. Bacillariophyceae is one of the phytoplankton classes that are commonly found in large numbers and are an important part of the marine food chain. The percentage of Bacillariophyceae in the Timor Sea is around 70%. This class is highly tolerant and adaptive to the environment (Tomas, 1997).

Bacillariophyceae and Dinophyceae are commonly found in tropical waters, particularly in the surface water and the photic zone. Cyanophyceae (blue green algae) commonly occur in coastal and brackish waters, and Chrysophyceae are mainly found in coastal and oceanic waters with its abundance decreasing towards coasts with brackish waters. Composition and the amount of phytoplankton types at every station are shown in Figure 6.6.




(6.6.a)




(6.6.b)

**Figure 6.6.** (a) Composition and (b) total types of phytoplankton in the Timor Sea

The distribution of phytoplankton in Figure 6.6 indicates that from the surface to 50 m depth, there are between 91 and 99 types phytoplankton, greater than the deeper layer. Between 100 m and 2,500 m, the number of phytoplankton types is between 2 and 31. Phytoplankton types are found in greater number in the euphotic zone. According to Nontji (1993), phytoplankton can be found throughout the entire section of water column where light intensity is still sufficient for photosynthesis. This is why phytoplankton is considered as having the most important role in marine ecosystem.

Figure 6.7 shows the lateral distribution of phytoplankton abundance. The greatest abundance occurs at Stations 3 and 8 in the surface waters and at 25 m. At the surface waters of Station 8, phytoplankton concentration is 37.9 x $10^6$ cells/l, while at 25 m, it is 33.4 x $10^6$ cells/l.

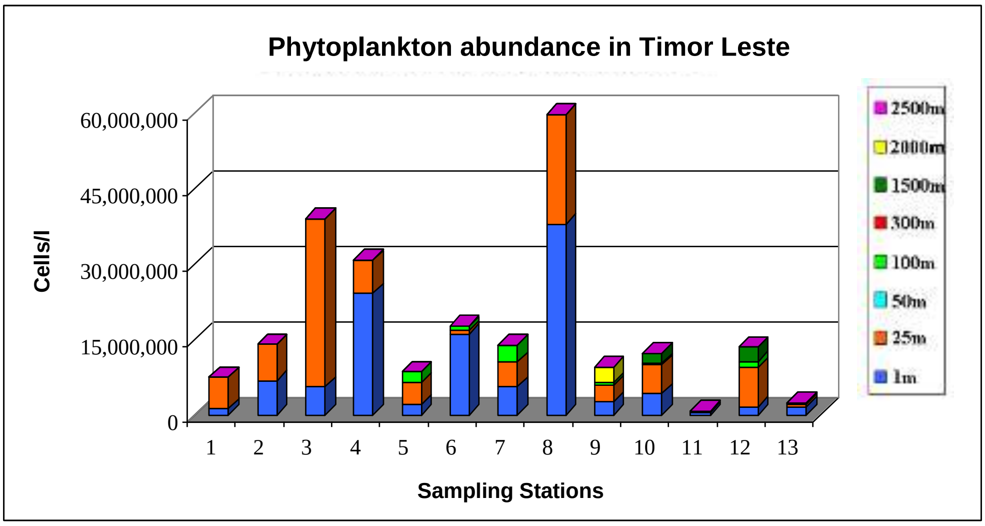



**Figure 6.7.** Lateral distribution of phytoplankton abundance in the Timor Sea

A relatively high concentration of phytoplankton is found only at three stations, namely Stations 3, 4 and 8, from the surface water to 25 m. The other stations indicate a lower range of concentration in the water column, from the surface water to deep water, decreasing in range with depth. The high abundance at Station 3, 4 and 8 may be related to weak currents at those stations (between 547.85 and 853.24 mm/s). Such conditions enable the phytoplankton to form colonies and not to spread out.

The average concentration of phytoplankton in the Timor Sea is relatively low, in the range of 9.23 x $10^3$ to 8.5 x $10^6$ cells/l. Considering the range in phytoplankton concentration, the waters of the Timor Sea can be categorized as mesotropic, where the water is environmentally disturbed and the plankton community is affected. If the pollutant concentrations increase even a small amount, the resulting changes in the structure of the plankton community may be extreme. Another condition that has to be considered is that it was raining during the sampling in the Timor Sea, which may cause changes in structure of plankton community toward more diversity.

Phytoplankton concentration is similar to that of chlorophyll-a, consisting of low amounts from 0.2 to 0.45 $mg/m^3$. The low abundances of both chlorophyll-a and phytoplankton indicate that the waters are either polluted or not productive. Chlorophyll-a concentration can be used as an indicator of phytoplankton abundance in seawater, and sometimes phytoplankton concentration is stated in chlorophyll-a concentration (Arinardi *et al*., 1997).

Phytoplankton communities in the Timor Sea show a low average of indexes. Diversity index ranges between 0.05 and 1.35, uniformity index is between 0.05 and 0.71 and dominance index ranges between 0.03 and 0.46. Phytoplankton community structure is shown in Figure 6.8.

The low index of phytoplankton community structure in the Timor Sea indicates that the sea has a low diversity index with a low individual distribution, but shows uniform dominance by one genus. This condition may cause low stability in the phytoplankton community due to ecological pressure on a large area of the sea. The dominant genus in the Timor Sea was *Chaetoceros* spp. The large abundance of this one phytoplankton type is due to its capability to utilize more energy in comparison to the others, thus causing its rapid growth (Praseno and Adnan, 1993).

## Diversity Index

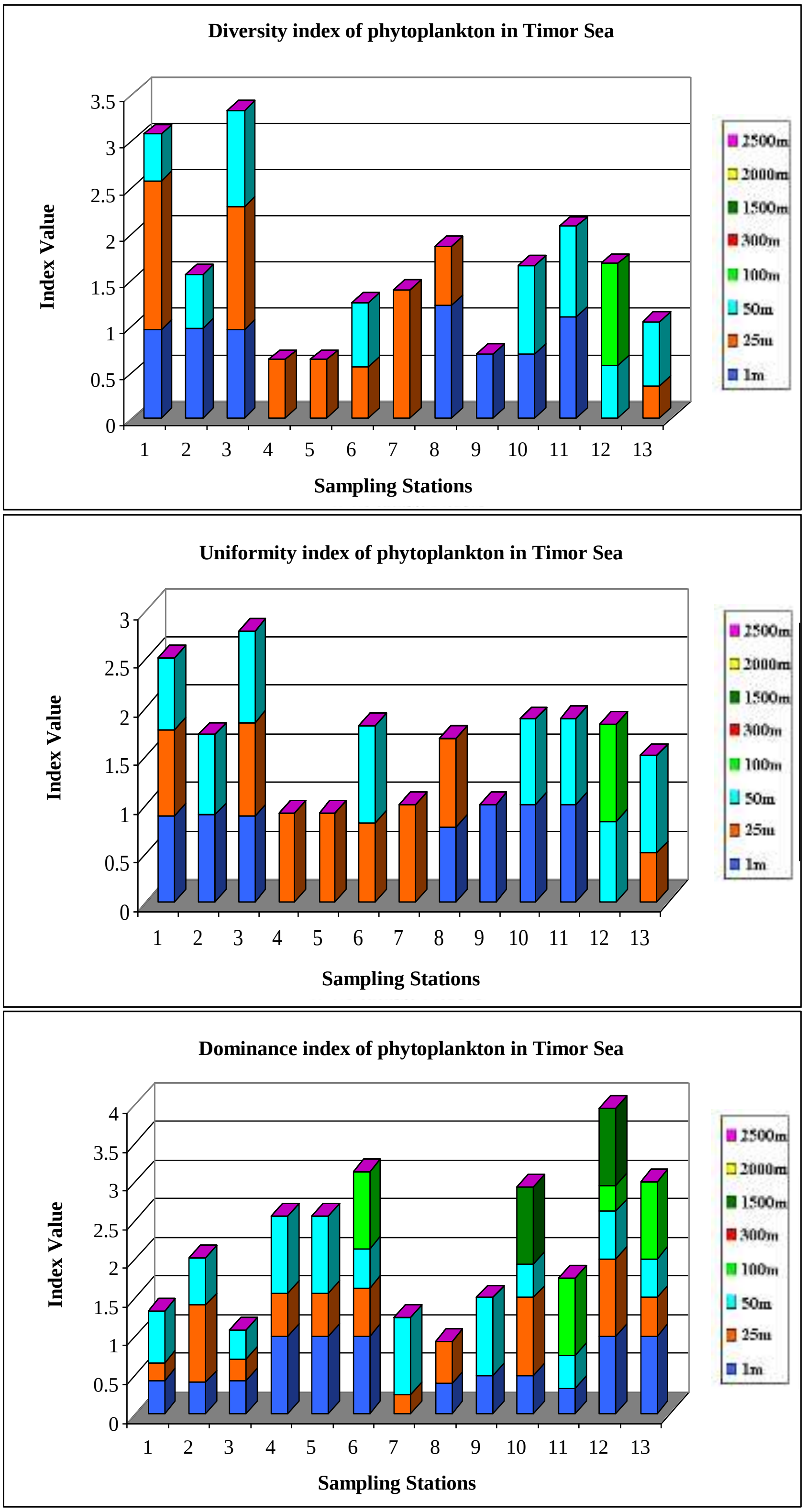



**Figure 6.8.** Phytoplankton community structure in the Timor Sea

## Vertical distribution of phytoplankton in Timor Sea

The vertical distribution of phytoplankton in the Timor Sea is shown in Figure 6.9. General observations indicate that the abundance of phytoplankton in this area decreases with depth, as indicated at Stations 4, 5, 6, 11 and 12. At stations 1, 2 and 3, however, the abundance of phytoplankton increases with depth, particularly at 50 m.

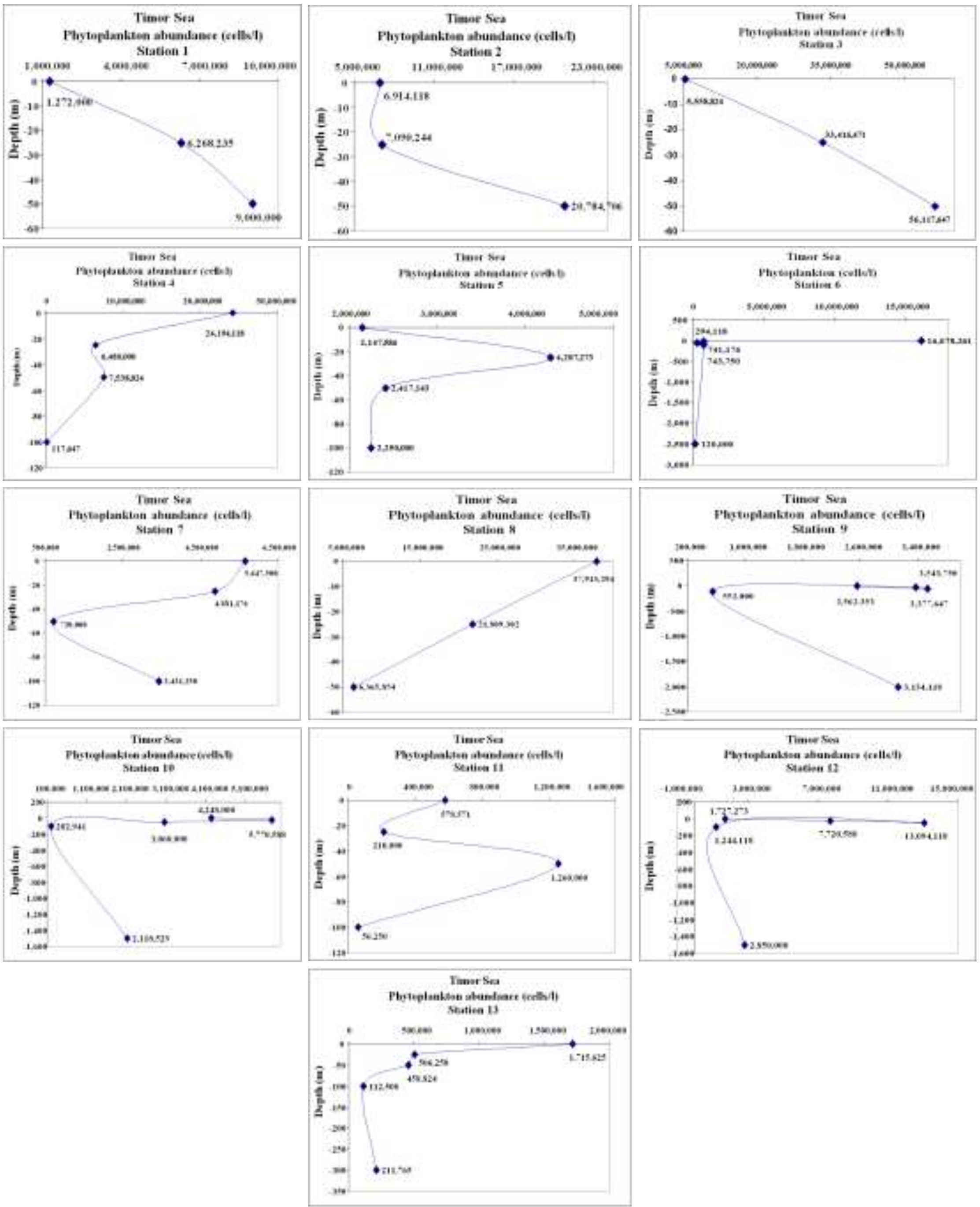
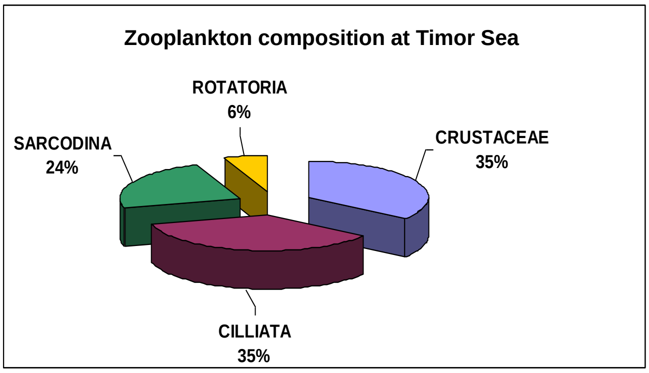



**Figure 6.9.** Vertical distribution of phytoplankton in the Timor Sea

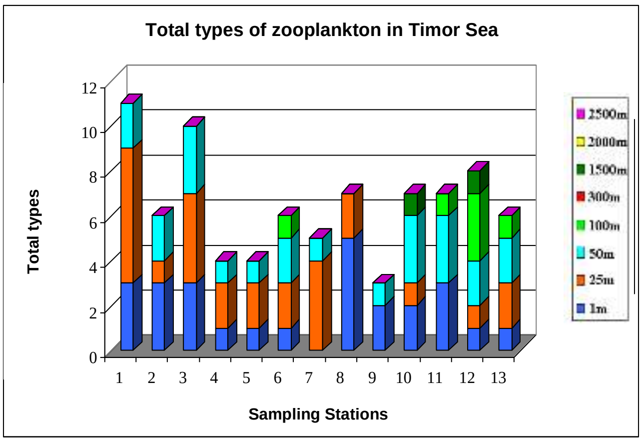
The decrease in concentration at depths greater than 25 m at the remaining stations may be due to the decrease of light intensity, therefore phytoplankton growth is not optimal. Alternatively, the samples only reflect the sea water condition during sampling time, which is influenced by weather conditions. The abundance of phytoplankton is directly related to nutrient content, such as nitrate and phosphate. Phytoplankton is highly abundance at the surface layer, with large concentrations of organic carbon, and decreases significantly below the euphotic zone. Phytoplankton can be found in the entire water column where light intensity is sufficient to support the photosynthetic process.

## Lateral distribution of zooplankton in Timor Sea

The zooplankton found contained 17 genera from 4 classes in the Timor Sea which includes Crustacea and *Ciliata* from 6 genera (35%), Sarcodina of 4 genera (24%) and Rotatoria from one genus (6%). Zooplankton composition and total number of species are shown in Figure 6.10.




(6.10.a)




(6.10.b)

**Figure 6.10.** (a) Composition and (b) total species of zooplankton in the Timor Sea

The highest number of zooplankton species observed in surface samples comes from Station 8 which contains five species: *Acartia* sp, *Calanus* sp, *Eutintinnus* sp, *Parafavella* sp and *Tintinnopsis* sp. The total number of species increases to six at 25 m and decreases afterward. At 1,500 m, only one species of zooplankton was found: *Acartia* sp.

The highest concentration of zooplankton in the Timor Sea is at Station 1. Surface samples (1 to 25m) contain 6.36 x $10^5$ cells/l, and increases to 1 x $10^6$ cells/l at 25 to 50 m.  These results reflect the fact that zooplankton feed on phytoplankton and reach optimum growth at Station 1. The average concentration of zooplankton in the Timor Sea water column at the top 1 m is 2.18 x $10^5$ cells/l; from 1 to 25 m it is 2.3 x $10^5$ cells/l; from 25 m to 50 m it is 1.91 x $10^5$ cells/l; from 50 m to 100 m it is 3.08 x $10^5$ cells/l and from 100 to 1,500 m it is 2.3 x $10^5$ cells/l. The average concentrations of zooplankton in the Timor Sea indicate that zooplankton concentrations are low (Figure 6.11).

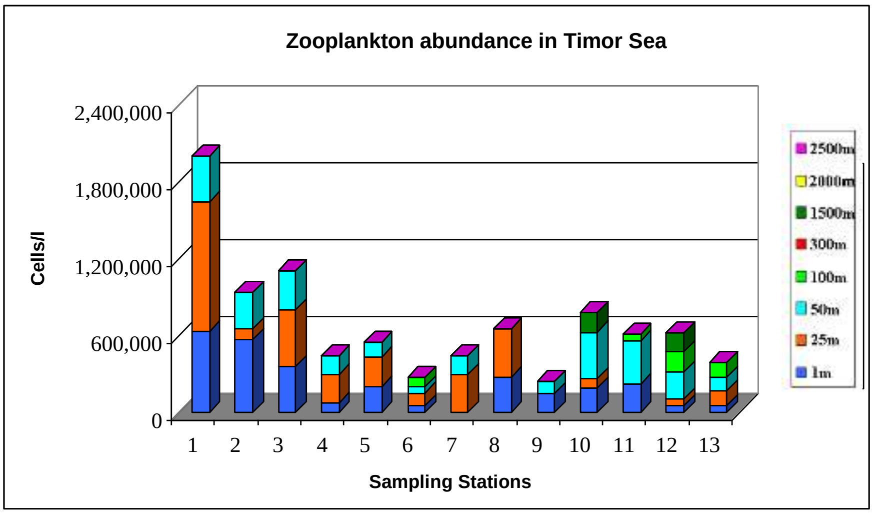



**Figure 6.11.** Zooplankton abundances in the Timor Sea

The structure of the zooplankton community is reflected by several indices concerning diversity, uniformity and dominance in the area. Figure 6.12 illustrates those indices of zooplankton in the Timor Sea.

# Diversity Index

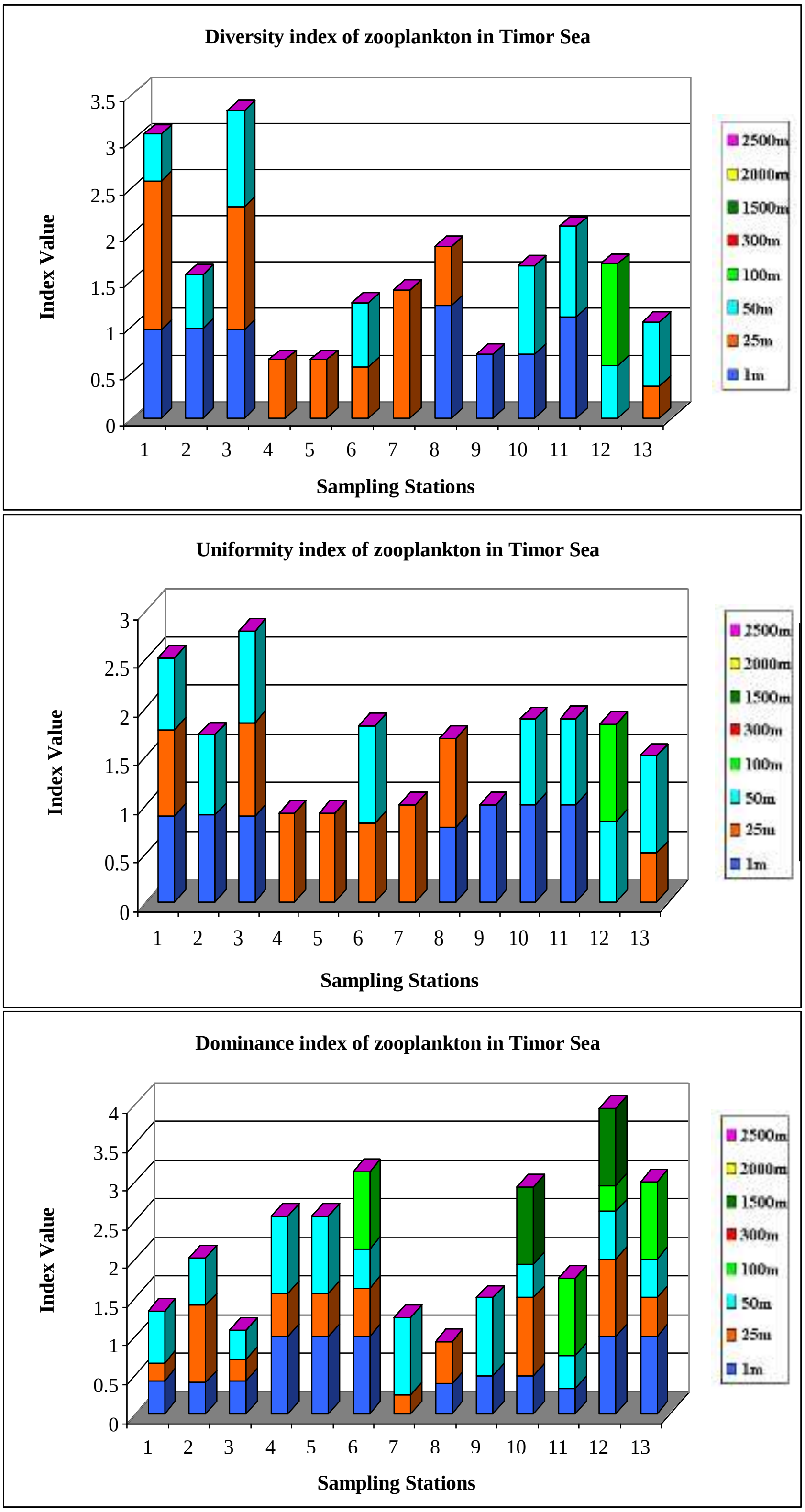



**Figure 6.12.** Structure of zooplankton community in the Timor Sea

The average structure of the zooplankton community from 1 to 2,500 m in the Timor Sea is reflected by the an index of diversity of 0.08 to 0.5; an index of uniformity of 0.07 to 0.5 and an index of dominance of 0.1 to 0.6. The range of concentrations does not differ greatly from that of phytoplankton; zooplankton in the Timor Sea show low diversity and low uniformity indices. However, the dominance index indicates that there is a dominating genus, namely *Acartia*, both in the surface layer and in the deeper portion of the water column.

Observation of the phytoplankton and zooplankton in the Timor Sea has lead to the suggestion that the marine environment may have experienced environmental disturbance which resulted in the low marine productivity. This condition may affect the food chain in the Timor Sea.

### Vertical distribution of zooplankton in the Timor Sea

The vertical distribution of zooplankton in the Timor Sea within the water column from 1 m to 2,500 m was characterized by low concentrations in the surface layers, increasing at 25 m. The zooplankton concentrations decrease to their lowest values at depths of 50 m to 1,500 m. The increase of zooplankton abundances at 25 m may be related to a sufficient supply of food and nutrients at this depth, enabling optimum growth of phytoplankton, the zooplankton food supply. The vertical distribution of zooplankton concentrations in the Timor Sea is illustrated in Figure 6.13.

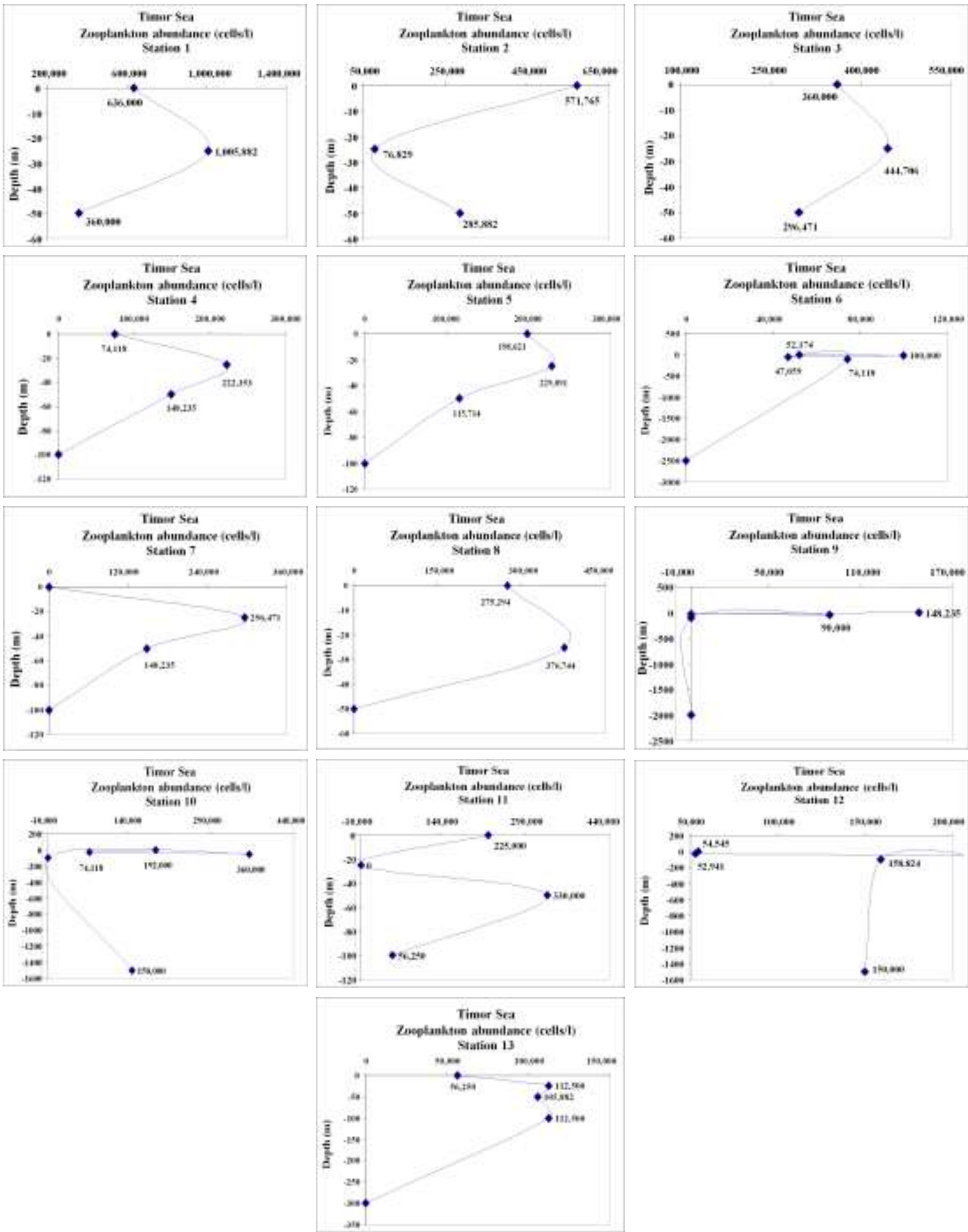



**Figure 6.13.** Vertical distribution of zooplankton at all stations in the Timor Sea

The occurrence and concentration of zooplankton may reflect $CO_2$ distribution in the area. Zooplankton feed on the $CO_2$ absorbing phytoplankton, and the carbon becomes part of sediment inputs when the zooplankton settle down to the surface sediment at the bottom of the sea.

## Nutrient content

## Nitrate ($NO_3^-$)

The average concentration of nitrate in the Timor Sea ranges between 0.27 and 13.70 µg/l. The minimum value of 0.27 µg/l is in the surface layer, and the maximum value of 13.70 µg/l is found at a depth of 50 m. The vertical distribution of nitrate is shown in Figure 6.14.

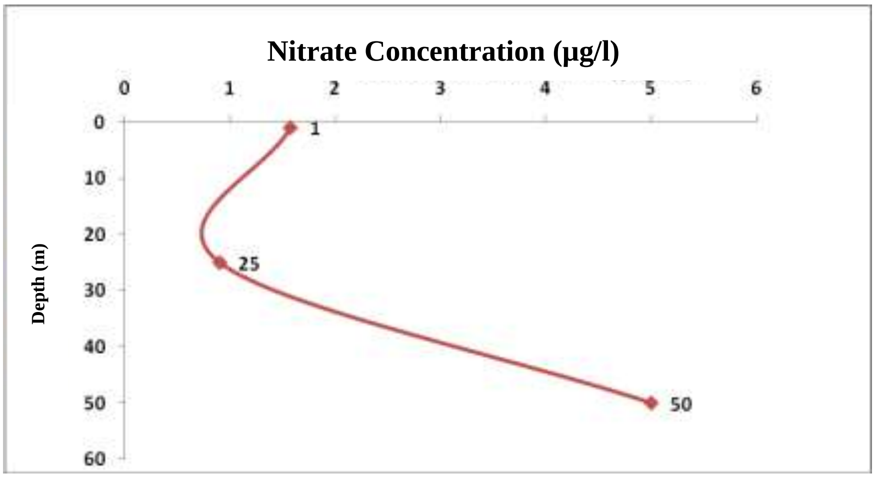



**Figure 6.14.** Vertical distribution of nitrate in the Timor Sea

The concentration of nitrate in the Timor Sea decreases gradually from the surface layer to a depth of 25 m, and increases significantly at depths greater than 25 m at all stations. This condition may be caused by the mixing of water mass at that depth and also may be affected by nutrient distribution.

## Phosphate ($PO_4^-$)

The average phosphate concentration in the Timor Sea ranges between 0.09 and 3.09 µg/l. Similar to the nitrate concentration, the minimum phosphate concentrations (0.09 µg/l) is observed in the surface layer and the maximum value of 3.09 µg/l is within the water layer at 50 m. Vertical distribution of phosphate is illustrated in Figure 6.15.

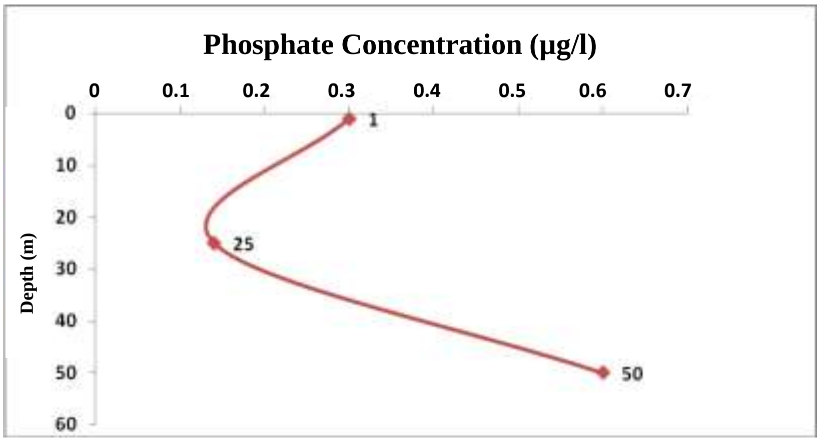



**Figure 6.15.** Vertical distribution of phosphate in the Timor Sea

Phosphate concentration in the Timor Sea decreases gradually from the surface layer to 25 m, and then increases significantly at depths greater than 25 m. This condition may be due to the mixing of water mass, which results in a higher concentration of phosphate at depth. The vertical distribution of nitrate and phosphate indicate similar characteristics: high concentrations in the surface layer and a decrease below 25 m. The maximum phosphate and nitrate concentrations occur at 50 m.

## Ammonium ($NH_4$)

Average concentration of ammonium in the Timor Sea ranges between 0.05 and 7.22 µg/l. The minimum value of 0.05 µg/l is observed between the surface layer and 25 m. The maximum value of 7.22 µg/l is found at 50 m. The vertical distribution of ammonium in the Timor Sea is shown in Figure 6.16.

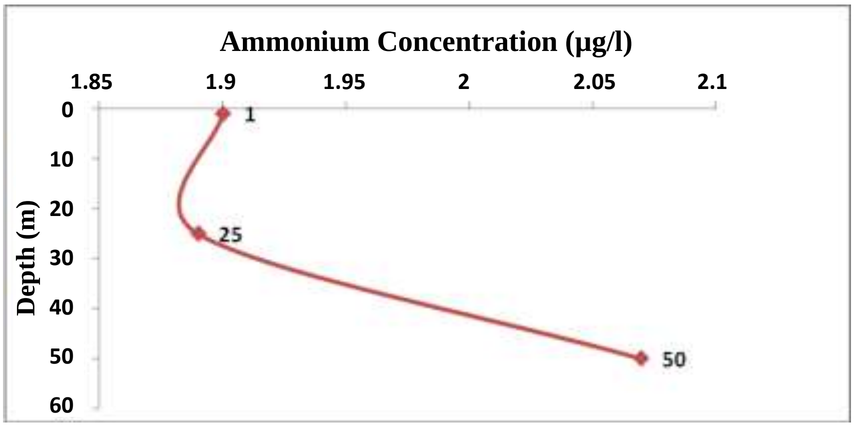



**Figure 6.16.** Vertical distribution of ammonium in the Timor Sea

The distribution of ammonium in the Timor Sea is generally low in the upper layer to a depth of 25 m. At depths greater than 25 m, the ammonium concentration increases significantly. In the marine environment, ammonium is produced by the metabolism of organic nitrogen by microheterotrophic bacteria.

The low concentration of ammonium at 25 m in the Timor Sea may be related to water mass mixing, facilitating the regeneration process of ammonium by microheterotrophs. Ammonium is one of the main energy sources for phytoplankton, preferably taken from other nutrient sources in marine ecosystems (Dortch, 1990).

## Silicate ($SiO_2$)

The average concentration of silicate in the Timor Sea is 0.70 to 18.39 µg/l. A minimum value of 0.70 µg/l is found between the upper layer and 25 m. The maximum value of 18.39 µg/l is observed at 50 m. A vertical distribution of silicate in the Timor Sea is shown in Figure 6.17.

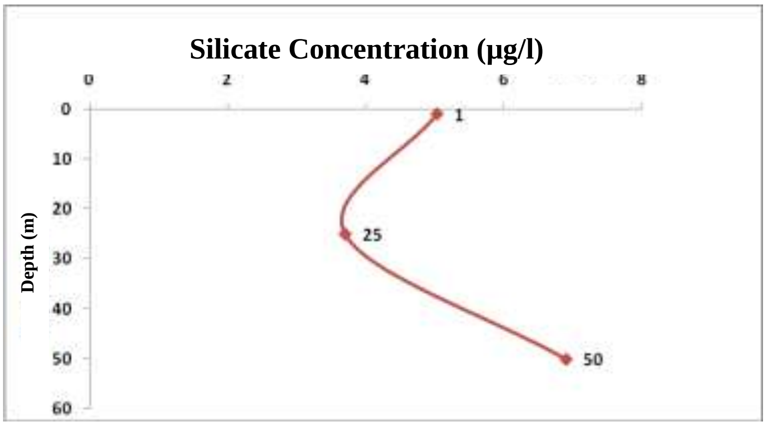



**Figure 6.17.** Vertical distribution of silicate in the Timor Sea

The concentration of silicate in the Timor Sea is generally high in the upper layer, decreasing gradually to 25 m. At depths greater than 25 m, the silicate concentration increases significantly to 50 m. The silicate distribution shows the same trend as other nutrient species. Silicate is one of the limiting resources for some shell-bearing zooplankton.

### 6.4.2. Pelagic conditions in the Arafura Sea

#### Chlorophyll-a content

The lateral distribution of chlorophyll-a in the Arafura Sea is shown in Figure 6.18.

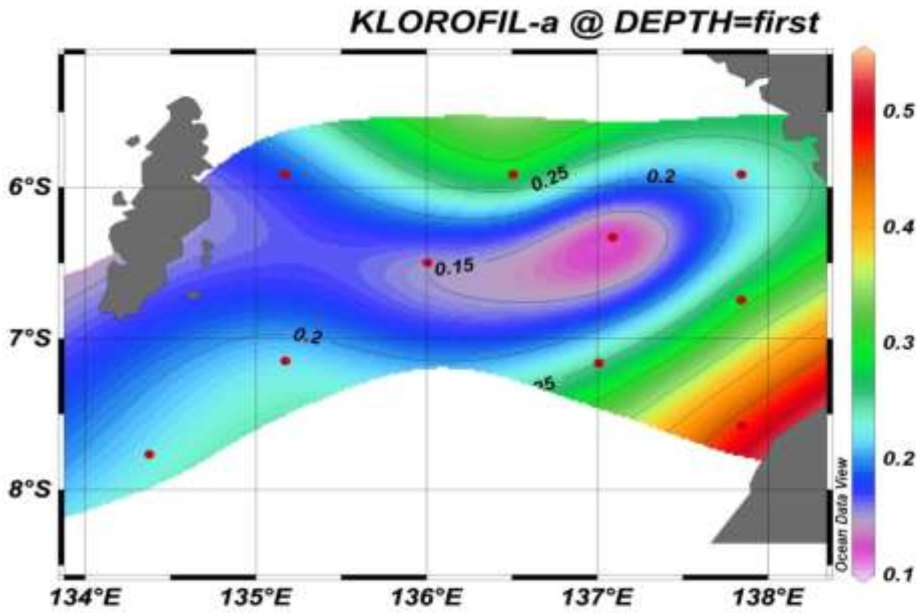



**Figure 6.18.** Lateral distribution of chlorophyll-a in the surface layer of the Arafura Sea

The chlorophyll-a concentration in the upper layer of the Arafura Sea ranges between 0.15 and 0.25 mg/m$^3$. The distribution pattern indicates homogeneous distribution.

The average value of chlorophyll-a concentration at 17 m is between 0.2 and 0.4 mg/m$^3$(Figure 6.19). Distribution patterns of chlorophyll-a at this depth show homogeneous distribution.

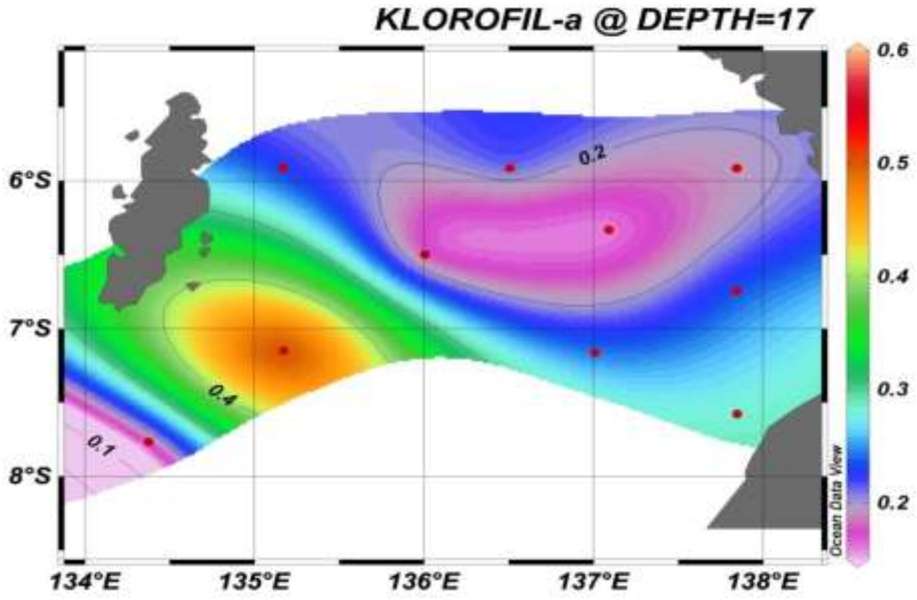



**Figure 6.19.** Distribution of chlorophyll-a at 17 m in the Arafura Sea

The chlorophyll-a concentration at 25 m ranges between 0.3 and 0.6 mg/m$^3$ (Figure 6.20). The highest concentration of chlorophyll-a is observed in the area adjacent to the Timor Sea, and it may be related to the upwelling of high nutrient water to the Timor Sea.

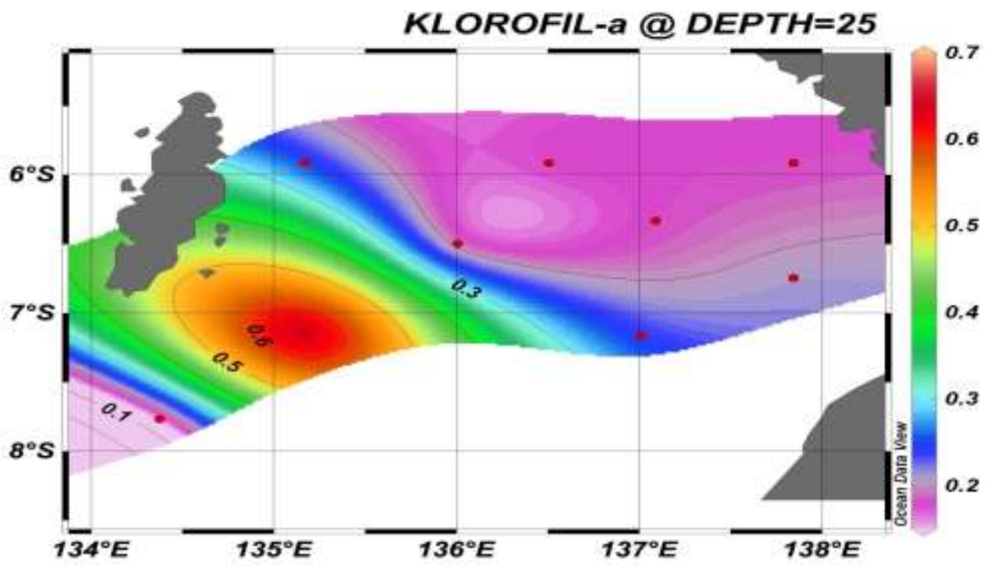



**Figure 6.20.** Distribution of chlorophyll-a at 25 m in the Arafura Sea

The chlorophyll-a concentration at 45 m in the Arafura Sea (Figure 6.21) is 0.2 mg/m$^3$, the lowest chlorophyll-a concentration in the entire water column. This condition may be related to the minimal light intensity penetrating to this depth.

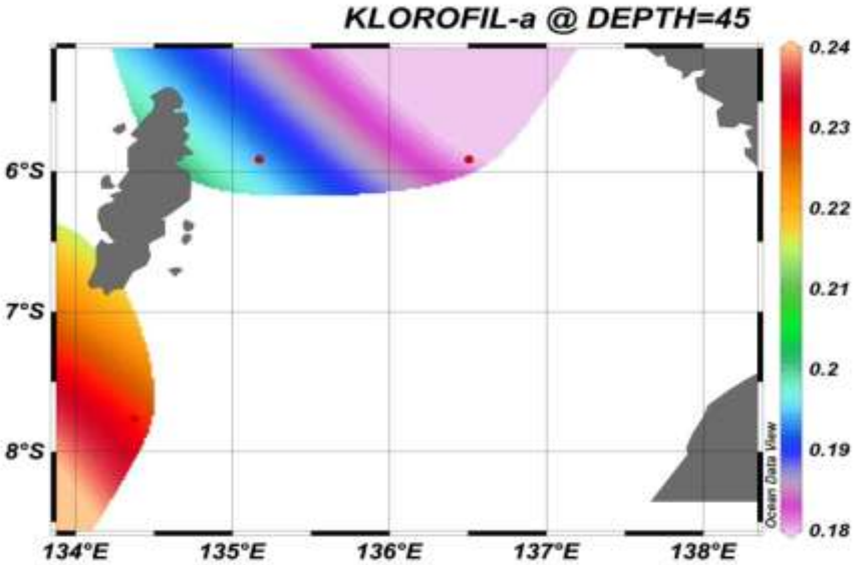



**Figure 6.21.** Distribution of chlorophyll-a at 45 m in the Arafura Sea

## Vertical distribution of chlorophyll-a in Arafura Sea

Figure 6.22 shows that the vertical distribution of chlorophyll-a in the Arafura Sea was relatively homogeneous, indicating that the Arafura Sea is well mixed.

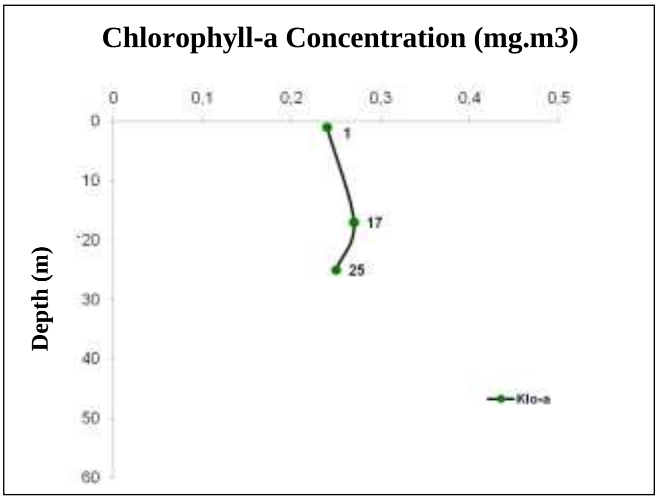
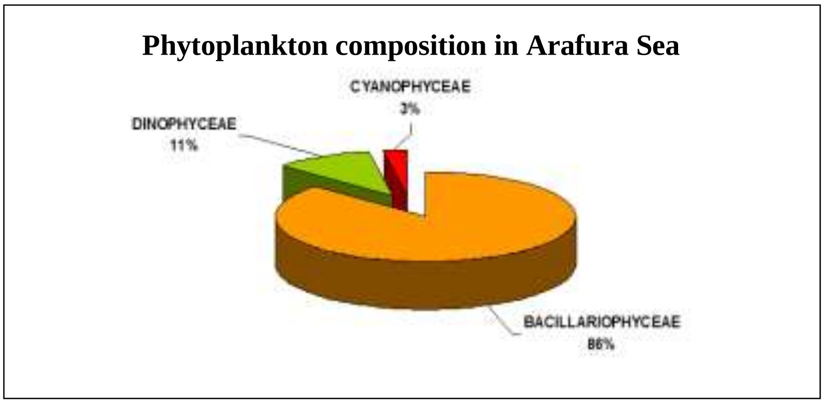



**Figure 6.22.** Vertical distribution of chlorophyll-a in the Arafura Sea

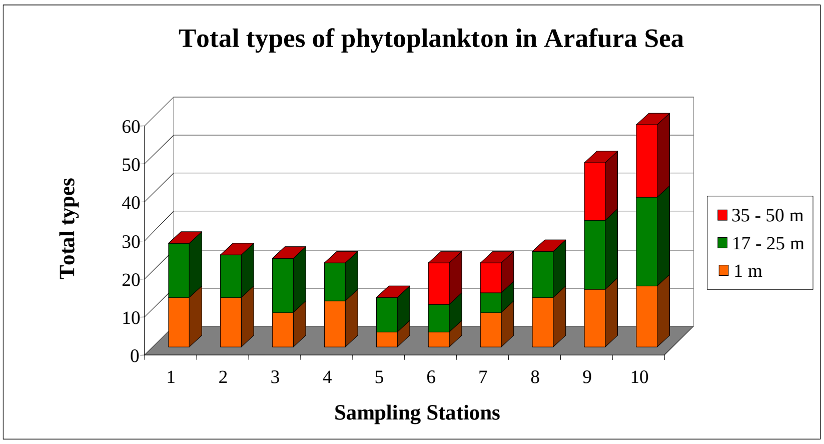
## Plankton

## Lateral distribution of phytoplankton in Arafura Sea

Phytoplankton samples at ten stations in the Arafura Sea indicate that phytoplankton consists of three families as follows: 68% Bacillariophyceae (33 genera), 11% of Dinophyceae (4 genera) and 3% of Cyanophyceae (1 genus). The composition and total number of plankton families are shown in Figure 6.23.




(6.23.a)




(6.23.b)

**Figure 6.23.** (a) Composition and (b) total number of phytoplankton types in the Arafura Sea

Phytoplankton in this area is dominated by Bacillariophyceae. The high diversity of these diatoms may be related to the nutrient supply from the surrounding land, as reflected by a nitrate concentration of 7.60 µg/l. Furthermore, terrestrial sediments transported to the Arafura Sea cause low water clarity and tint the water a greenish brown color.

Diatom classes are often found in large numbers and they are an important part of the food chain. When nutrient concentrations increase, diatoms are able to utilize them faster than the other phytoplankton, undergoing mitosis three times in 24 hours; in comparison with dinoflagellates which can only undergo one mitotic division within 24 hours. Furthermore, diatoms are able to assimilate organic nutrients and synthesis it within their body using sunlight, and are widely distributed, establishing their role in food chain of an ecosystem (Tomas, 1997).

The average concentration of phytoplankton in the surface water is 28.7 x $10^6$ cells/l; at 17 to 25 m, it is 27.6 x $10^6$ cells/l; and at 50 m, it is 15.2 x $10^6$ cells/l. Station 9 has the highest abundance of phytoplankton from the surface to 50 m. At 1 m, the concentration is 157.5 x $10^6$ cells/l; at 17 to 25 m, it is 115 x$10^6$ cells/l; and at 50m, it is 108.4 x $10^6$ cells/l. Phytoplankton abundances in the Arafura Sea are shown in Figure 6.24.

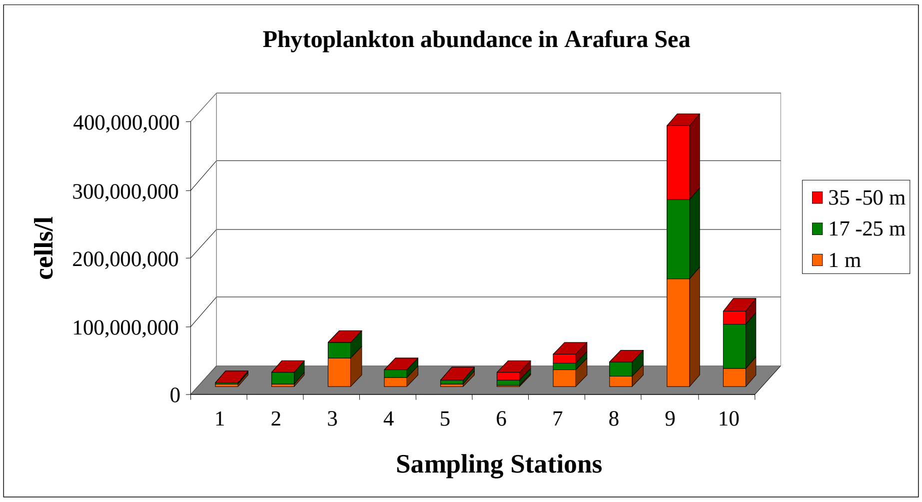



**Figure 6.24.** Phytoplankton concentrations in the Arafura Sea

The phytoplankton concentrations in the Arafura Sea indicate that the waters are eutrophic, meaning too fertile for phytoplankton growth. This is due to the large inputs of nutrients from the rivers. When the phytoplankton abundance is high, the seas tend to have high productivity, a positive relation between abundance and fertility of the sea (Raymont, 1963). The range of abundance reflects the phytoplankton community structure, as shown in Figure 6.25.

## Diversity Index

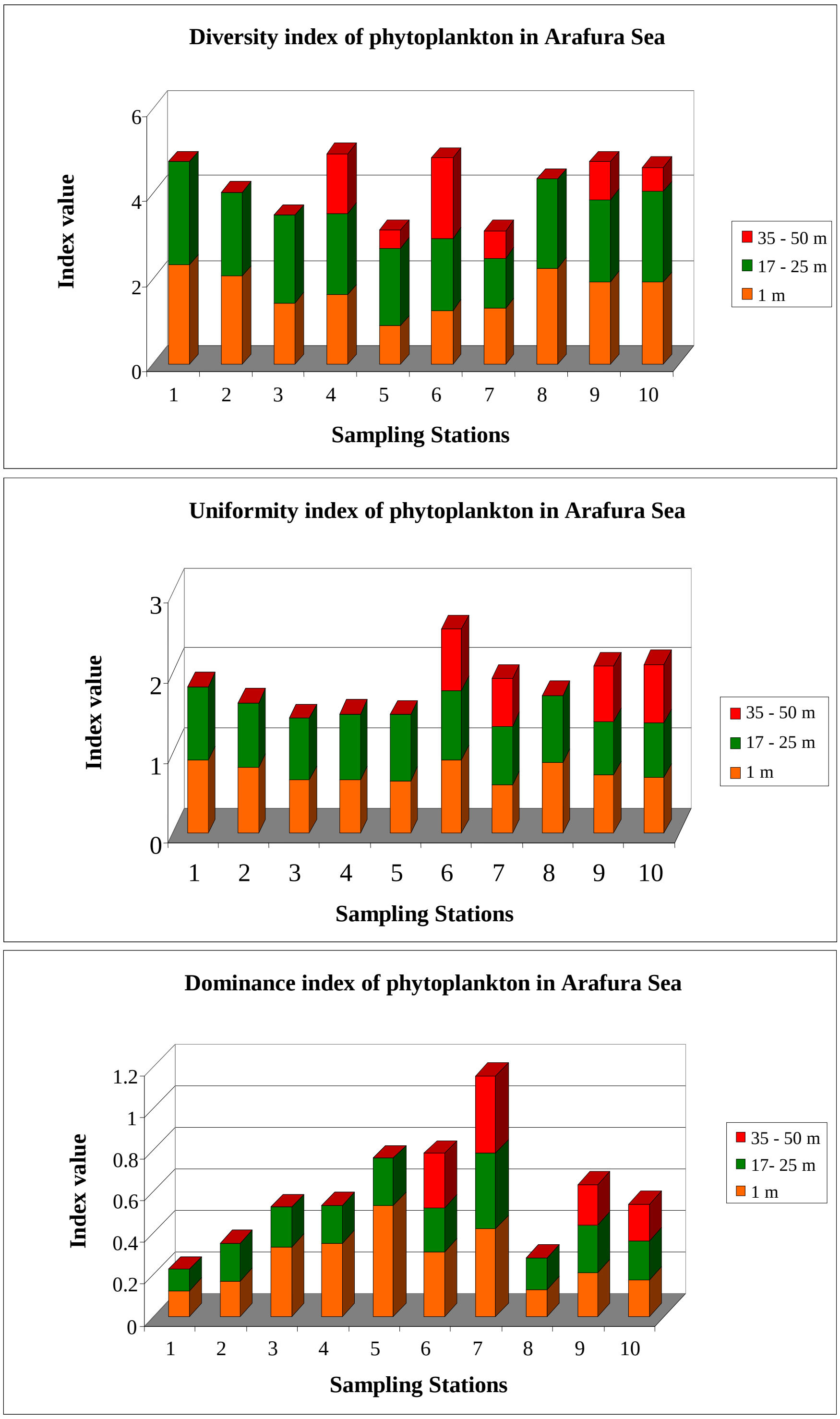



**Figure 6.25.** Phytoplankton community structure in the Arafura Sea

The phytoplankton community structure in the Arafura Sea has an average diversity index range of 1 to 2, a uniformity index of 1 and a dominance index of 0.1 to 0.3. Based upon the values of the indices, the diversity of phytoplankton in the Arafura Sea is of a medium value, with a moderate distribution of total individuals, resulting in a plankton community of medium stability. The total population of phytoplankton from each genera does not differ much from one genera to the next, therefore no one genera dominates the Arafura Sea. However, there is an ecological pressure from sedimentation which can cause a decrease in water clarity.

## Vertical distribution of phytoplankton in Arafura Sea

The general trend of the phytoplankton vertical distribution shows a high concentration in the surface water, and an increase with depth (Figure 6.26). The increase of phytoplankton concentration at greater depths indicates that the light in the water column reaches fairly deep, even though the water clarity was low. Nutrient supply from the surrounding land enables the phytoplankton to grow optimally. The high phytoplankton abundance indicates a sea fertile and rich with marine biota and fish.

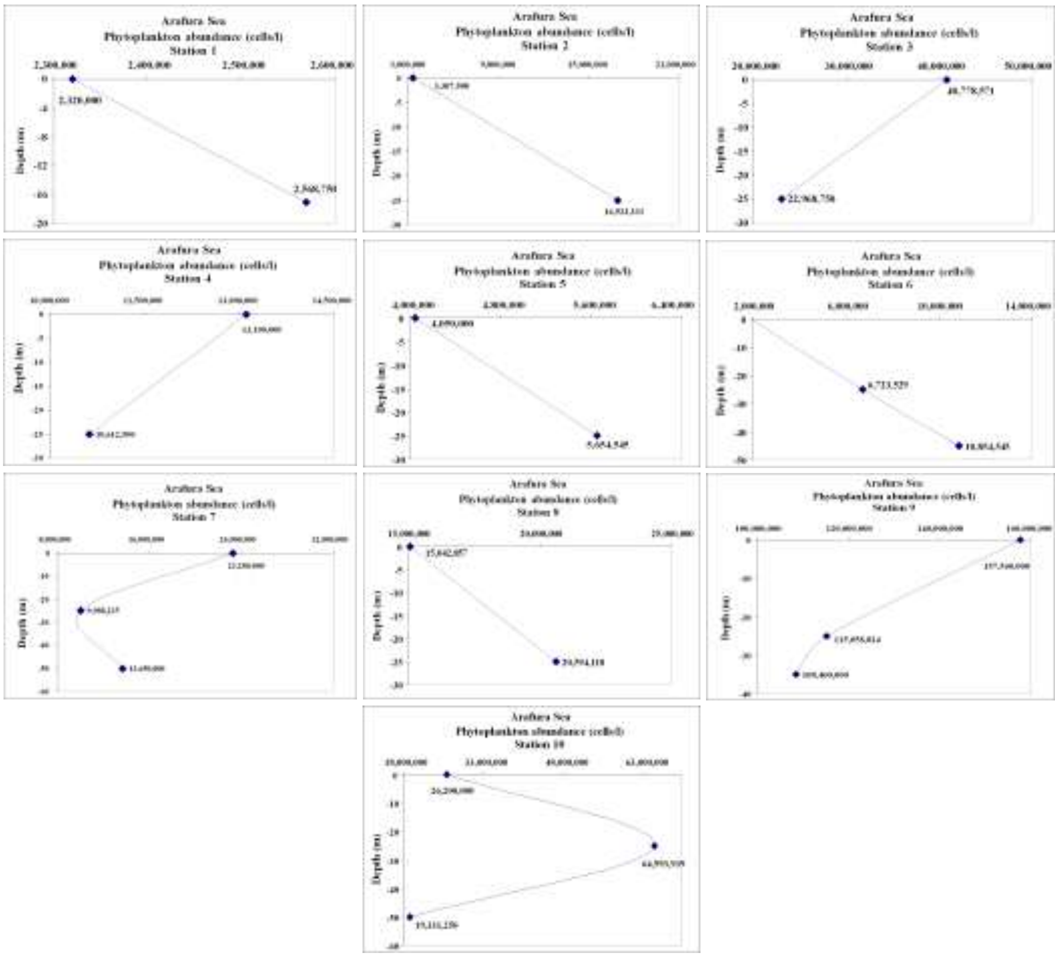
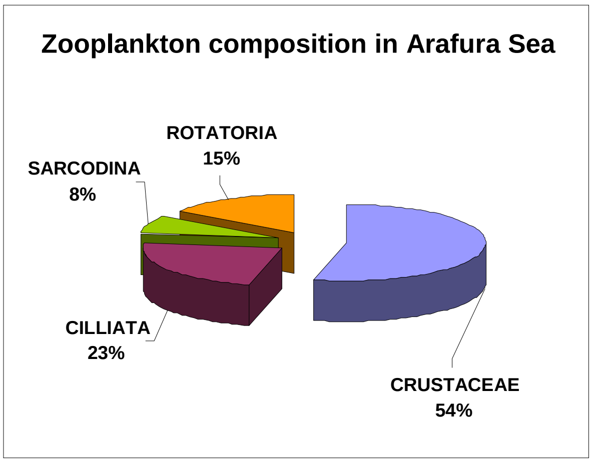


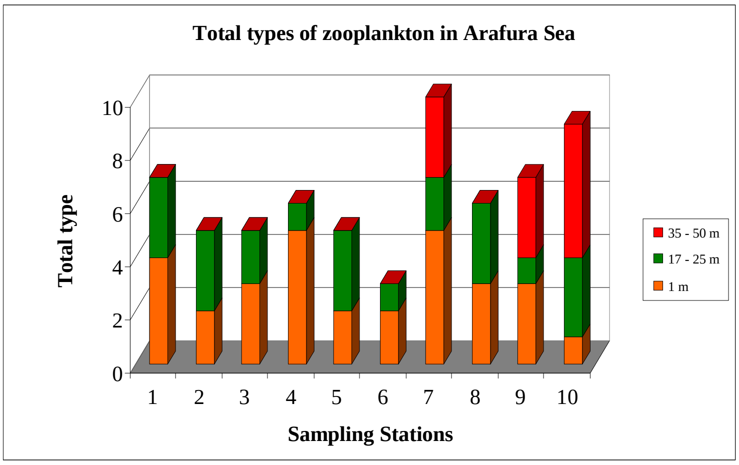

**Figure 6.26.** Vertical distribution of phytoplankton in the Arafura Sea

## Horizontal Distribution of Zooplankton in Arafura Sea

The composition of zooplankton in the Arafura Sea consists of 54% Crustacea (7 genera), 23% Cilliata (3 genera), 15% Rotatoria (2 genera) and 8% Sarcodina (1 genus). The composition and total number of zooplankton classes are shown in Figure 6.27.




(6.27.a)




(6.27.b)

**Figure 6.27.** Composition and total number of zooplankton classes in the Arafura Sea

The total number of zooplankton in the upper layer exceeds that of the deeper layer. The highest total numbers of the five classes occur at Stations 4 and 7 in the upper layer, followed by five genera at 35 to 50 m. These genera include the following: *Acartia*, *Calanus*, *Oithona*, *Codonellopsis*, *Tintinnopsis* and *Brachionus*.

The highest average zooplankton concentration occurs in the upper layer and ranges between 1.27 x $10^6$ cells/l and 2.31 x $10^6$ cells/l, with the highest value at Station 3. The average phytoplankton concentration decreases gradually in the deeper water; the concentration from 17 to 25 m is 4.47 x $10^5$ cells/l, and from 35 to 50 m, it is 1.88 x $10^5$ cells/l. The average zooplankton concentrations at the stations reflect the general concentrations in the Arafura Sea, and can be categorized as medium abundance. Zooplankton abundances are shown in Figure 6.28.

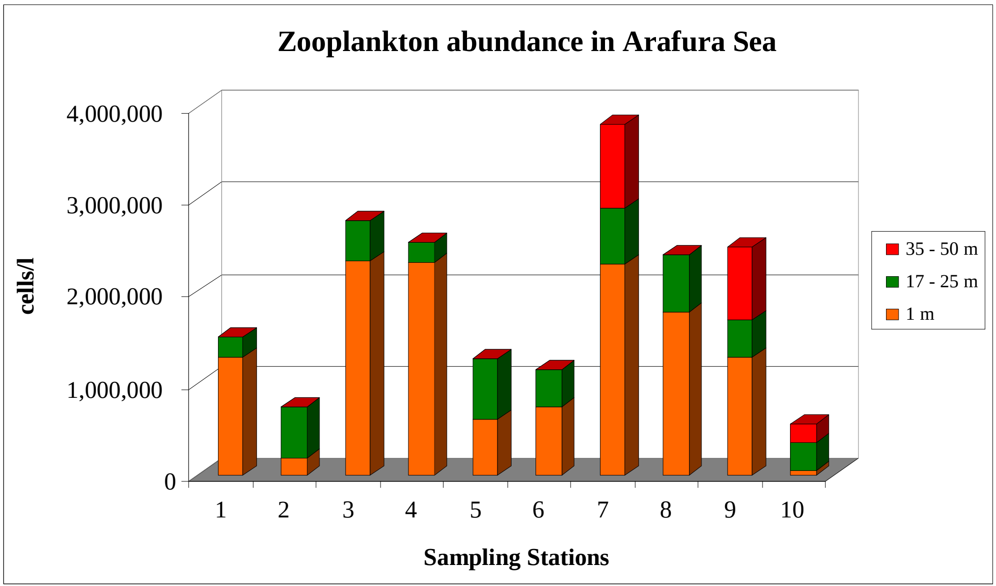



**Figure 6.28.** Zooplankton abundances in the Arafura Sea

An increase in phytoplankton concentration with depth, along with low zooplankton concentrations, may reflect the fact that the consumption of phytoplankton by the zooplankton is less than maximal. This condition may be related to the effect of temperature. Zooplankton are poikilothermic, and therefore their digestive, respiratory and reproductive systems are sensitive to temperature changes (Mulya, 2002).

The average diversity index indicates a medium value of 0.3 to 0.8; a uniformity index of 0.2 to 0.8 and a dominance index of 0.1 to 0.6. Community structure of zooplankton in the Arafura Sea is shown in Figure 6.29.

## Diversity Index

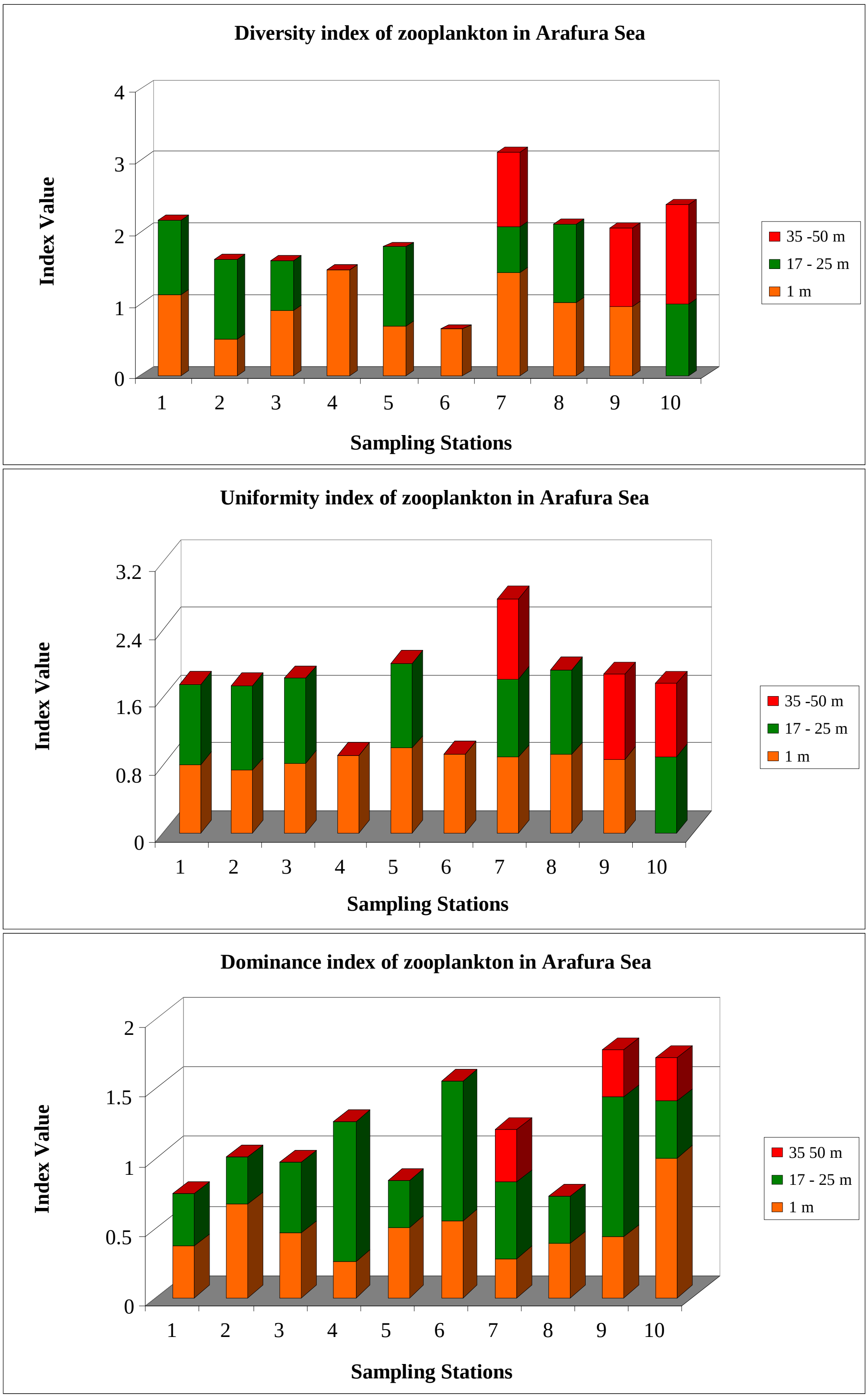



**Figure 6.29.** Zooplankton community structure in the Arafura Sea

Zooplankton diversity in the Arafura Sea is low and dominated by one genus, *Acartia*.

## Vertical distribution of zooplankton in the Arafura Sea

The vertical distribution of zooplankton is characterized by the high concentrations in the upper layer and a decrease in concentration with depth. The vertical distribution of zooplankton is shown in Figure 6.30.

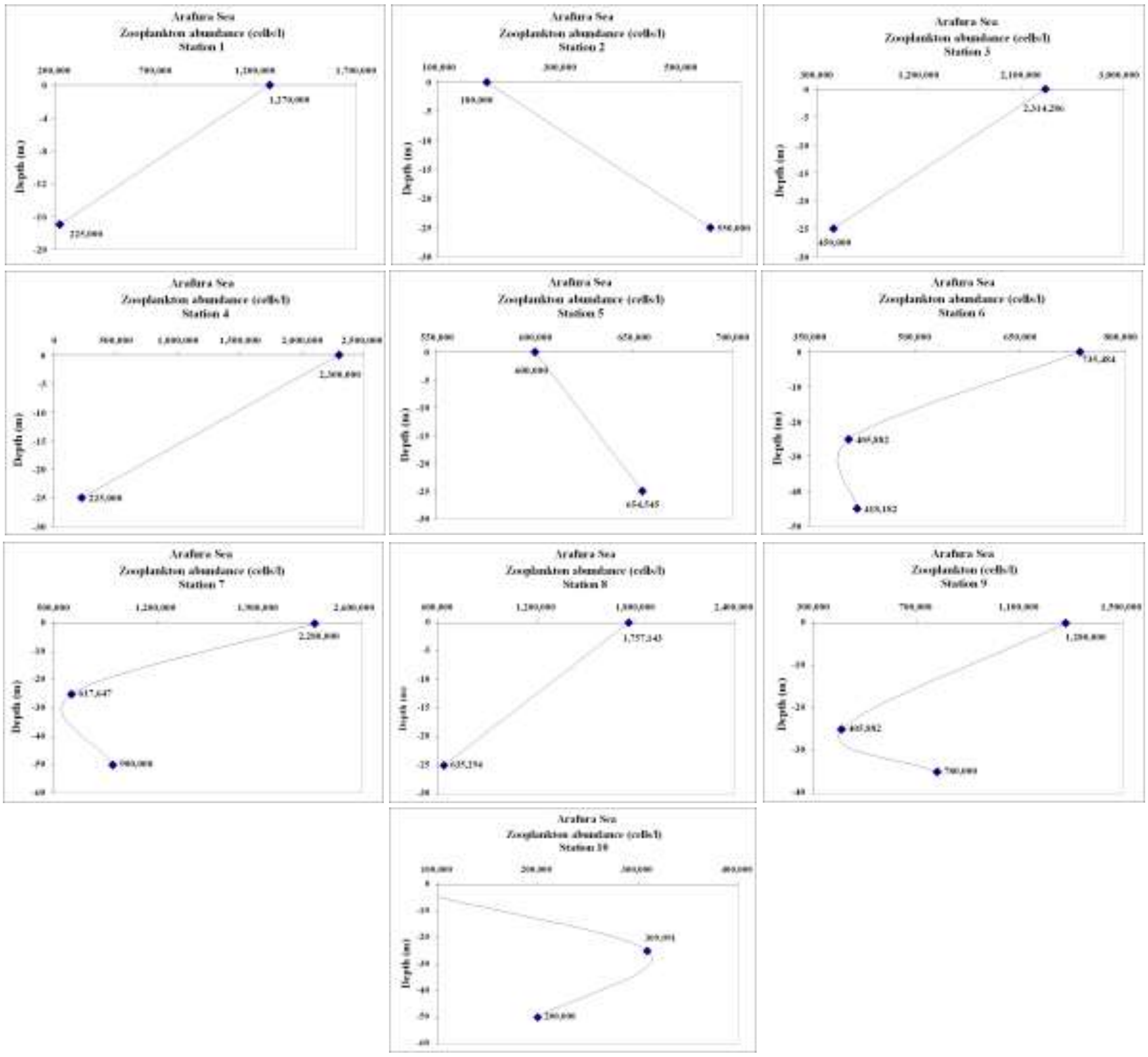



**Figure 6.30.** Vertical distribution of zooplankton in the Arafura Sea

## Nutrient content

### Nitrate ($NO_3^-$)

The average concentration of nitrate in the Arafura Sea ranges between 0.09 and 7.60 µg/l. A minimum value of 0.09 µg/l is found in the upper layer and the maximum value of 7.60 µg/l is observed at 40 m. Vertical distribution of nitrate is shown in Figure 6.31.

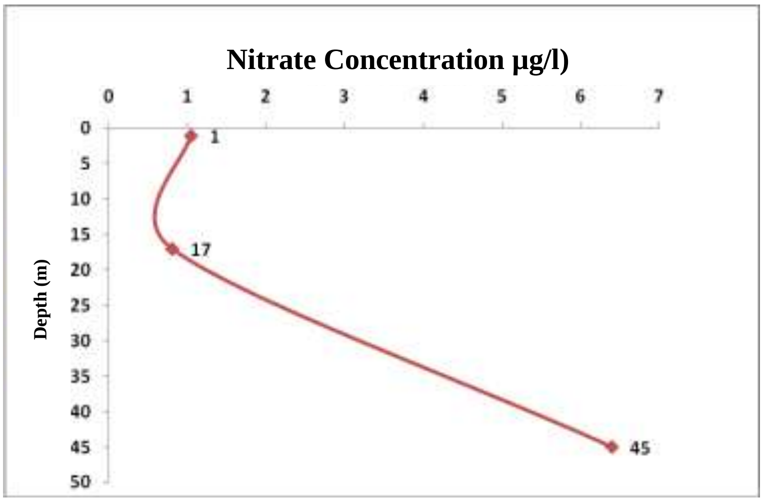



**Figure 6.31.** Vertical distribution of nitrate in the Arafura Sea

The vertical distribution of nitrate in the Arafura Sea from the surface layer down to the depth of 17 m is relatively homogeneous. Nitrate concentration increases significantly at deeper depth. This condition is probably related to settling and decomposition of organic matter at the bottom of the sea.

## Phosphate ($PO_4^-$)

The average phosphate concentration in the Arafura Sea ranges from 0.13 to 0.94 µg/l. A minimum value of 0.13 µg/l is present in the surface layer and the highest value of 0.94 µg/l is found at 40 m. A vertical distribution of phosphate in the Arafura Sea is shown in Figure 6.32.

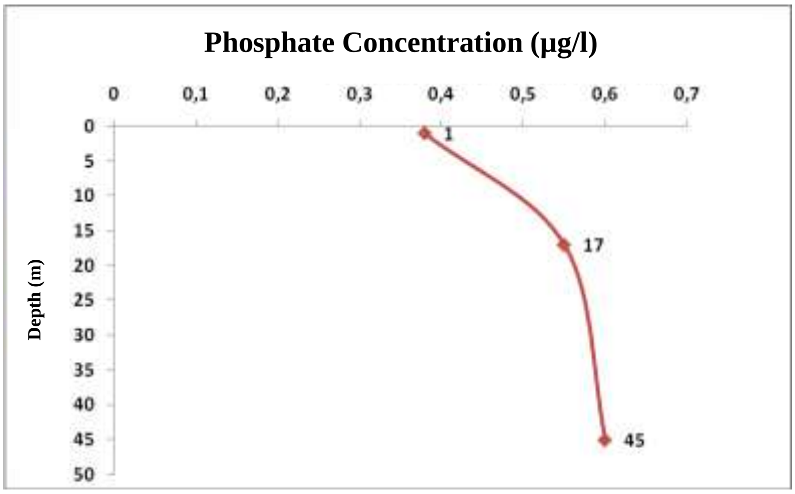



**Figure 6.32.** Vertical distribution of phosphate in the Arafura Sea

The vertical distribution of phosphate in the Arafura Sea, from the surface layer to depth of 45 m, is relatively homogeneous. The phosphate distribution tends to be homogeneous in both vertical and lateral directions, and therefore productivity levels in the Arafura Sea tend to be homogeneous both in vertical and lateral directions.

## Ammonium ($NH_3$)

The average concentration of ammonium in the Arafura Sea ranges from 0.38 to 5.75 μg/l. Both the minimum value of 0.38 μg/l and the maximum value of 5.75 μg/l are found in the surface layer. The vertical distribution of ammonium in the Arafura Sea is shown in Figure 6.33.

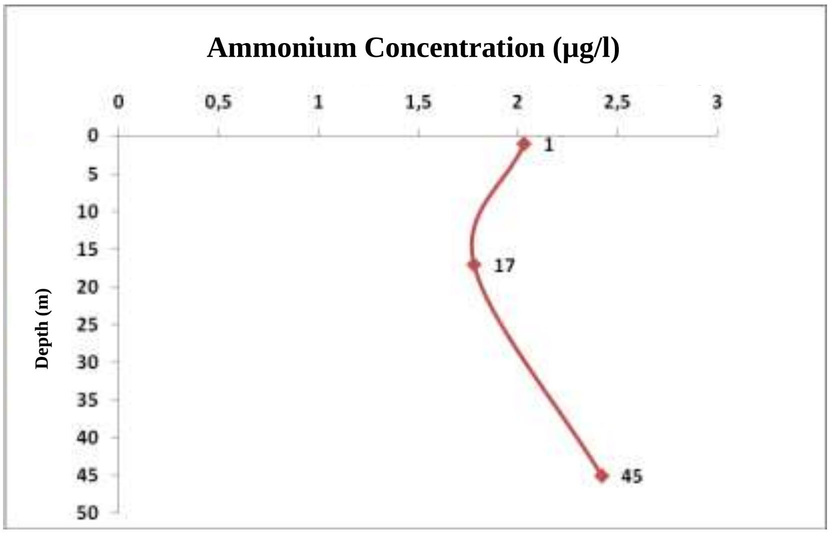



**Figure 6.33.** Vertical distribution of ammonium in the Arafura Sea

The distribution of ammonium is relatively homogeneous, probably due to the mixing of water masses, in addition to ammonium regeneration by plankton.

## Silicate ($SiO_2$)

The average silicate concentration in the Arafura Sea ranges from 5.90 to 17.49 μg/l. The minimum value of 5.90 μg/l is found in the surface layer and the highest value of 17.49 μg/l is found at 40 m. The vertical distribution of silicate in the Arafura Sea is shown in Figure 6.34.

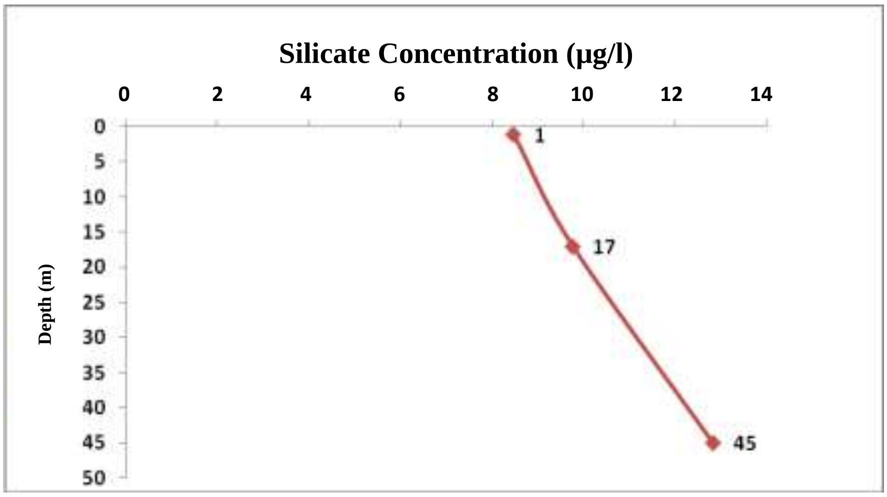



**Figure 6.34.** Vertical distribution of silicate in the Arafura Sea

The vertical distribution of silicate in the Arafura Sea shows that silicate content increases gradually from the surface layer to 45 m. Silicate concentration in the Arafura Sea was similar to the other nutrient species, all of which have a higher concentration at the bottom layer.

## 6.5. Conclusions

Based on the analysis of the concentrations of nutrients and chlorophyll-a, as well as plankton in the Arafura and Timor Seas, several conclusions can be drawn:

1. The chlorophyll-a concentration of 0.2 to 0.9 mg/m$^3$ in the Timor Sea was larger than that of the Arafura Sea (0.15 to 0.4 mg/m$^3$). The phytoplankton concentration range and community structure in the Timor Sea was lower than that of the Arafura Sea.

2. In general, chlorophyll-a, nitrate and phosphate concentrations in the Timor Sea are high at 25 m, suggesting higher primary productivity at this depth. However, the Arafura Sea shows a homogeneous level of productivity, both vertically and laterally, due to the homogeneous distribution of chlorophyll-a and nutrients. The latter may well be due to well mixed conditions in the Arafura Sea.

3. Observations indicate that the Arafura Sea has an above-average level of phytoplankton productivity.

Chapter VII

# DISTRIBUTION OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) AND HEAVY METALS IN COASTAL WATERS OF TIMOR SEA

**Dede Falahudin[1], Zainal Arifin[1], Tonny Wagey[2]**

[1]Research Centre for Oseanography (RCO) – LIPI
Email : *dfalahudin@yahoo.com*

[2]Arafura Timor Sea Ecosystem Action (ATSEA) Program

## 7.1. Introduction

The Timor Sea, in the southeast of Timor Island, has unique characteristics because it covers the Sahul continental shelf of northwest Australia, part of the Timor shelf and the Timor Through which reaches depths of over 3, 300 m (10, 800 feet) (Wagey and Arifin, 2008). The Timor Sea is the site of important oil fields, and there have been explorations for deposits on the Sahul Shelf off the northwest coast of Australia (Morrison and Delaney, 1996). Oil drilling activities, and related industries, may cause contamination of the waters by materials such as heavy metals and persistent organic pollutants (POPs). These contaminants could have potential impacts to marine resources. On August 21, 2009 the explosion of the Montara oil field caused oil to spill into the Timor Sea. The existence of this oil contamination, and other related organic pollutant, could have lead to the accumulation of various compounds which are toxic, persistent, bioaccumulative, and pose a significant risk to aquatic ecosystems and human health.

Polycyclic aromatic hydrocarbons (PAHs), made up of two or more benzene rings, resist oxidation, are hydrophobic in nature and are ubiquitous, persistent pollutants in environmental contaminants (Zakaria *et al*., 2009). Aqueous solubility, vapor pressure and partition coefficient of octanol-water and organic carbon-water may be an important factor influencing environmental behavior of the PAH compounds. PAHs with high molecular weight have significant toxicities.

The characterization of PAH compounds were conducted in order to determine their sources and to asses their migrations (Hiller *et al*., 2010). There are several approaches in determining PAH sources, such as the use of a unique compound as a molecular marker or by using the differences in thermodynamic stabilities among PAH species to distinguish between pyrogenic and petrogenic PAHs (Saha *et al*., 2009). Several researchers have used ratio diagnostic models, based on the differences in the thermodynamic stabilities of PAHs, to determine the origins of these compounds in water sediments, and biota; principal component analysis (PCA) and hierarchical cluster analysis (HCA) are used to clarify individual PAHs from several sources of PAH (Yunker and Macdonal, 1995; Wenchuan, 2002; Yunker *et al*., 2002; Mostafa, 2003; Jinshu, 2004, Nemr *et al*., 2004; Nemr *et al*., 2006; Opuene, 2009; Jun Luo, 2008; Grigoriadou, 2008; Hiller *et al*., 2010).

The objective of this study is two fold: firstly, to detect and identify PAH compounds and heavy metals in seawater and sediment samples from the Timor Sea, and secondly to identify PAH sources in the seawaters samples.

## 7.2. Materials and Methods

### Study Area

The field study was carried out during the ATSEA cruise on May 10 to 27, 2010. Twelve PAH samples were taken from surface water at Stations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, and 13, and two samples were collected from surface sediments at Stations. 12 and 13. Heavy metal samples were taken from 21 water samples (Stations 1 to 23) and 11 sediment samples (Stations 12 to 23)(Figure 7.1, Table 7.1).

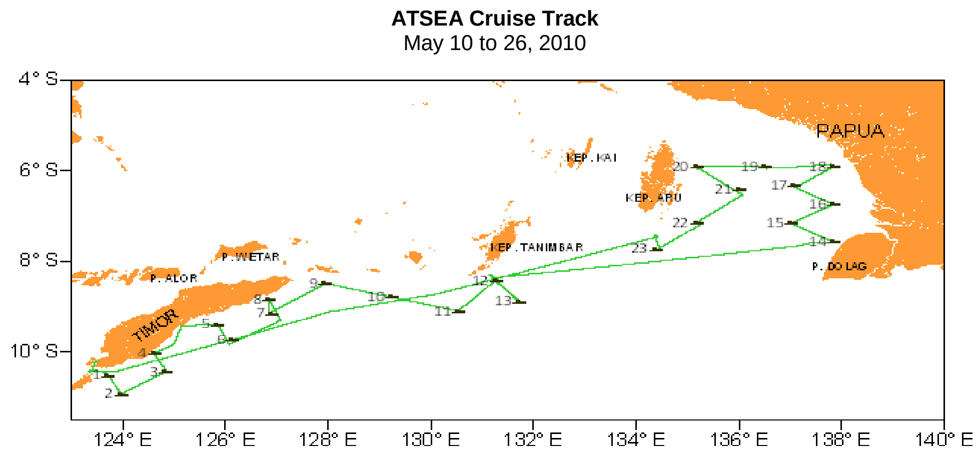



**Figure 7.1.** Location of sampling stations during the ASEA Cruise, 2010 (Stations 1 to 13)

**Table 7.1.** Water and sediment samples collected from the ATSEA Cruise

| No | Station | Position | | Depth (m) | Time of Sampling | | Sample | |
|---|---|---|---|---|---|---|---|---|
| | | Latitude (S) | Longitude (E) | | Date | Time (GMT) | Water | Sediment |
| 1 | Station 1 | 10°31.011' | 123°43.963' | 272 | 10-May-10 | 18:24 | X o | |
| 2 | Station 2 | 10°55.485' | 123°58.057' | 2000 | 10-May-10 | 23:16 | X o | |
| 3 | Station 3 | 10°25.902' | 123°51.090' | 1939 | 11-May-10 | 9:34 | X o | |
| 4 | Station 4 | 10°01.727' | 124°37.184' | 746 | 11-May-10 | 15:09 | X o | |
| 5 | Station 5 | 09°23.029' | 125°50.942' | 1007 | 12-May-10 | 7:08 | X o | |
| 6 | Station 6 | 08°50.899' | 126°51.487' | 583 | 13-May-10 | 7:17 | X o | |
| 7 | Station 7 | 09°09.055' | 126°51.623' | 1589 | 13-May-10 | 10:00 | X o | |
| 8 | Station 8 | 08°29.229' | 127°56.967' | 2016 | 13-May-10 | 20:35 | X o | |
| 9 | Station 9 | 08°47.405' | 129°14.310' | 1615 | 14-May-10 | 9:40 | X o | |
| 10 | Station 10 | 09°05.925' | 130°32.074' | 633 | 14-May-10 | 21:45 | X o | |
| 11 | Station 12 | 08°25.007' | 131°16.029' | 1506 | 15-May-10 | 7:17 | X o | X o |
| 12 | Station 13 | 08°53.266' | 131°43.331' | 339 | 15-May-10 | 15:38 | X o | X o |
| 13 | Station 14 | 07°34.590' | 137°$^{5}$0.722' | 19 | 18-May-10 | 13:43 | o | o |
| 14 | Station 15 | 07°09.705' | 137°00.500' | 35 | 19-May-10 | 1:09 | o | o |
| 15 | Station 16 | 06°44.641' | 137°50.604' | 29 | 19-May-10 | 11:23 | o | o |
| 16 | Station 17 | 06°19.758' | 137°05.383' | 35 | 19-May-10 | 22:38 | o | o |
| 17 | Station 18 | 05°54.806' | 137°50.616' | 37 | 20-May-10 | 8:50 | o | o |
| 18 | Station 19 | 05°54.738' | 136°30.347' | 48 | 20-May-10 | 23:40 | o | o |
| 19 | Station 20 | 05°54.711' | 135°10.184' | 57 | 21-May-10 | 14:46 | | |
| 20 | Station 21 | 06°24.776' | 136°00.283' | 35 | 22-May-10 | 1:49 | o | o |
| 21 | Station 22 | 07°08.750' | 135°10.350' | 38 | 22-May-10 | 13:36 | o | o |
| 22 | Station 23 | 07° 43.841' | 134°22.470' | 59 | 23-May-10 | 1:23 | o | o |

Note: X = PAH sampling , o = heavy metals sampling

## 7.3. PAH Analysis

Surface water samples were taken using a stainless steel water sampler at a depth of less than 1.0 meter, and were stored in dark bottles of 2.5 L volume. The water samples were immediately filtered using 0.45 µm glass fiber filters (Whatman GF/C), and extracted by liquid-liquid partition with hexane pro analysis (p.a.) using a separatory funnel in three steps with volumes of 60, 30 then 30 ml. Upon completion of the extractions, the raw extract samples were stored at 4 ºC during transport to laboratory for analysis (Hutagalung, 1997). Sediment samples collected using a box core, were scooped into glass bottles with an aluminum spoon, covered with aluminum foil and then stored in a refrigerator at 4 $^{o}$C for analysis in laboratory.

PAHs were determined at the laboratory as follows: the raw extracts were dried by washing with $Na_2SO_4$, and then evaporated until 1 mL. Furthermore, 40 g of each sediment sample was dried in the oven at 50 $^{\circ}$C overnight, pureed, mushed in a mortar, and $Na_2SO_4$ was added to remove any water residues. They were then extracted in a Soxhlet extractor for 8 hours with 120 mL dichloromethane (DCM). The raw sediment extracts were evaporated until 1 ml. The concentrated extracts from the water and sediments samples were then cleaned by using alumina chromatography column cleanup technique with 4 g of aluminum oxide WB 5 basic SIGMA. The column was conditioned before use by eluting with 10 mL DCM and hexane. After that, a concentrated extract was transferred into the column, eluted with 4% diethyl ether in hexane and evaporated again until 1 mL.

The cleaned samples were separated and fractionated using silica gel chromatographic column with 4g Merck 7754 silica gel. This column was pre-conditioned with 10 mL DCM and hexane. Non-polar fraction (F1) was eluted with hexane for analysis of pesticides and saturated hydrocarbons; and polar fraction (F2) by 10% diethyl ether in hexane for analysis of PAHs. The polar fraction (F2) was analyzed using GC/FID (gas chromatography-flame ionization detector) method. The GC/FID separation is done through HP1 capillary column ( 12 m x 0.2 mm I.D., 0.33

µm film thickness) with a GC oven temperature program, i.e. oven temperature of 60 ºC for 2 min, heated to 280 ºC at 10 ºC/min, and then held for three minutes at 300 ºC. Injector temperature was 240 ºC with helium as a carrier gas. The GC-FID was calibrated with QTM PAH standard mixture (QTM PAH mix 47930-U Supelco). By utilizing this method, 15 PAH compounds were determined including naphthalene (Naph), acenaphthylene (Acethy), acenaphthene (Ace), fluorene (Fl), phenanthrene (Phe), anthracene (Ant), fluoranthene (Flu), pyrene (Pyr), benzo(a)anthracene (BaA), chrysene (Chr), benzo(b)fluoranthene (BbF), benzo(a)pyrene (BaP), indeno(123-cd)pyrene (InP), dibenzo(ah)anthracene (DBA), and benzo(ghi)pyrylene (BghiP) (EPA Methods 8001, 1986; Holden and Marsden, 1969; Greve and Grevenstuk, 1975; Duinker and Hillebrand, 1978).

Data analysis included calculating the concentrations of total and individual PAH compounds, identification of the composition of the diagnostic ratio, performing a principal component analysis (PCA), and hierarchical cluster analysis (HCA) using SPSS version 16.00. A diagnostic ratio to assess the PAH sources was done by using the ratio of Phe/Ant, Flu/Pyr, InP/ (InP + BghiP), Flu/ (Flu + pyr), BaP/(Bap + Chr), Ant/ (Ant + Phe), Ant/178 and BaA/228 (Yunker and Macdonal, 1995**;** Yunker *et al*., 2002).

## 7.4. Heavy metals analysis

Water samples for heavy metal analysis were taken using a rossette water sampler. One liter water samples were inserted into polyethylene bottles and stored in a cool box at approximately 4$^{o}$C and then filtered with 0.45µm cellulose nitrate filter paper. The filtrate was placed in polyethylene bottles and mixed with $HNO_3^+$ to a pH <2. Sediment samples were taken from a box core between 0 and 10 cm from the sediment surface, then 250g of each sample were placed in polyethylene bottles and stored in a cool box at 4$^{o}$C. Water determination was based on Hutagalung *et al*. (1997) and sediment analysis was done based on USEPA (1996) methods.

## 7.5. Results

### 7.5.1. Distribution of PAHs in surface seawater

A total of 15 compounds of US-EPA pollutant priority PAHs are found in the surface seawater; the samples range between 54.46 and 213.70 µg/l, with an average of 99.75 µg/l (Table 7.2).

**Table 7.2.** Concentration (µg/l) of PAH compounds in the Timor Sea

| PAH Compound | | Sta 1 | Sta 2 | Sta 3 | Sta 4 | Sta 5 | Sta 6 |
|---|---|---|---|---|---|---|---|
| Naphthalene | Naph | 0.33 | nd | 0.33 | 0.29 | 0.27 | 0.26 |
| Acenaphthylene | AceThy | nd | nd | nd | Nd | nd | Nd |
| Acenaphthene | Ace | 0.32 | 0.34 | 0.27 | 0.27 | 0.33 | 0.26 |
| Fluorene | Fl | 0.22 | nd | nd | nd | nd | Nd |
| Phenanthrene | Phe | 0.34 | nd | 0.27 | nd | 0.33 | 0.27 |
| Anthracene | Ant | 0.93 | 2.53 | 2.17 | 2.12 | 2.1 | 2.01 |
| Fluoranthene | Flu | 5.83 | 4.49 | 0.72 | 3.65 | 6.61 | 4.44 |
| Pyrene | Pyr | 9.87 | 4.95 | 0.86 | 3.42 | 4.88 | 4.53 |
| Benzo(a) Anthracene | BaA | 17.49 | 12.25 | 3.00 | 9.25 | 11.78 | 12.95 |
| Chrysene | Chr | 42.71 | 19.33 | 11.46 | 13.36 | 19.2 | 20.61 |
| Benzo(b)Fluoranthene | BbF | 32.05 | 7.04 | 14.81 | 6.29 | 8.23 | 9.6 |
| Benzo(a) Pyrene | BaP | 18.58 | 11.73 | 28.49 | 12.44 | 15.05 | 16.86 |
| Indeno(123-cd) Pyrene | DBahA | 46.6 | 12.48 | 23.38 | 11.16 | 11.02 | 11.85 |
| Dibenzo(ah)Anthracene | InP | 23.66 | 13.73 | 32.34 | 16.57 | 18.37 | 21.90 |
| Benzo(ghi) Pyrylene | BghiP | 14.79 | 4.06 | 9.46 | 2.77 | 2.37 | 5.57 |
| Total PAH | | **213.70** | **92.92** | **127.55** | **81.60** | **100.51** | **111.11** |

| PAH Compound | | Sta 7 | Sta 8 | Sta 9 | Sta 10 | Sta 12 | Sta 13 |
|---|---|---|---|---|---|---|---|
| Naphthalene | Naph | 0.26 | 0.49 | 0.52 | 1.09 | 1.10 | 1.19 |
| Acenaphthylene | AceThy | nd | nd | nd | 0.28 | 0.22 | 0.29 |
| Acenaphthene | Ace | 0.32 | 0.25 | 0.30 | 0.26 | 0.26 | 0.32 |
| Fluorene | Fl | nd | nd | nd | 0.39 | 0.33 | 0.50 |
| Phenanthrene | Phe | 0.32 | nd | nd | 0.59 | 0.42 | 0.64 |
| Anthracene | Ant | 2.23 | 2 | 2.81 | 2.84 | 2.77 | 3.35 |
| Fluoranthene | Flu | 5.67 | 5.64 | 3.19 | 3.78 | 6.00 | 4.30 |
| Pyrene | Pyr | 5.38 | 4.05 | 3.44 | 3.27 | 4.32 | 3.71 |
| Benzo(a) Anthracene | BaA | 15.61 | 9.13 | 10.93 | 8.49 | 12.28 | 9.96 |
| Chrysene | Chr | 25.78 | 10.73 | 14.72 | 9.54 | 17.55 | 14.52 |
| Benzo(b)Fluoranthene | BbF | 12.88 | 2.79 | 5.36 | 3.37 | 5.47 | 3.99 |
| Benzo(a) Pyrene | BaP | 22.03 | 7.78 | 11.03 | 8.05 | 9.28 | 8.14 |
| Indeno(123-cd) Pyrene | DBahA | 15.74 | 3.82 | 6.06 | 2.84 | 6.68 | 5.63 |
| Dibenzo(ah)Anthracene | InP | 27.02 | 9.15 | 12.19 | 9.68 | 13.67 | 10.83 |
| Benzo(ghi) Pyrylene | BghiP | 5.18 | nd | nd | nd | nd | 2.65 |
| Total PAH | | **138.4** | **55.85** | **70.55** | **54.46** | **80.33** | **70.02** |

Note : nd = not detected

The highest average total abundance of PAH compounds in the Timor Sea are: benzo(b)fluoranthene (BbF = 9.323 µg/l), benzo(a)anthracene (BaA = 11.039 µg/l), dibenzo(ah)anthracena (DbahA = 13.105 µg/l),benzo(a)pyrene (BaP = 14.122 µg/l), indeno(123-cd)pyrene (InP = 17.426 µg/l), and chrysene (Chr = 18.293 µg/l) (Figure 7.2).

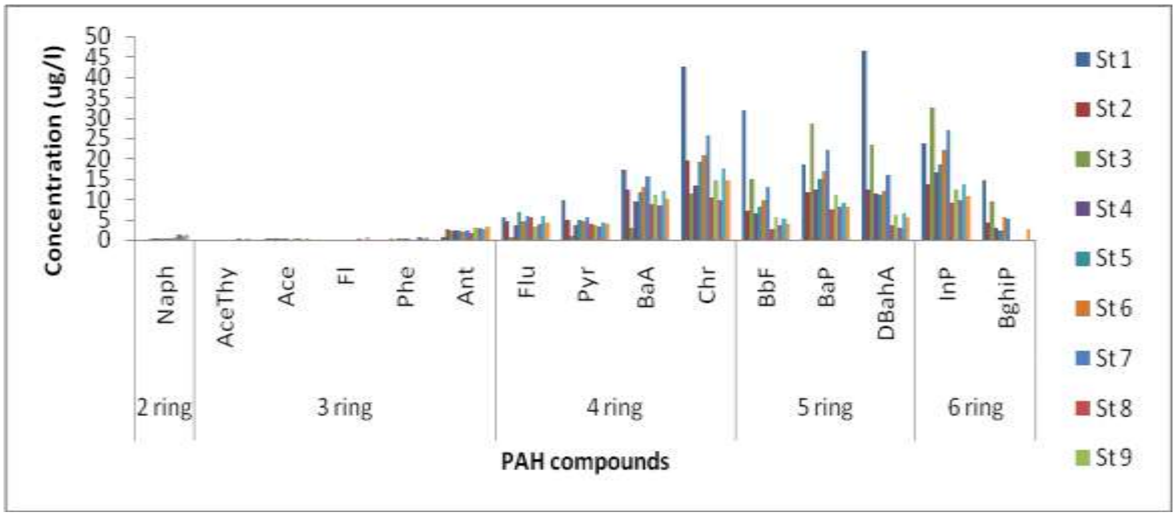



**Figure 7.2.** Distribution of individual PAH concentrations in the Timor Sea

### 7.5.2. Distribution of PAHs in sediments

PAHs in the sediment were determined from surface sediment samples from Stations 12 and 13. Total concentration of PAHs from the sediment samples range between 23.63 and 24.5 mg/kg dry weight (dw), with an average concentration of 24.06 mg/kg dw. The concentration of PAHs in the sediments were dominated by a carcinogenic PAH with a high molecular weight and similar characteristics as the surface seawater. Four PAH compounds in the sediments were relatively high in concentration, including anthracene (7.19 mg/kg), chrysene (8.11 mg/kg), benzo(a)pyrene (4.85 mg/kg), and indeno(123-cd)pyrena (12.21 mg/kg) (Figure. 7.3).

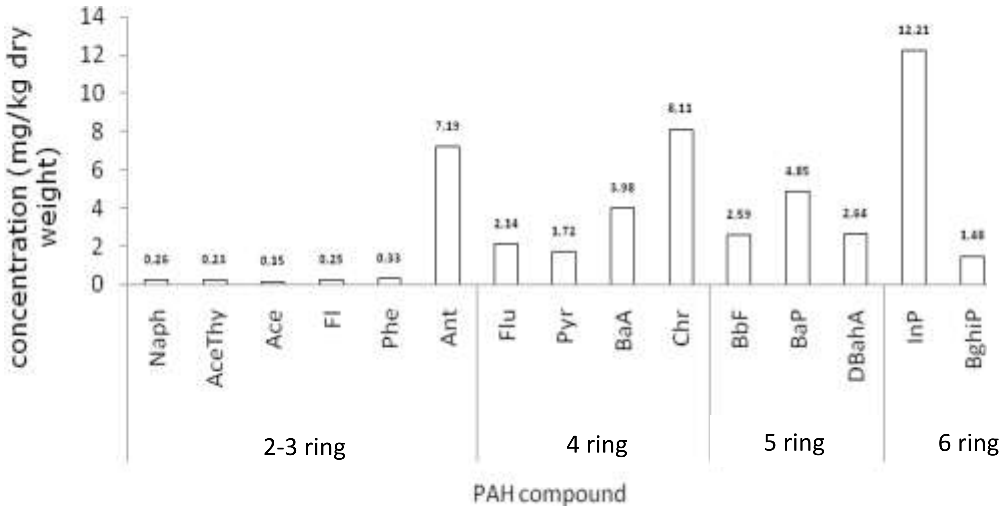



**Figure 7.3.** Distribution of total concentration of PAH in sediments from Stations 12 and 13

### 7.5.3. PAH concentration in other locations

PAH concentrations in the Timor Sea are compared to other pristine and dense areas. PAH concentrations in pristine areas, such as.the Atlantic region, are generally from 0.00006 to 0.0005 µg/l (6 x $10^{-5}$ to 50 x $10^{-5}$ µg/l). The PAH concentration in Lampung Bay (Stations 12 and 13) is 110.7 µg/l, significantly higher than that of the Atlantic region. This may be because PAHs in the area around the Lampung Bay come from many industrial activities that use fuel oil and from marine transportation activities (Munawir, 2008). Total concentration of PAHs in the Timor Sea were lower compared to the PAH concentrations in the waters of Rhode Island, United States, which was polluted by oil from the North Cape oil spill in 1996 (Table 7.3). The reason that PAH concentrations in the Timor Sea are lower than expected may be due to the great distance between it and the oil spill in Montara. Nevertheless, the Timor Sea region is very vulnerable considering the presence of sea storms and hurricanes that affect oil spill distribution, causing contamination in the coastal waters of Timor Island.

**Table 7.3**. Worldwide concentrations of total PAHs in seawater and sediments

| No | Area | Year of study | Total concentration of PAH | | References |
|---|---|---|---|---|---|
| | | | Seawater (µg/l) | Sediment (mg/kg) | |
| 1 | Timor Sea coastal waters | May, 2010 | 54.46-213.70 (99.75) | 23.63-24.50 (24.06) | present study |
| 2 | South Atlantik region | 2008 | 0.00006-0.0005 | - | Nizzetto at el. (2008) |
| 3 | Biscay bay, France | | 0.0007–0.001 | - | |
| 4 | Lampung Bay waters | 2008 | 5.52-411.69 (110.17) | 0.20-0.01 (0.32) | Munawir (2008) |
| 5 | Klabat-Bangka Bay waters | March, 2006 | 0.38-44.49 (7.47) | 0.03-0.21 (0.11) | Munawir (2007) |
| | | July, 2006 | 1.33-27.83 (15.2) | 1.00-4.79 (1.93) | |
| 6 | Sangatta coastal waters, Kaltim | 1999 | - | 6.28-8.45 | Razak (1996) |
| | Balikpapan coastal waters, Kaltim | | - | 0.10-4.32 | |
| 7 | Rhode Is., USA | 1996 | 115 | - | Reddy (1999) |

### 7.5.4. Sources of PAH contamination

The identification of PAH sources is imparative to the management of water quality, and for reducing the threat of PAH pollution. The objective of PAH source identification is to differentiate between petrogenic and pyrogenic sources, which is relevant considering the impact of PAH accumulation in aquatic life. Petrogenic PAHs are small molecular weight compounds, and may be more available for biological uptake than pyrogenic PAHs. with high molecular weights. There are several tools to identify PAH sources, including unique molecular compound markers, or diagnostic ratios (Saha *et al*., 2009). The diagnostic ratio method is based on the difference in thermodynamic stability among PAH species, and therefore distinguishing between natural and anthropogenic sources. PAH isomer ratio of the principal mass m/z = 178 (Ant/178, Phe/Ant, Ant/(Ant+Phe)), m/z = 202 (Flu/(Flu+Pyr), Flu/Pyr) and alkyl are used to distinguish petroleum from combustion; m/z = 228 (BaA/228), and m/z = 276 (InP/(InP+BghiP)) are used to corroborate the identification of combustion sources, 1.7/(2.6 + 1.7-DMP) is associated with wood combustion, and other applied PAH compounds ratio like BaP/(BaP+Chr) (Yunker *et al*., 2002; Nemr, 2006).

Based on the PAH isomer ratios determined by Yunker *et al*. (2002), PAHs m/z 178 and m/z 202 are generally used to distinguish between combustion and petroleum sources. An An/178 ratio < 0.10 indicates petroleum source while a ratio > 0.1 reflects the dominance of combustion; a ratio = 0.1 represents mixture of petrogenic and pyrogenic source. A Phe/Ant ratio > 10 indicates petroleum sources and a ratio of < 10 for combustion sources; Ant/(Ant+Phe) ratio of <0.1 usually indicates petroleum source, and a ratio >0.1 indicates the combustion of diesel oil, shale oil, coal, and/or crude oil. Flu/Pyr ratio <1 reflects a petroleum source and the ratio >1 for combustion sources; Flu/(Flu+Pyr) <0.4 implies petroleum (crude oil samples, but for Australian crude oil is >0.4), 0.4-0.5 implies petroleum combustion (vehicle, crude oil, gasoline, diesel, fuel oil, emisions from cars and diesel trucks), whereas ratios > 0.5 reflects kerosene, grass, wood, coal combustions, and creosote. A BaA/228 ratio less than 0.2 indicates a petroleum source, whereas the ratio of 0.2 to 0.35 indicates either a petroleum or combustion source; a ratio > 0.35 implies combustion. InP/(InP+BghiP) ratios <0.2 reflect petroleum sources, the ratio between 0.20 to 0.50 indicates liquid fossil fuel (vehicle and crude oil) combustion, while the ratio > 0.50 is associated with grass, wood soot, creosote, and coal combustion. The last ratio is BaP/(BaP+Chr); less than 0.2 represents combustion, between 0.4 to 0.6 reflects a mixture of petroleum and combustion, and between 0.6 to 0.9 is for petroleum sources (Yunker *et al*. 2002; Opuene, 2009; Hiller *et al*., 2010). PAHs with molecular masses between 228 and 276 g/mol were also used for the identification of PAH sources.

The results of diagnostic ratio shown in Table 7.4 indicate that at Station 1, the most common PAH sources are from petroleum and petroleum combustion. These PAH sources are inferred from the biplot analysis of Ant/178 vs Flu/(Flu+Pyr), BaA/228 vs Flu/(Flu+Pyr), BaP/(BaP+Chr), Ant/(Ant+Phe) vs Flu/(Flu+Pyr), BaA/(BaA+Chr) vs Flu/(Flu+Pyr), and from BaP/(BaP+Chr) vs Ant/(Ant+Phe); and partly reflects the source of combustion from the analysis of Inp/(Inp+BghiP) vs Flu/(Flu+Pyr), Inp/(Inp+BghiP) vs Ant/(Ant+Phe), and BaP/(BaP+Chr) vs Inp/(Inp+BghiP). As already described, the ratio of Inp/(Inp+BghiP) and Flu/(Flu+Pyr) indicate a combustion product.

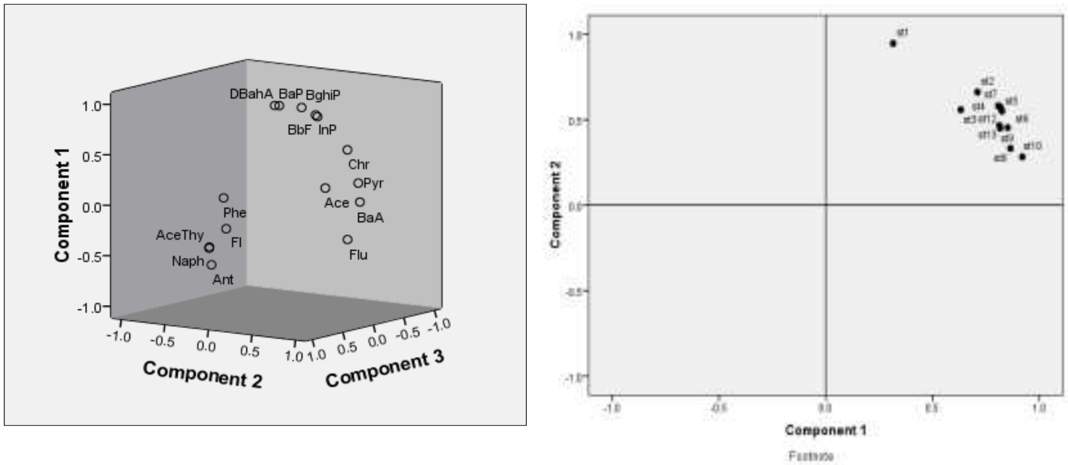
**Table 7.4.** Diagnostic ratio of PAH compounds in seawater and sediment from the Timor Sea

| Station/ Ratio | Ant/178 | | Phe/Ant | | Ant/(Ant+Phe) | | Flu/(Flu+Pyr) | | FluPyr | | BaA/228 | | InP/(InP+BghiP) | | BaP/(BaP+Chr) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sta 1 | 0.01 | P | 0.36 | CM | 0.73 | CPP | 0.37 | P | 0.59 | P | 0.1 | P | 0.62 | CM | 0.3 | CM |
| Sta 2 | 0.01 | P | NA | NA | 1 | CPP | 0.48 | CPP | 0.91 | P | 0.1 | P | 0.77 | CM | 0.38 | CP |
| Sta 3 | 0.01 | P | 0.12 | CM | 0.89 | CPP | 0.46 | CPP | 0.84 | P | 0 | P | 0.77 | CM | 0.71 | P |
| Sta 4 | 0.01 | P | NA | NA | 1 | CPP | 0.52 | CPP | 1.07 | CM | 0 | P | 0.86 | CM | 0.48 | CP |
| Sta 5 | 0.01 | P | 0.16 | CM | 0.86 | CPP | 0.58 | CM | 1.35 | CM | 0.1 | P | 0.89 | CM | 0.44 | CP |
| Sta 6 | 0.01 | P | 0.14 | CM | 0.88 | CPP | 0.5 | CPP | 0.98 | P | 0.1 | P | 0.8 | CM | 0.45 | CP |
| Sta 7 | 0.01 | P | 0.14 | CM | 0.88 | CPP | 0.51 | CPP | 1.05 | CM | 0.1 | P | 0.84 | CM | 0.46 | CP |
| Sta 8 | 0.01 | P | NA | NA | 1 | CPP | 0.58 | CM | 1.39 | CM | 0 | P | 1 | CM | 0.42 | CP |
| Sta 9 | 0.02 | P | NA | NA | 1 | CPP | 0.48 | CPP | 0.93 | P | 0.1 | P | 1 | CM | 0.43 | CP |
| Sta 10 | 0.02 | P | 0.21 | CM | 0.83 | CPP | 0.54 | CPP | 1.15 | CM | 0 | P | 1 | CM | 0.46 | CP |
| Sta 12 | 0.02 | P | 0.15 | CM | 0.87 | CPP | 0.58 | CM | 1.39 | CM | 0.1 | P | 1 | CM | 0.35 | CP |
| Sta 13 | 0.02 | P | 0.19 | CM | 0.84 | CPP | 0.54 | CPP | 1.16 | CM | 0 | P | 0.8 | CM | 0.36 | CP |
| Sta 12L | 0.03 | P | 0.03 | CM | 0.97 | CPP | 0.47 | CPP | 0.89 | P | 0 | P | 0.93 | CM | 0.4 | CP |
| Sta 13L | 0.01 | P | 0.09 | CM | 0.92 | CPP | 0.57 | CM | 1.33 | CM | 0 | P | 0.8 | CM | 0.35 | CP |

Note : CM = combustion mixture such as grass, wood soot, and creosote; P = Petroleum sources; CP = Combustion and Petroleum mixture; CPP = combustion of diesel oil, shale oil, crude oil, fuel oil, emission from car and truck.

## 7.6. PCA and HCA Analysis

The PCA analysis was used to examine the relationship and correlation between individual PAHs, and to determine the component factor variable (Hiller *et al*., 2010; Nemr *et al*., 2006; Yunker *et al*., 2002). Figure 7.4 shows the plot of factor coordinates distribution of individual PAHs as well as their location. The PCA of seawater is represented by PAHs on a three dimensional plot. The first component of the plot reflects petrogenic factors associated with acenaphtylene, naphthalene, phenanthrene, fluorene, and anthracene. The second component correlates with pyrogenic factors associated with dibenzo(ah)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(123-cd)pyrene. The last component indicates a mixture of petrogenic and pyrogenic factors correlated with chrysene, pyrene, fluoranthene, acenaphthene, and benzo(a)anthracene. In Figure 7.4b, Station 1 is significantly different than the other stations; Station 1 has the highest total PAH concentration of all the stations. Hierarchical cluster analysis (HCA) of PAH was used to separate individual PAH compounds into cluster groups (Nemr *et al*., 2006). The dendogram in Figure 7.5 shows three major groups in the cluster. The grouping follow a similar trend with the PCA results determining petrogenic, pyrogenic or a mixture of both sources, from individual compounds. Analysis of PAH compounds in the water of the Timor Sea indicate the contibution of three major groups sources; however, petroleum and petroleum combustion are likely the main source for PAH pollution in the Timor Sea coastal waters.




(7.4.a) (7.4.b)

**Figure 7.4** (a) The PCA loading plot of 3D component factor illustrates the distribution of individual PAH compound in surface seawater and
(b) Plot of factor coordinates of the surface seawater sampling location in Timor Sea

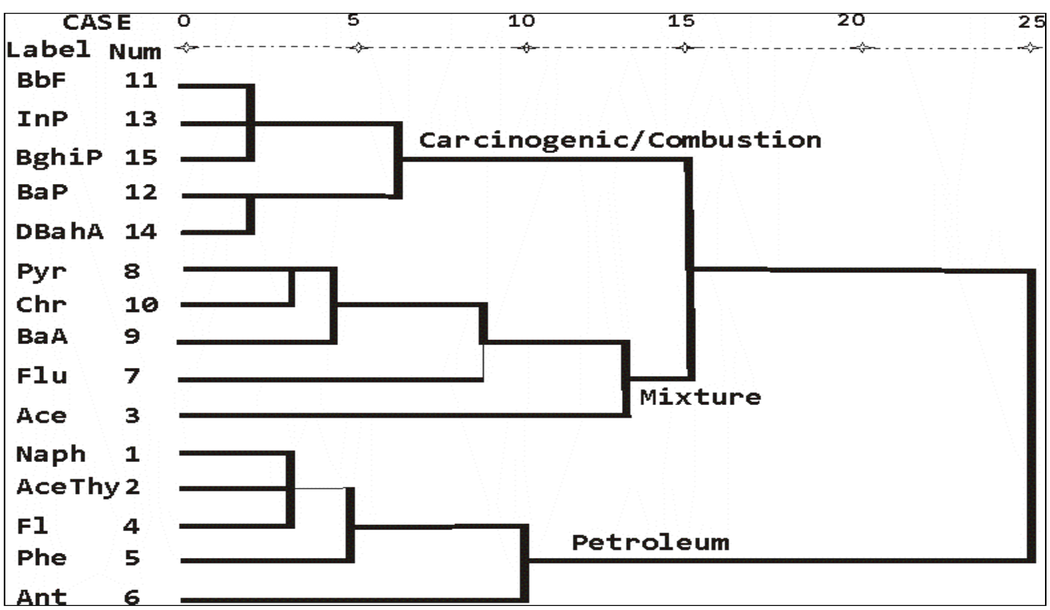



**Figure 7.5.** HCA histogram analysis of PAH compound in the coastal waters of the Timor sea

## 7.7. Heavy Metal Concentrations

Oil contamination usually contains not only oil, but also other related compounds such as organic materials and heavy metals. Concentration of heavy metals from sea waters and sediment in the Timor and Arafura Seas is shown in Table 7.5 and Table 7.6, respectively. Six heavy metal compounds were detected, including lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), nickel (Ni), and iron (Fe). The concentration of the heavy metals in solute form in seawater at most of the stations in the Timor and Arafura Seas is significantly lower compared to that of the Seawater Quality Criteria from Ministry of Environment of the Republic of Indonesia (SQC-MEvRI). The heavy metal concentrations in the seawater samples are as follows: Pb (<0.001 ppm to 0.003 ppm), Cd (<0.001 ppm), Cu (<0.001 ppm to 0.003 ppm), Zn (<0.001 ppm to 0.004 ppm), and Fe (0.004 ppm to 0.029 ppm).

**Table 7.5.** Heavy metal concentrations in seawater from the Arafura and Timor Seas

| Parameter | Location of water samples (ppm) | | | SQC-MEv RI (2004) |
|---|---|---|---|---|
| | Timor Island St. 1-10 | Tanimbar Islands St. 11- 13 | Aru Islands St. 14-23 | |
| **Pb** | < 0.001 – 0.003 | < 0.001 – 0.001 | < 0.001 – 0.003 | 0.008 |
| **Cd** | < 0.001 | < 0.001 | < 0.001 | <0.001 |
| **Cu** | < 0.001 – 0.001 | < 0.001 – 0.003 | < 0.001 – 0.003 | 0.008 |
| **Zn** | < 0.001 | < 0.001 | < 0.001 – 0.004 | 0.05 |
| **Ni** | 0.001 – 0.003 | 0.001 – 0.003 | 0.002 – 0.005 | 0.05 |
| **Fe** | 0.004 – 0.015 | 0.012 – 0.015 | 0.002 – 0.029 | - |

Moreover, the concentration of heavy metals in sediment samples from the Timor and Arafura Seas does not show any evidence of contamination from human activity. The average metal concentrations are lower compared to Sediment Quality Criteria of the Ministry of Environment (KLH, 2010) and to that of average shale (Forstner and Wittmann, 1979) (Table 7.6). Hence, the concentrations of heavy metals in marine sediment and seawater are in natural amounts.

**Table 7.6.** Heavy metals concentration in sediments from the Arafura and Timor Seas

| Parameter | Location of sediments samples (mg/kg) | | SdQC-MEv RI (2010) (draft)[*a] | Forstner and Wittmann, (1979)[*b] |
|---|---|---|---|---|
| | Tanimbar islands St. 11 - 13 | Aru islands St. 14 - 23 | | |
| Pb | 6.97 – 7.46<br>x = 7.22 ± 0.34 | 4.99 – 25.52<br>x = 11.04 ± 6.06 | 36.8 | 20 |
| Cd | 0.07 – 0.33<br>X = 0.20 ± 0.19 | 0.07<br>X = 0.07 | 6.2 | 0.3 |
| Cu | 8.50 – 28.43<br>X = 18.47 ± 14.09 | 1.87 – 16.82<br>X = 5.99 ± 4.38 | 108 | 45 |
| Zn | 52.21 – 96.76<br>X = 74.48 ± 31.50 | 28 – 234<br>X = 75 ± 57 | 271 | 95 |
| Ni | 16.47 – 41.02<br>X = 28.75 ± 17.4 | 10.8 – 28.9<br>X = 17.9 ± 5.1 | - | - |
| Fe | 1344 – 4072<br>X = 2708 ± 1928 | 2080 - 57695<br>X = 17946 ± 15880 | - | - |

**Note : *a = proposed environmentat criteria for marine sediment (mg/kg), *b= average shale (ppm)**

## 7.8 Conclusion

The samples collected from southern coastal region of Timor Island show contamination by PAHs, with concentrations ranging from 54.46 to 213.7 µg/l (an average of 99.75 µg/l) in surface sea water, and from 23.63 to 24.05 mg/kg dw in sediments. The contamination is from three groups of sources: petroleum, petroleum combustion and combustion of a mixture of organic materials. However, heavy metal concentrations in seawater and marine sediments are in small quantity and do not indicate any contamination from human activity.

Chapter VIII

# BENTHIC BIOGEOCHEMISTRY OF THE NORTHERN ARAFURA SEA

**Daniel M. Alongi, Lindsay A. Trott**

Australian Institute of Marine Science, Australia
Email: *d.alongi@aims.gov.au*

## 8.1. Introduction

The northern Arafura Sea, most commonly known as the Aru Sea, is a unique environment, dominated by enormous discharges of freshwater and sediment from as many as 20 rivers along the southwest coast of the island of New Guinea. The Aru Sea, in terms of the ratio of discharge to shelf area, is one of the most river-dominated shelf environments in the world's coastal ocean (Alongi, 1997).

Shelf sediments derived from such tropical rivers have been characterized as suboxic incinerators of organic matter, being highly efficient in burning off organic carbon derived from mainly riverine sources. However, such generalizations have been made based on research conducted off the Amazon and in the Gulf of Papua, located off the southeast coast of New Guinea. These two shelves are more open to the open ocean than the Aru Sea, offering us the potential to observe if more semi-enclosed conditions have lead to proportionally more burial of organic carbon and other elements, such as trace and heavy metals, in the coastal zone. If true, such conditions have important consequences for our current estimates of carbon cycling and retention in the world ocean.

Accordingly, we sampled 11 stations within the Aru Sea, measuring rates and pathways of organic carbon mineralization and ammonification and stable isotope signatures in relation to distance from the Papuan rivers to identify sources and mixtures of organic matter, and to identify zones of potential burial of carbon and other elements in this important region of the tropical ocean.

Preliminary sampling and analysis of sediments from the Timor and Arafura seas was conducted during the ATSEA cruise in May 2010.

## 8.2. Study area and sample collecting

Eleven stations (Figure 8.1) were sampled based on their location with respect to potential upwelling (Station 13), the relative dominance of riverine sources of organic matter (Stations 14, 15, 16, 17, 18 and 19), and influence of increased carbonate deposits derived from the highly diverse coral reefs surrounding the Aru Islands (Stations 20, 21, 22 and 23). Cores were taken for surface sediments and flux measurements across the sediment-water interface, using a standard USNEL boxcorer. Vertical profiles of rates of microbial activity and concentrations of carbon, nitrogen and other elements were obtained by subsampling cores taken using a standard gravity corer. The subsamples were taken at discrete depth intervals over a 0 to 250 cm sediment depth horizon.

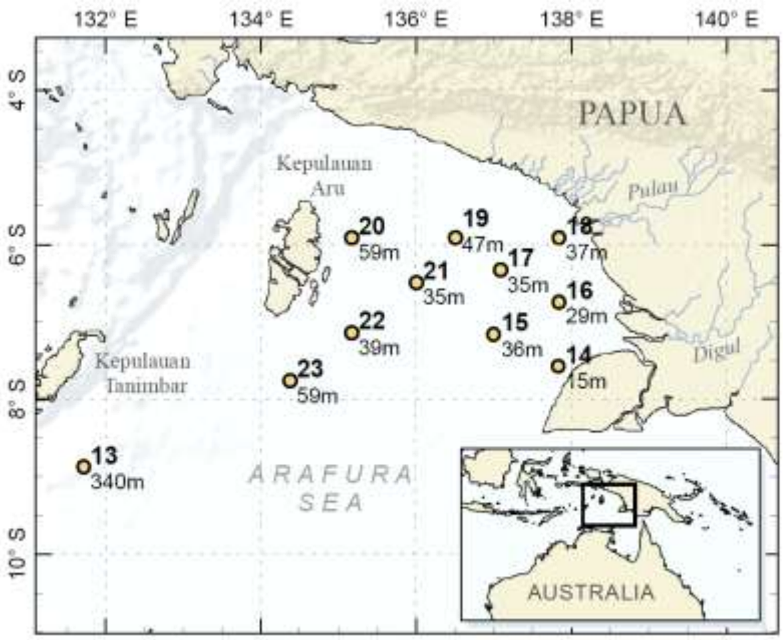



**Figure 8.1.** Benthic stations in the Aru Sea

### Nutrient concentrations.

Samples were collected for measuring of particulate and dissolved nutrients, sediment particle size and rates of nutrient release from sediments. Sediment particle size was measured on a Malvern Mastersizer 2000. Two additional samples were taken for the estimation of porosity (water content). Samples returned to AIMS were dried and ground to a fine powder for determination of total carbon and total nitrogen on a Perkin-Elmer 2400 CHNS/O Series II Analyzer and for total organic carbon on a Shimadzu TOC Analyzer with solid sampler. Other elements (phosphorous (P), sulphur (S), manganese (Mn), iron (Fe)) were determined after strong acid digestion on a Varian Liberty inductively-coupled atomic emission spectrometer following the procedure of Loring and Rantala (1997).

## Sulfate reduction

Rates of sulfate reduction were measured by taking triplicate 2.7-cm diameter plastic cores horizontally from the gravity cores. The samples were incubated for 9-18 h, and then each 20 mg sediment sample was stored in a 50 ml centrifuge tube containing 10 ml of 20% zinc acetate. On return to AIMS, the samples were distilled with acid and heated (Fossing and Jorgensen 1989) to determine the fraction of sulfur label shunted into the acid-volatile sulfide (AVS) and chromium-reducible (CRS) sulfur pools.

## Total carbon mineralization, metal reduction, and ammonification

The sediment incubation method (Alongi *et al*., 2010) was used to measure rates of total carbon mineralization, microbial iron and manganese reduction and potential ammonification. Briefly, one set of sediment samples was immediately centrifuged to obtain for measuring concentrations of dissolved inorganic carbon, dissolved iron, manganese and ammonium. Another set of samples from the same core were place in opaque glass jars, sealed and incubated for 4 to 8 days to allow ingrowth of solutes. From the sediment and porewater volume and knowing the time of incubation and changes in porewater concentrations, rates of total carbon mineralization, iron and manganese reduction and ammonification were calculated. Iron and manganese were determined using methods detailed in Alongi *et al*. (2010).

## Dissolved inorganic carbon, oxygen and nutrient fluxes

The release of dissolved solutes across the sediment-water interface was measured using three or four opaque chambers (volume: 1 l; area: 82 $cm^2$) from which dissolved inorganic carbon (DIC), $O_2$ and dissolved inorganic nutrient and metal samples were taken at 1 h intervals for 3 h. The chambers were gently placed into each boxcorer sample and incubated in the dark in a seawater bath to maintain ambient seawater temperature (Figure 8.2). Each chamber had a propeller-electric motor unit and two sampling ports on opposite sides of the chamber (Alongi *et al*., 2010). Dissolved oxygen was measured using an $O_2$ probe (TPS™ Model WP-82 DO meters) placed into one sampling port; the other port was fitted with plastic tubing to draw off 10 ml samples for $\sum CO_2$ and dissolved nutrients and metals. The samples for DIC and dissolved inorganic nutrients were filtered (0.45 µm Minisart® filters) and either kept cool and dark (DIC) or frozen in 3 or 12 ml plastic test tubes. On return to AIMS, concentrations of DIC, $NH_4^+$, $NO_2^-$+$NO_3^-$ and $PO_4^{3-}$ were determined using automated techniques (Alongi *et al*., 2010).

**Figure 8.2.** Opaque chambers for measuring dissolved oxygen

## Stable isotopes

Three to five plastic vials of sediments were taken at each site for analysis of stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) for identification of terrestrial *vs* marine origin of sediment organic matter. Samples were analyzed as detailed in Alongi *et al*., (2010).

## 8.3. Preliminary Results and Discussion

### Rates of benthic respiration

Rates of benthic respiration varied greatly across the Aru Sea with highest rates of microbial activity at Stations 21, 22 and 23. These respiration rates are high compared with rates of respiration ordinarily measured in tropical coastal sediments and probably reflect higher rates of phytoplankton production. It is a typical pattern off tropical rivers that rates of primary production are maximal distal from the river mouth, beyond the region of high turbidity and severe light limitation, but still within the influence of the transport of high levels of dissolved nutrients derived from the rivers (Alongi, 1997).

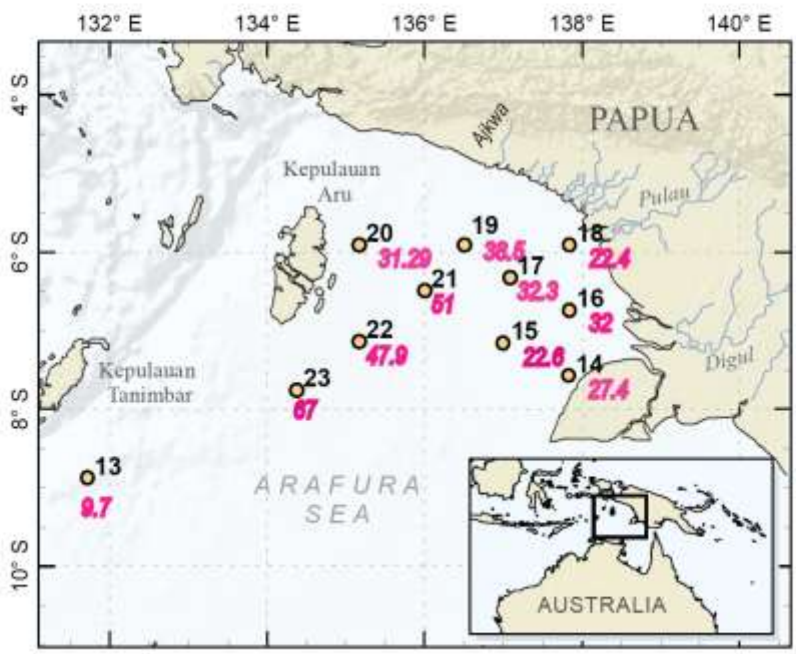



**Figure 8.3.** Red numbers indicate rate of benthic respiration (mmol $m^{-2}$ $d^{-1}$) at stations

The table 8.1 shows the mean concentrations of sediment total organic carbon (TOC), total nitrogen (TN) and the molar carbon to nitrogen (C/N) ratio over the entire depth profile at each station. While concentrations are typical of tropical coastal and marine sediments, the molar ratios are at the low end of the range of values observed in other sediment deposits, indicating high quality of organic matter. This is especially true for the three western Aru Sea sites where highest respiration rates were measured and where primary production is probably greatest.

**Table 8.1.** Rates of benthic respiration (mmol $m^{-2}$ $d^{-1}$) across the Aru Sea.

| Station Number | Respiration mmol.m-2.d-1 | TOC % | TN % | C/N Ratio |
|---|---|---|---|---|
| 13 | 9.7 | 1.64 | 0.19 | 10.42 |
| 14 | 27.4 | 0.85 | 0.10 | 10.03 |
| 15 | 22.6 | 0.60 | 0.06 | 12.10 |
| 16 | 32.0 | 0.87 | 0.09 | 11.20 |
| 17 | 32.3 | 0.33 | 0.04 | 10.33 |
| 18 | 22.4 | 0.83 | 0.07 | 14.33 |
| 19 | 38.5 | 0.67 | 0.05 | 16.31 |
| 20 | 31.2 | 1.01 | 0.09 | 14.40 |
| 21 | 51.0 | 0.61 | 0.07 | 9.73 |
| 22 | 47.9 | 0.33 | 0.04 | 9.03 |
| 23 | 67.0 | 0.38 | 0.05 | 9.62 |

## Stable isotope signatures

Figure 8.4 summarizes the pattern of stable carbon and nitrogen values in the surface sediments of the Aru Sea. There is an overall trend toward enrichment of both elements with increasing distance from the coast. This suggests a decline in influence of river-derived organic matter and a relative increase in the importance of plankton-derived organic matter, with increasing distance from the great Papuan rivers. This pattern is not true for all stations, implying that there may have been some plankton inputs further inshore.

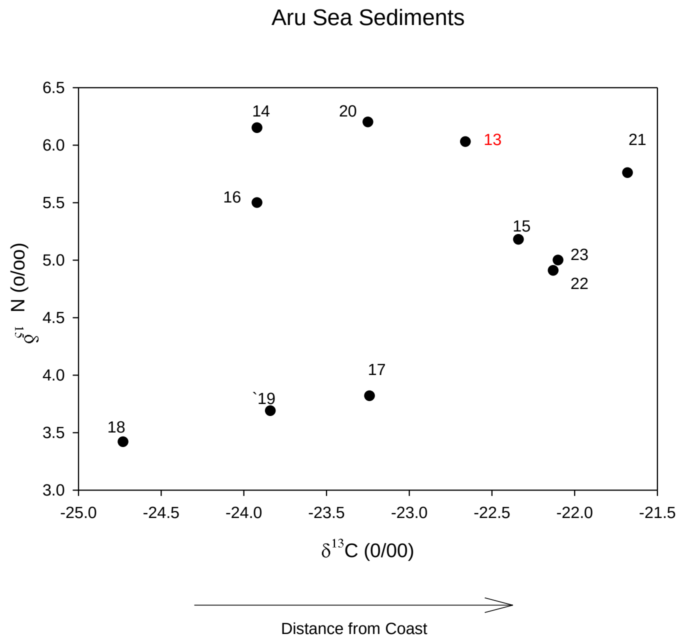



**Figure 8.4.** Plot of the relationship between stable C and N signatures in surface sediments of the Aru Sea.

.

## Importance of individual microbial metabolic pathways and implications for the coastal ocean

Very low rates of sulfate reduction (5 to 10 mmol S $m^{-2}$ $d^{-1}$) were detected only at Stations 21, 22 and 23. There was an inverse pattern in rates of iron and manganese reduction in that these processes were only measurable at the stations closest to the rivers. Iron reduction was low (2 to 5 mmol Fe $m^{-2}$ $d^{-1}$) but rates of manganese reduction were high (15 to 30 mmol $m^{-2}$ $d^{-1}$) as this was the dominant microbial process in the sediments of the Aru Sea. This is puzzling, as iron content in some of the Aru deposits approached 12% by sediment dry weight, greater than concentrations of total iron measured off the Amazon (6 to 9%) and in the Gulf of Papua (4 to 8%), locations where iron reduction dominates early diagenesis of organic matter. However, manganese concentrations were high (>600 ppm) compared with manganese content off the Amazon and in the Gulf of Papua. Manganese reduction is theoretically favored over iron reduction if sediment redox conditions are poised at a suboxic state. Such appears to be the case off these Papuan rivers and such conditions have major consequences of the long-term cycling of the metals and other elements in the tropical coastal ocean. For instance, assuming that element concentrations increase with increasing depth into the seabed, there may indeed be high levels of preservation of carbon and these essential elements in the Aru Sea, greater than is often supposed for the tropical coastal ocean based solely on work done off the Amazon, the Gulf of Papua and off a few other major tropical rivers.

Evidence for significant burial of carbon comes from the vertical profiles of elements in the long 2.5m gravity core samples. This is most dramatically seen at Station 18 (Figure 8.5), where there is a clear increase in organic carbon concentrations with increasing depth into the seabed, where sand overlies a deep mud horizon. Furthermore, there were clear bands of both iron/manganese minerals and of terrestrial plant detritus between sediment depths of 60 and 70 cm and 240 to 250 cm.

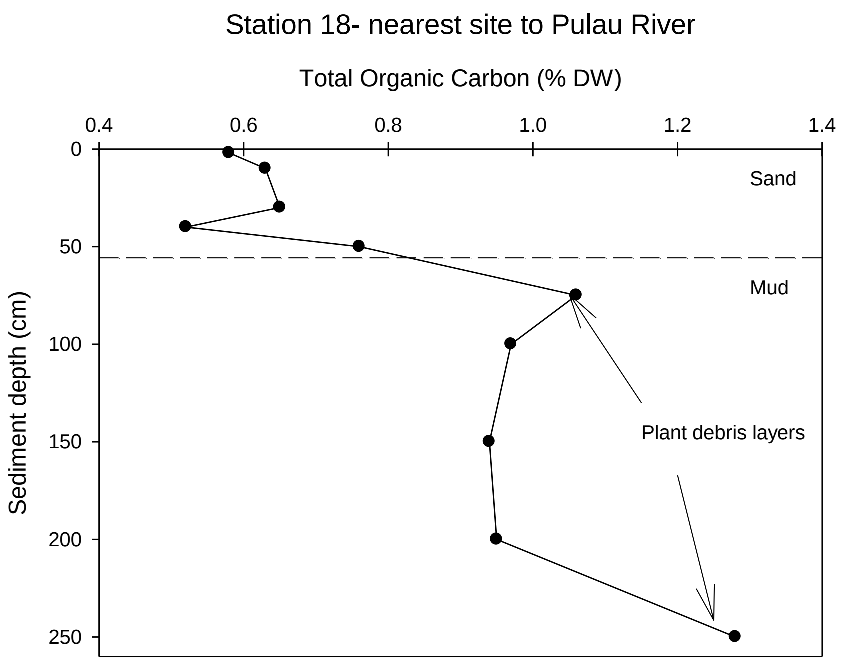



**Figure 8.5.** Total organic carbon in Station 18

## 8.4. Conclusions

High rates of benthic decomposition of organic matter were found in the western area of the Aru Sea, probably related to higher rates of primary production stimulated by the large dissolved nutrient loads coming from the Papuan rivers. Manganese reduction was the dominant microbial process, and coupled with evidence of significant burial of terrestrial organic matter and metals, such processes suggest that the coastal zone of the Aru Sea is an area of carbon burial, having important implications for our current estimates of the fate of carbon in the tropical global ocean.

## Chapter IX

# SURFACE SEDIMENTS

**M. Hasanudin[1], Sugiarta Wirasantosa[2], Rubiman Muhajirin[1]**

[1]Research Centre for Oceanography (RCO) – LIPI, Indonesia
Email: *mhasanudin@lipi.go.id*

[2]Arafura and Timor Seas Ecosystem Action (ATSEA) Program

## 9.1. Introduction

Sediment samples were collected at various stations in the Arafura Sea as part of a fisheries environment study. Station distribution is shown in Figure 9.1, consisting of stations representing near coastal and shelf areas, as well as the deep sea. Ten stations located near the coast and in the Sahul shelf area, characterize shallow sea with depths not exceeding 60 m. The other two stations (Stations 12 and 13) represent the bottom of a deeper area, exceeding 300 m and 1,500 m, respectively. Samples were taken between May 15 and 23, 2010.

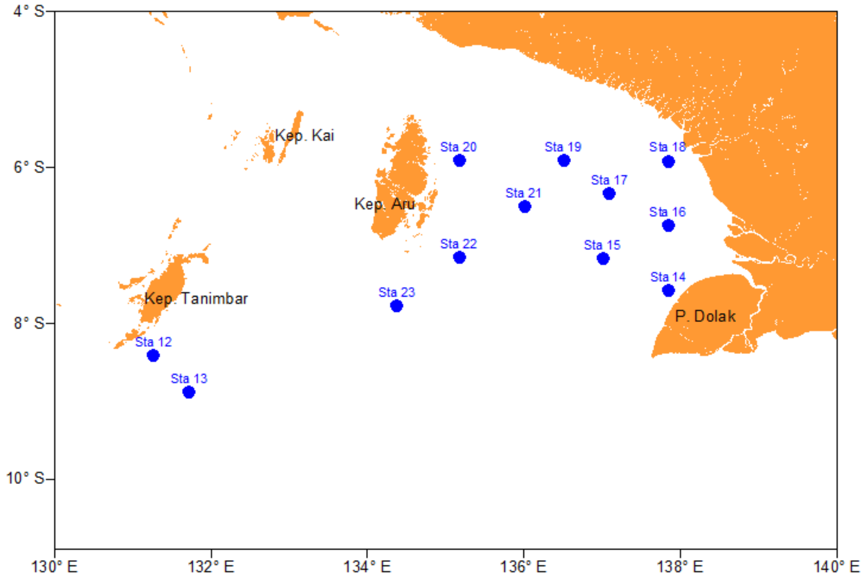



**Figure 9.1.** Distribution of the sampling stations

## 9.2. Methods

Sediment samples were taken onboard the *RV Baruna Jaya VIII* during the ATSEA cruise with gravity and box corers. The length of the gravity corer was 3 m with a diameter of 2.5 in. The color of the sediment was determined based on Munsell soil color chart. The box corer capacity was 0.3 $m^3$.

## 9.3. Results

Sample description and their photos are shown in Appendix 9.1. Deep sea samples indicate clay of grey color, massive and sometimes showing fine grain shell fragments. Shelf sediments, however, indicate more variation in grain size and color, from clay/mud to silt or sand grey, yellowish or blackish in color. Figure 9.2 shows the distribution of the sediments in the Arafura Sea and Lemola area.

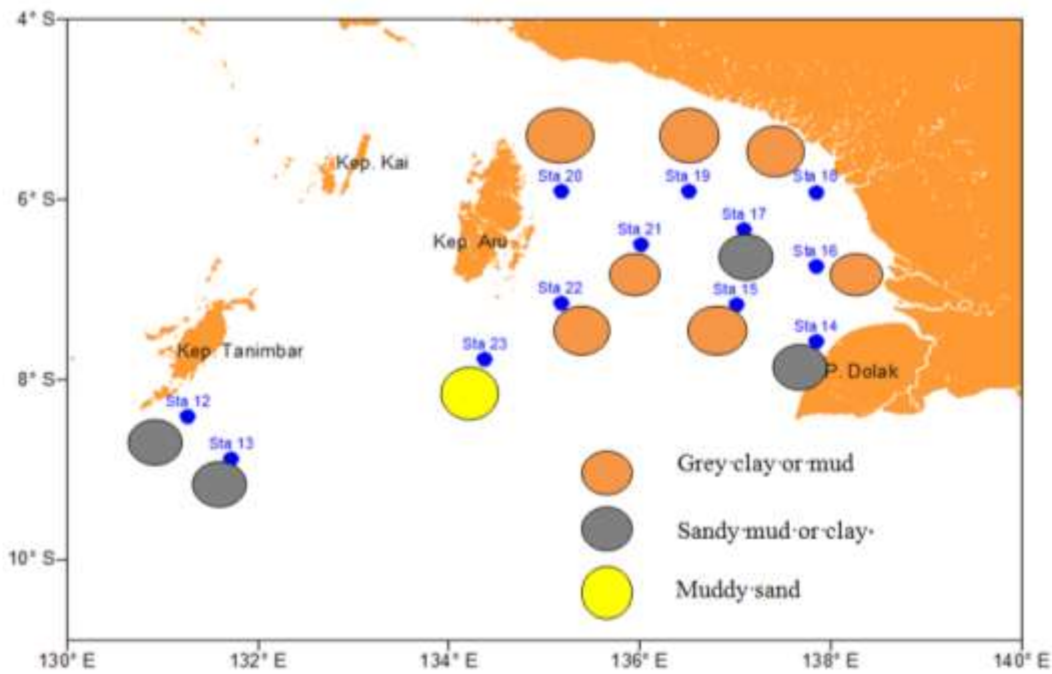



**Figure 9.2.** Distribution of surface sediments in Arafura Sea and Lemola area

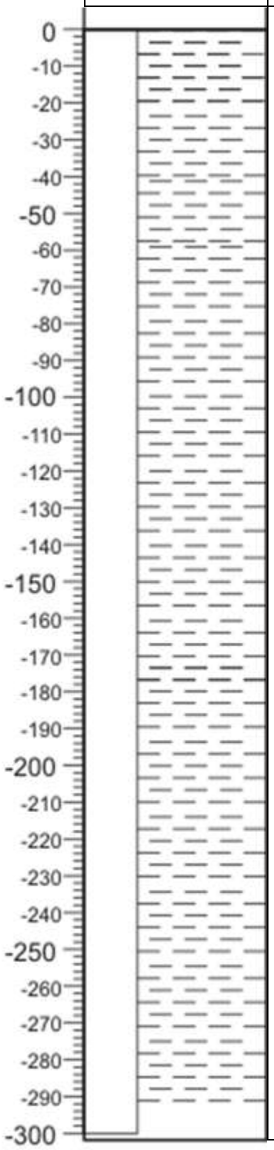
## Appendix 9.1

# Lithology Description of Gravity Core

### LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/15 10:30**

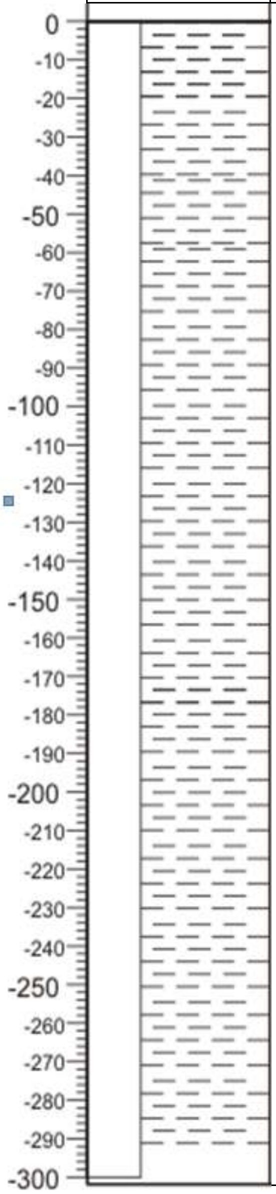
**Core Site : ATSEF 12**
**Position : -8°24.990’**
**131°16.151’**
**Sea Depth : 1,503 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-292 | Grey clay (5Y 7/2), a few shells from marine life, fine size with a thickness between 164 and 242 cm, massive structure, odorless | Grey clay |

# LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/15 16:09**

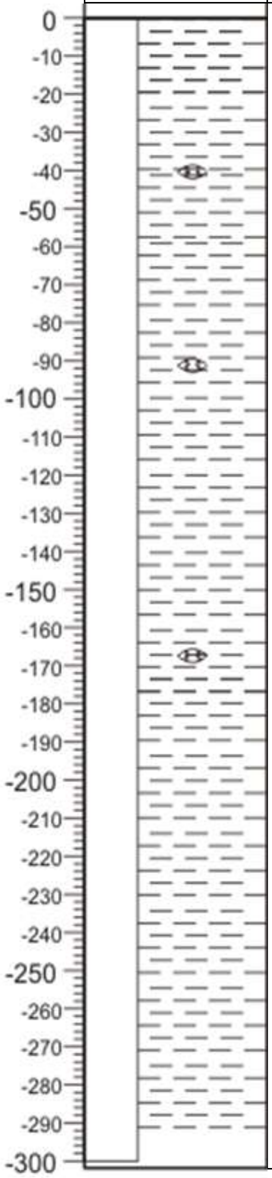
**Core Site : ATSEF 13**
**Position : -8°53.030’**
**131°43.359’**
**Sea Depth : 341 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|   | 0-291 | Grey clay (5Y 7/2), massive structure, odorless | Grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/18 15:52**

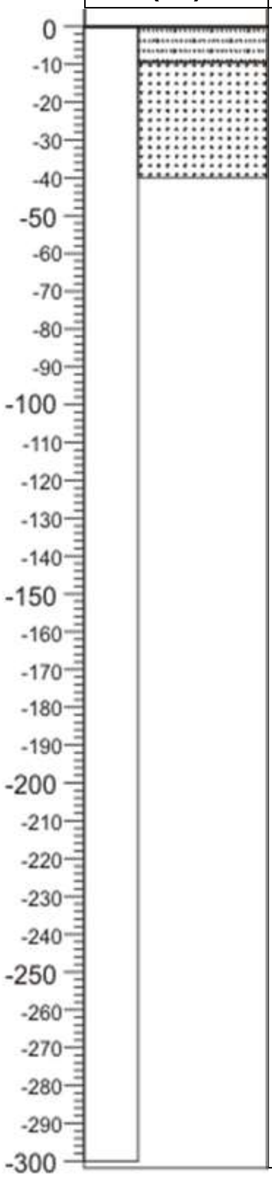
**Core Site : ATSEF 14**
**Position : -7°34.590'**
**131°50.722**
**Sea Depth : 19 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|   | 0-292 | Grey clay (5Y 7/2), a few shells from marine life, fine to rough size, massive structure, odor in the layer between 120 and 250 cm | Grey clay containing shell detritus |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/18 03:30**

**Core Site : ATSEF 15**
**Position : -7°9.667'**
**137°0.438'**
**Sea Depth : 35 m**

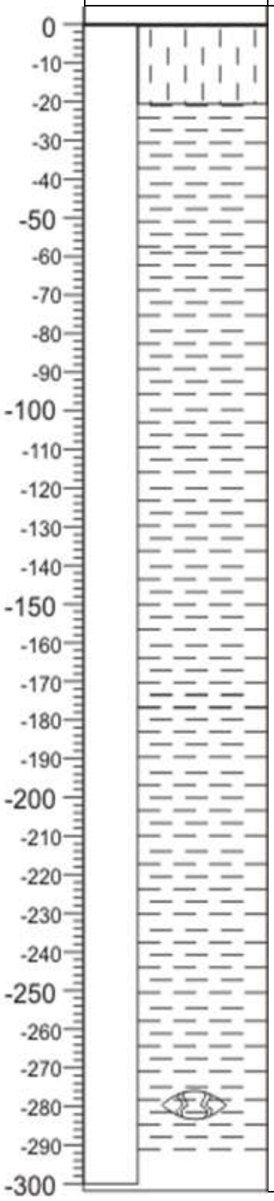



| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
| | 0-10 | Grey sandy mud (5Y 7/2), odorless | Sandy mud, grey, odorless |
| | 10-40 | Black sand with medium grain size, marine life shell insertion rough, insertion of wood of size between 25 and 30cm, dots of mud forming colloidal structure, odorless | Black sand medium grain size |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/19 13:39**

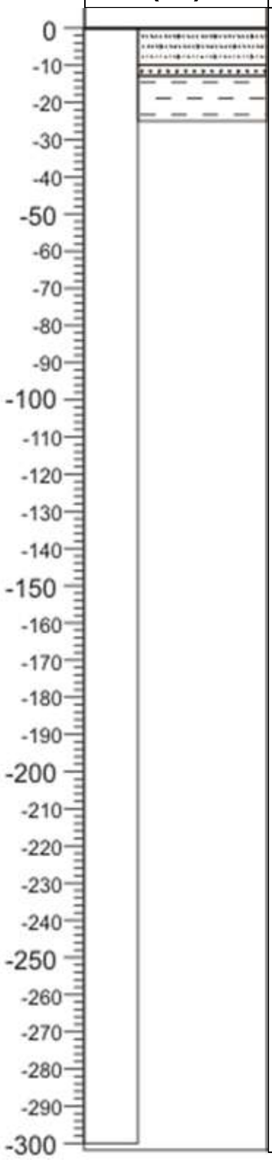
**Core Site : ATSEF 16**
**Position : -6°44.645'**
**137°50.610**
**Sea Depth : 29 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-20 | Grey silt (5Y 6/2), insertion of marine life shells of a size from fine to rough, odorless | Grey silt |
| | 20-292 | Grey clay (5Y 6/2), getting darker downward, marine life shells from fine size to rough, especially at the bottom | Grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/20 00:50**

**Core Site : ATSEF 17**
**Position : -6°19.745'**
**137°5.381**
**Sea Depth : 35 m**

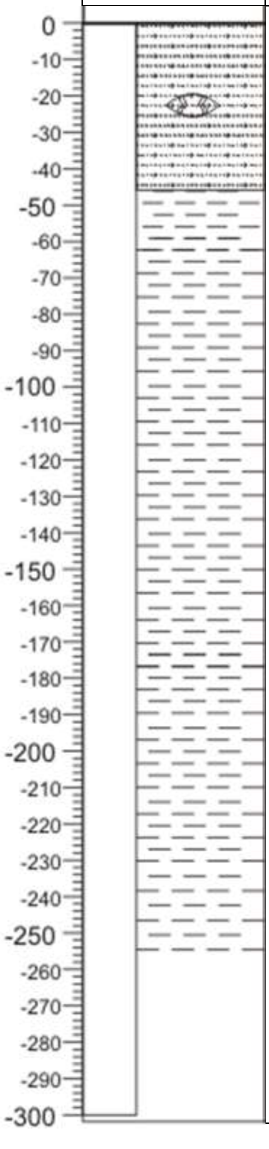



| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
| | 0-10 | Grey mud (5Y 5/2), odourless | Grey mud |
| | 10-13 | Grainy black sand of medium size, insertion of medium sized marine life shells, odorless | Medium sand, black |
| | 13-25 | Yellowish grey clay (5Y 8/6), compact, odorless | Yellowish grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/20 10:59**

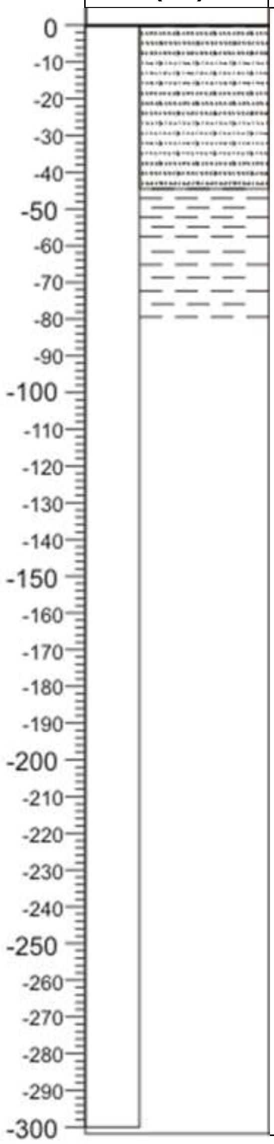
**Core Site : ATSEF 18**
**Position : -5°54.804’**
**137°50.617**
**Sea Depth : 38 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-45 | Grey sandy mud (5Y 6/2), insertion of marine life shells of a size from fine to rough, odorless | Sandy mud, grey |
| | 45-256 | Grey clay (5Y 6/1), compact, odorless | Grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/21 02:04**

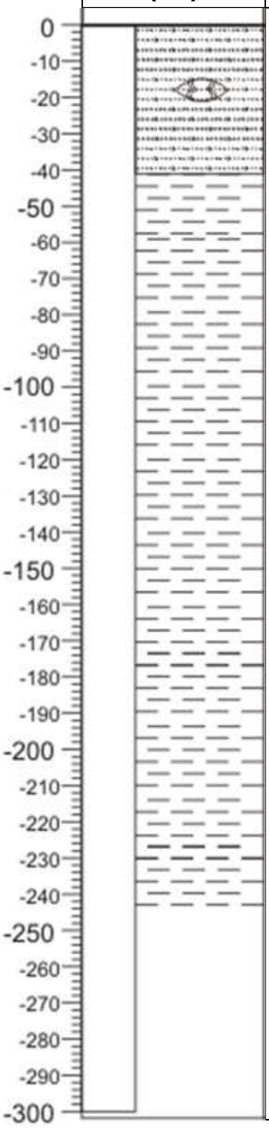
**Core Site : ATSEF 19**
**Position : -5$^{o}$54.718'**
**136$^{o}$30.33'**
**Sea Depth : 48 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-45 | Grey sandy mud (5Y 7/1), insertion of marine life shells of a size from fine to rough, odorless | Sandy mud with fine grain shell |
| | 45-80 | Grey clay (5Y 6/2), compact, odorless | Grey clay |

# LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/21 17:06**

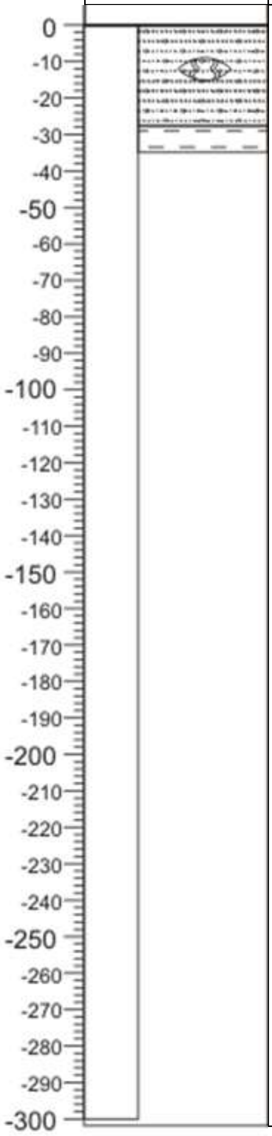
**Core Site : ATSEF 20**
**Position : -5°54.673’**
**135°10.267’**
**Sea Depth : 60 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-41 | Grey sandy mud (5Y 6/2), insertion of marine life shells of a size from fine to rough, odorless | Sandy mud, grey with fine to coarse grain shell |
| | 41-242 | Grey clay (5Y 6/1), darker downward, compact, odorless | Grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/22 04:07**

**Core Site : ATSEF 21**
**Position : -6°29.675’**
**136°0.299**
**Sea Depth : 35 m**

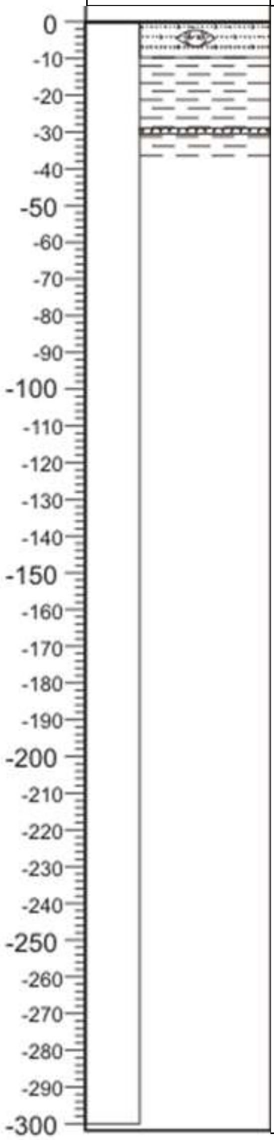



| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
| | 0-27 | Grey sandy mud (5Y 6/2), insertion of marine life shells of a size from medium to rough, odorless | Sandy mud, grey with fine to coarse grain shell |
| | 27-35 | Yellowish grey clay (5Y 7/1), solid, odorless | Yellowish grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/22 15:56**

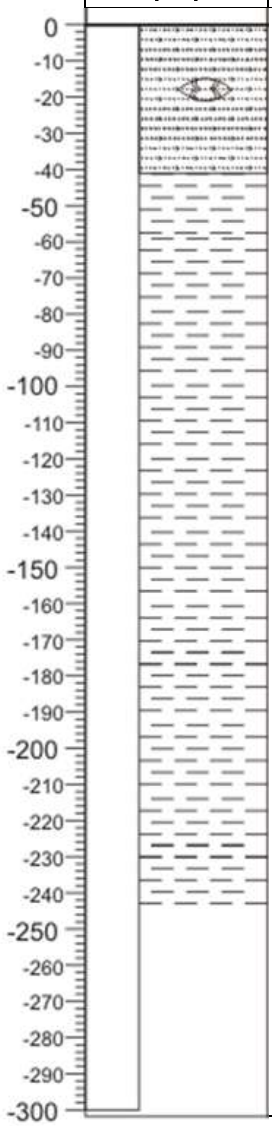
**Core Site : ATSEF 22**
**Position : -7°8.685'**
**135°10.350'**
**Sea Depth : 38 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-9 | Grey sandy mud (5Y 7/2), insertion of marine life shells of a size from medium to rough, odorless | Sandy mud, grey with medium to coarse grain shell |
| | 9-37 | Yellowish grey clay (5Y 7/6), solid, insertion of 1 cm fine sand at 20 cm depth, odorless | Yellowish grey clay |

## LITHOLOGY DESCRIPTION OF GRAVITY CORE

**Official :**
**Location : ARAFURA SEA**
**Year/Month/Day : 2010/05/23 03:35**

**Core Site : ATSEF 23**
**Position : -7°45.944'**
**134°22.45'**
**Sea Depth : 59 m**

| Lithology Column (cm) | Depth (cm) | Lithology Description | Explanation |
|---|---|---|---|
|  | 0-32 | Grey muddy sand (5Y 7/2), insertion of marine life of a size from fine to rough, medium to rough grained sand, odorless | Muddy sand, grey with fine to medium grain shell |
| | 32-42 | Yellowish grey clay (5Y 7/6), solid, odorless | Yellowish grey clay |

Chapter X

# IUU FISHING DOCUMENTATION

**Handy Chandra**

Center of Assessment and Engineering for Marine and Fisheries Technology
Ministry of Marine Affairs and Fisheries, Indonesia
Email: *handavin@gmail.com*

## 10.1. Introduction

Observations of fishing activities in the Arafura and Timor Seas was conducted onboard the *RV Baruna Jaya VIII* during the ATSEA cruise which began May 10 and concluded on May 27, 2010. Using direct observation, first hand information was gathered on the activities of fishing vessels in the field. Observation data were recorded and compared to the data on fishing vessels from the Directorate General (DG) of Surveillance. Fishing vessels that were observed at sea but were not recorded by the Directorate General were probably illegal fishing vessels.

This report presents the result of radar and visual observations from the bridge during the ATSEA cruise. Positions of the observed vessels were recorded in terms of day, hour and their geographic positions.

## 10.2. Observations

Field observation during ATSEA cruise has recorded 92 vessels of various types (Appendix 10.1), among those were gill-net type fishing boats (Figure 10.1), a Hiu Macan 6 patrol vessel, commercial and cargo vessels, and a number of small and large fishing boats. Positions of the vessels during the ATSEA cruise are shown in Figures 10.2, 10.3 and 10.4, including the positions of the *RV Baruna Jaya VIII* during the operations.

**Figure 10.1.** Gill-net type fishing boat observed in the Arafura Sea.

**Figure 10.2.** Positions of vessels in the Arafura Sea observed by onboard radar. Red flags indicate other vessels and blue flags reflects the positions of the *RV Baruna Jaya VIII*.

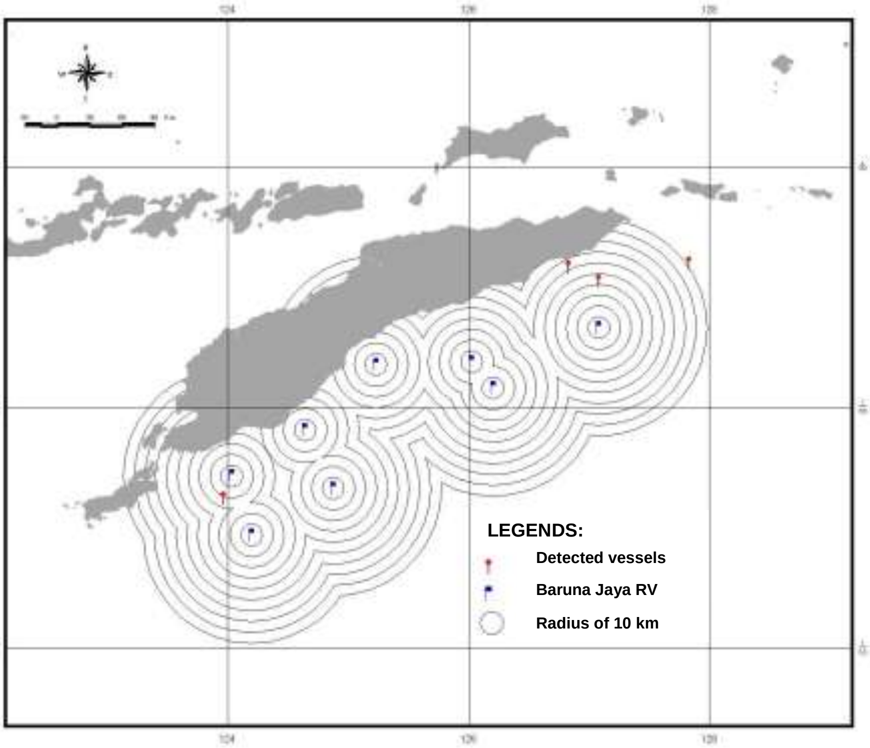



**Figure 10.3.** Various positions of the *RV Baruna Jaya VIII* (blue flags) and other vessels (red flags) in the Timor Sea, based on radar observations.

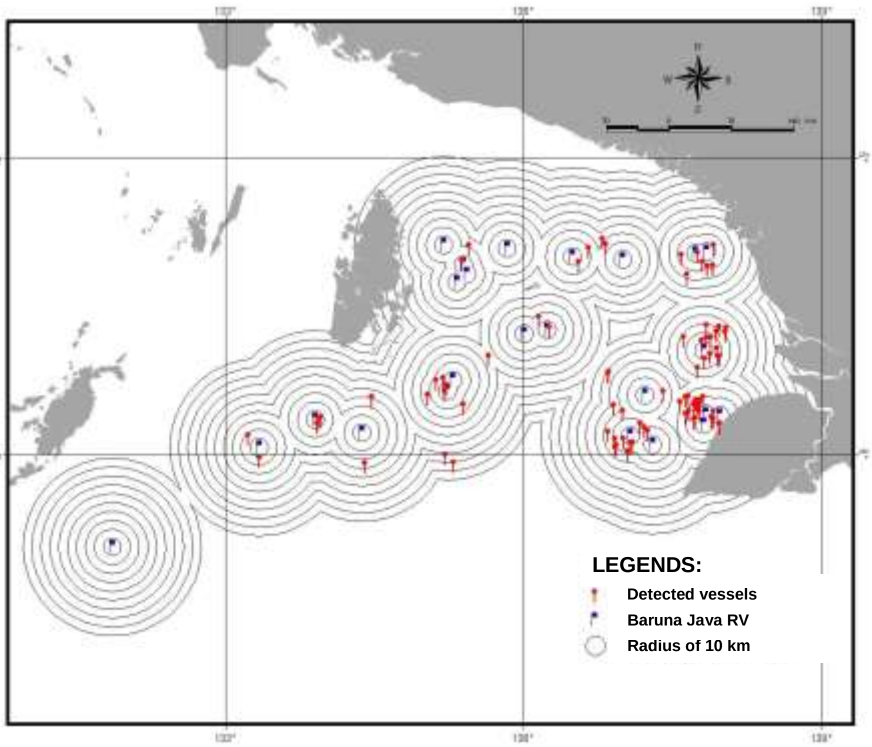



**Figure 10.4.** Various positions of the *RV Baruna Jaya VIII* (blue flags) and other vessels (red flags) in the Arafura Sea, based on radar observations.

Visual Monitoring System (VMS) data from the DG of Surveillance show that 26 fishing vessels were in the area during the ATSEA field observation (Table 10.1). The difference between field data and the official VMS data indentifies Illegal, Unreported and Unregulated (IUU) activities occuring in the area.

**Table 10.1.** VMS data of fishing activities in the Timor and Arafura Seas during the ATSEA field observation.

| No. | Latitude | Longitude | Vessel |
|---|---|---|---|
| 1 | -7.7967 | 136.8467 | Dofior 150 |
| 2 | -7.7733 | 136.8233 | Dofior 121 |
| 3 | -7.7733 | 136.8283 | Dofior 120 |
| 4 | -7.4000 | 137.2283 | Dwikarya 25 |
| 5 | -7.4550 | 137.6387 | Dwikarya 50 |
| 6 | -7.4347 | 137.6600 | Dwikarya 26 |
| 7 | -7.4982 | 137.7165 | Dwikarya 8 |
| 8 | -7.4592 | 137.7758 | Dwikarya 22 |
| 9 | -7.4468 | 137.7120 | Dwikarya 11 |
| 10 | -7.4482 | 137.6700 | Dwikarya 39 |
| 11 | -7.5077 | 137.6180 | Dwikarya 8 |
| 12 | -7.4160 | 137.6708 | Dwikarya 25 |
| 13 | -7.4905 | 137.7675 | Dwikarya 56 |
| 14 | -7.4843 | 137.7677 | Dwikarya 22 |
| 15 | -7.4837 | 137.7509 | Dwikarya 11 |
| 16 | -7.4845 | 137.7350 | Dwikarya 9 |
| 17 | -7.4500 | 137.6667 | Dwikarya 39 |
| 18 | -7.4503 | 137.6336 | Dwikarya 50 |
| 19 | -6.8412 | 137.7625 | Dofior 135 |
| 20 | -6.7405 | 137.6008 | Sohibul Barokah 7 |

| No. | Latitude | Longitude | Vessel |
|---|---|---|---|
| 21 | -6.6277 | 137.7832 | Reksa 3 |
| 22 | -6.5471 | 137.8303 | Resa 702 |
| 23 | -5.9543 | 137.4587 | Dwikarya 1 |
| 24 | -7.2040 | 134.9805 | Tamina 11 |
| 25 | -7.1983 | 134.9553 | Tamina 1 |
| 26 | -7.2868 | 135.1706 | Tamina 12 |

## 10.3. Discussions

Fishing activities in Indonesian waters have been regulated by various laws and regulations. One such regulation relevant to the monitoring of fishing vessel activities is the Ministerial Decree No 05/MEN/2008, concerning Capture Fisheries. Article 88 verse (1) stated that every fishing vessel and/or fish transporting boat having foreign flag shall install and activate a transmitter or the fishing VMS. Verse (2) stated that every fishing vessel and/or fishing transport boat with an Indonesian flag having tonnage of exceeding 30 GT, shall install and activate a transmitter or the fishing vessel monitoring system (Vessel Monitoring System/VMS). Therefore, every fishing vessel found in the Arafura and Timor Seas should have been recorded by the monitoring (VMS) centre at the DG of Surveillance. Those vessels recognized by the monitoring centre have proper fishing permits and documentation. Those that were not recorded by the monitoring centre were probably or potentially illegal fishing boats.

Radar and visual observation recorded 92 vessels were in the area of the Timor and Arafura Seas during the ATSEA cruise. The Monitoring Centre only recognized 26 of these. The others, except for commercial and cargo vessels and surveillance boats, were probably fishing vessels conducting IUU fishing activities.

## Appendix 10.1.

# Observation data on fishing activities in the Arafura and Timor Seas

| No | Date | Western Indonesia Time | Position of B.J. VIII | | | | Observation | Position of other vessel | | | | Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (S) | | Longitude (E) | | | Latitude (S) | | Longitude (E) | | |
| | | | Degree | Minute | Degree | Minute | | Degree | Minute | Degree | Minute | |
| 1 | Monday | 18 | 10 | 34 | 124 | 2 | No fishing vessel | | | | | |
| | May 10, 2010 | 23.25 | 10 | 55.5 | 123 | 57.9 | Commercial vessel with AIS (Automatic Identification System) | 10 | 30.9 | 123 | 43.9 | PACIFIC MARINER<br>Length= 180m |
| 2 | Tuesday | 10 | 10 | 25.9 | 124 | 51.1 | No fishing vessel | | | | | |
| | May 11, 2010 | 16.09 | 10 | 1.6 | 124 | 37.1 | No fishing vessel | | | | | |
| 3 | Wednesday | 1.15 | 9 | 25.8 | 125 | 9.3 | No fishing vessel | | | | | |
| | May 12, 2010 | 8.08 | 9 | 22.9 | 125 | 50.7 | No fishing vessel | | | | | |
| | | 12.1 | 9 | 50 | 126 | 4.5 | No fishing vessel | | | | | |
| 4 | Thursday | 1.15 | 9 | 20 | 127 | 5 | No fishing vessel | | | | | |
| | May 13, 2010 | 7.25 | 8 | 50 | 126 | 50 | 2 cargo vessels in Timor Leste between Alimbata and Elomar, only visual | 8 | 50.4 | 126 | 50.9 | BRO CAROLINE, tanker heading: 282 degree to Singapore; LOA 180 m |
| | | 20.2 | 8 | 33.9 | 127 | 49.06 | 2 cargo ships , AIS identified | | | | | RBD FIUGGI; heading to Qingdao, China; LOA 218 m |
| 5 | Friday<br>May 14, 2010<br>Stations<br>10-11 | | 8 | 30.841 | 123 | 43.057 | | | | | | |
| 6 | Saturday<br>May 15, 2010 | | 8 | 51.3 | 131 | 40.7 | 2 vessels, AIS identified | | | | | TPC TAURANGA; COG 225 degree |
| | | | | | | | | | | | | KOTA PERMATA: COG 105 degree Destination: Brisbane |

| No | Date | Western Indonesia Time | Position of B.J. VIII | | | | Observation | Position of other vessel | | | | Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (S) | | Longitude (E) | | | Latitude (S) | | Longitude (E) | | |
| | | | Degree | Minute | Degree | Minute | | Degree | Minute | Degree | Minute | |
| 7 | Sunday May 16, 2010 | | | | | | No observation | | | | | |
| 8 | Monday May 17, 2010 | | | | | | No observation | | | | | |
| 9 | Tuesday May 18, 2010 | 6.55 | 7 | 42.4 | 136 | 50.9 | 7 Fishing vessels identified by Radar and visual | 7 | 47.5 | 136 | 50.9 | |
| | | | | | | | | 7 | 42.38 | 136 | 51.02 | |
| | | | | | | | | 7 | 47.8 | 136 | 50.8 | Dofior 150 |
| | | | | | | | | 7 | 46.4 | 136 | 49.4 | Dofior 121 |
| | | | | | | | | 7 | 46.4 | 136 | 49.7 | Dofior 120 |
| | | | | | | | | 7 | 45.7 | 136 | 48.5 | |
| | | | | | | | | 7 | 32.23 | 136 | 52.5 | |
| | | 7.25 | 7 | 42.4 | 136 | 50.9 | 4 fishing vessels in sight | 7 | 37.4 | 136 | 59.7 | |
| | | | | | | | | 7 | 38.47 | 137 | 0.8 | |
| | | | | | | | | 7 | 31.1 | 136 | 53.1 | |
| | | | | | | | | 7 | 39.94 | 137 | 3.2 | |
| | | 9.15 | 7 | 39.9 | 137 | 10.5 | Cargo ship | 7 | 51.4 | 136 | 51.27 | ANELLY; from Gresik to Merauke |
| | | | | | | | 2 fishing vessels on radar | 7 | 38.6 | 137 | 10.32 | |
| | | | | | | | | 7 | 24 | 137 | 13.7 | Dwikarya 25 |
| | | 12.15 | 7 | 35.4 | 137 | 36.8 | 4 fishing vessels on radar | 7 | 27.3 | 137 | 38.32 | Dwikarya 50 |
| | | | | | | | | 7 | 26.08 | 137 | 39.6 | Dwikarya 26 |
| | | | | | | | | 7 | 29.89 | 137 | 42.99 | Dwikarya 8 |
| | | | | | | | | 7 | 28.76 | 137 | 44.66 | |
| | | 15.45 | 7 | 35.07 | 137 | 48.67 | 7 fishing vessels on radar | 7 | 32.68 | 137 | 44.9 | - |
| | | | | | | | | 7 | 27.55 | 137 | 46.55 | Dwikarya 22 |

| No | Date | Western Indonesia Time | Position of B.J. VIII | | | | Observation | Position of other vessel | | | | Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (S) | | Longitude (E) | | | Latitude (S) | | Longitude (E) | | |
| | | | Degree | Minute | Degree | Minute | | Degree | Minute | Degree | Minute | |
| | | | | | | | | 7 | 26.81 | 137 | 42.72 | Dwikarya 11 |
| | | | | | | | | 7 | 26.89 | 137 | 40.2 | Dwikarya 39 |
| | | | | | | | | 7 | 28.48 | 137 | 38.15 | - |
| | | | | | | | | 7 | 30.46 | 137 | 37.08 | Dwikarya 8 |
| | | | | | | | | 7 | 24.96 | 137 | 40.25 | Dwikarya 25 |
| | | 18.5 | 7 | 31.26 | 137 | 42.5 | 12 fishing vessels on radar | 7 | 29.43 | 137 | 46.049 | Dwikarya 56 |
| | | | | | | | | 7 | 29.06 | 137 | 46.061 | Dwikarya 22 |
| | | | | | | | | 7 | 28.08 | 137 | 45.095 | - |
| | | | | | | | | 7 | 29.019 | 137 | 45.051 | Dwikarya 11 |
| | | | | | | | | 7 | 29.07 | 137 | 44.097 | Dwikarya 9 |
| | | | | | | | | 7 | 28.06 | 137 | 44.049 | - |
| | | | | | | | | 7 | 29.022 | 137 | 43.098 | - |
| | | | | | | | | 7 | 29.05 | 137 | 44.006 | - |
| | | | | | | | | 7 | 29.064 | 137 | 44.018 | - |
| | | | | | | | | 7 | 27 | 137 | 40.002 | Dwikarya 39 |
| | | | | | | | | 7 | 27.015 | 137 | 38.013 | Dwikarya 50 |
| | | | | | | | | 7 | 29.086 | 137 | 34.056 | - |
| 10 | Wednesday 19-May-10 | 1.3 | 7 | 9.9 | 136 | 59.88 | 2 fishing vessels on radar | 7 | 2.65 | 136 | 51.017 | - |
| | | | | | | | | 7 | 6.37 | 136 | 51.055 | - |
| | | 10.3 | 6 | 47.27 | 137 | 45.5 | 11 fishing vessels on radar | 6 | 48.87 | 137 | 46.7 | - |
| | | | | | | | | 6 | 50.47 | 137 | 45.75 | Dofior 135 |
| | | | | | | | | 6 | 44.43 | 137 | 36.05 | Sohibul Barokah 7 |
| | | | | | | | | 6 | 41.73 | 137 | 37.65 | - |
| | | | | | | | | 6 | 38.8 | 137 | 40.65 | - |
| | | | | | | | | 6 | 37.47 | 137 | 51.46 | - |

| No | Date | Western Indonesia Time | Position of B.J. VIII | | | | Observation | Position of other vessel | | | | Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (S) | | Longitude (E) | | | Latitude (S) | | Longitude (E) | | |
| | | | Degree | Minute | Degree | Minute | | Degree | Minute | Degree | Minute | |
| | | | | | | | | 6 | 49.9 | 137 | 35.88 | - |
| | | | | | | | | 6 | 51.69 | 137 | 57.12 | - |
| | | | | | | | | 6 | 47.04 | 137 | 56.05 | - |
| | | | | | | | | 6 | 47.05 | 137 | 56.05 | - |
| | | | | | | | | 6 | 59.63 | 137 | 42.22 | - |
| | | 14.2 | 6 | 42.89 | 137 | 46.2 | 4 fishing vessels on radar | 6 | 35.53 | 137 | 47.23 | - |
| | | | | | | | | 6 | 37.66 | 137 | 46.99 | Reksa 3 |
| | | | | | | | | 6 | 54.43 | 137 | 44.549 | - |
| | | | | | | | | 6 | 32.823 | 137 | 49.818 | Resa 702 |
| 11 | Thursday 20-May-10 | 9.3 | 5 | 55.113 | 137 | 50.065 | 2 large fishing ships on radar | 5 | 55.299 | 137 | 42.218 | |
| | | | | | | | | 5 | 55.777 | 137 | 47.273 | |
| | | | | | | | 3 fishing boats on radar | 5 | 54.08 | 137 | 54.06 | - |
| | | | | | | | | 5 | 57.645 | 137 | 48.404 | - |
| | | | | | | | | 5 | 54.683 | 137 | 47.079 | |
| | | 14 | 5 | 52.35 | 137 | 40.26 | 2 ships on radar | 5 | 57.258 | 137 | 27.519 | Dwikarya 1 |
| | | | | | | | | 6 | 0.79 | 137 | 31.5 | - |
| | | 21 | 5 | 56.349 | 136 | 47.806 | 2 Ships on radar | 5 | 48.21 | 136 | 42.37 | - |
| | | | | | | | | 5 | 47.485 | 136 | 48.133 | - |
| 12 | Friday 21 May 2010 | 0.1 | 5 | 44.955 | 136 | 30.003 | 2 Ships on radar | 5 | 52.29 | 136 | 34.345 | - |
| | | | | | | | | 5 | 57.505 | 136 | 22.7 | |
| | | 15.55 | 5 | 54.645 | 135 | 8.956 | 3 ships on radar | 5 | 51.114 | 135 | 11.059 | |
| | | | | | | | | 5 | 54.07 | 135 | 12.921 | - |
| | | | | | | | | 5 | 53.7 | 135 | 9.838 | - |
| | | 20.3 | 5 | 59.999 | 135 | 20 | Patrol Boat detected on AIS | | | | | Hiu-6 Patrol Boat |

| No | Date | Western Indonesia Time | Position of B.J. VIII | | | | Observation | Position of other vessel | | | | Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (S) | | Longitude (E) | | | Latitude (S) | | Longitude (E) | | |
| | | | Degree | Minute | Degree | Minute | | Degree | Minute | Degree | Minute | |
| 13 | Saturday 22-May-10 | 6 | 6 | 37.584 | 135 | 56.291 | 2 ships on radar | 6 | 37.101 | 136 | 3.386 | - |
| | | | | | | | | 6 | 44.059 | 136 | 1.882 | - |
| | | 8 | | | | | 1 Thailand fishing vessel | 6 | 49.804 | 135 | 37.129 | towing trawl at distance 0.4 mi from BJ-8 |
| | | 14.45 | 7 | 7.867 | 135 | 10.26 | 7 Ships on radar | 7 | 12.241 | 134 | 58.827 | Tamina 11 |
| | | | | | | | | 7 | 11.9 | 134 | 57.316 | Tamina 1 |
| | | | | | | | | 7 | 16.693 | 134 | 13.924 | |
| | | | | | | | | 7 | 58.557 | 135 | 10.469 | - |
| | | | | | | | | 7 | 58.279 | 135 | 8.303 | - |
| | | | | | | | | 7 | 8.962 | 134 | 57.925 | - |
| | | | | | | | | 7 | 24.488 | 135 | 9.903 | - |
| | | 17.15 | 7 | 13.113 | 135 | 12.343 | 2 Ships on radar | 7 | 17.206 | 135 | 10.236 | Tamina 12 |
| | | | | | | | | 7 | 2.904 | 135 | 2.315 | - |
| 14 | Sunday 23-May-10 | 2 | 7 | 46.042 | 134 | 22.033 | 1 fishing vessel on radar | 7 | 58.575 | 134 | 10.85 | - |
| | | 12.55 | 7 | 37.111 | 133 | 53.088 | 3 gill net ships on radar; was heading toward Arafura | 7 | 37.215 | 133 | 54.151 | - |
| | | | | | | | | 7 | 37.15 | 133 | 48.597 | - |
| | | | | | | | | 7 | 38.324 | 133 | 46.572 | - |
| | | 17.15 | 7 | 49.391 | 133 | 16.264 | 2 Ships on radar and visual | 7 | 48.981 | 133 | 16.264 | - |
| | | | | | | | | 7 | 47.229 | 133 | 11.157 | - |

## ANNEX I

# RESEARCH VESSEL BARUNA JAYA VIII

### General Information

| | |
|---|---|
| Ship Name | : KR Baruna Jaya VIII |
| IMO Number | : 9155171 |
| Call Sign | : YFZQ |
| Nationality | : Indonesia |
| Owner | : Institute of Sciences Research Center for Oceanography |
| Address | : Jl. Pasir Putih I Ancol Timur, Jakarta 11048 |
| Port Register | : Jakarta |
| Name & Place Register | : Mjellem & Karlsen AS Bergen, Norway |
| Year of Build | : July 1997 – August 1998 |
| Certificate Class | : BKI |
| Class | : BKI |
| Construction | : Hull Carbon Steel Superstructure Marine Alumunium |

### Main Dimension

| | |
|---|---|
| LOA | : 53.20 m |
| LBP | : 46.50 m |
| LWL | : 48.89 m |
| Moulded Breath | : 12.50 m |
| Maximum Draft | : 4.30 m + 0.5 m |
| Gross Tonnage | : 1273 ton |
| Net Tonnage | : 382 ton |
| Cruise Speed | : 10 knot – 12 knot (emergency) |
| Duration | : 5000 miles / 20 days |
| Accomodation | : 24 persons crew + 30 persons surveyor |

### Propulsion System & Auxiliary Machine

| | |
|---|---|
| Main Engine | : Caterpillar 3516B, 2000HP |
| Auxiliary Engine | : Cummins (2 units) KTA 19-G2, @ 336 kW |
| Emergency Generator | : Cummins Seri C 6CTA8, 175 kVA, 140 kW |
| Fuel Tank Capacity | : 176.6 KL |

Fresh Water Generator : WWS – AQUASEP, 8 Ton/Day
Incinerator : TEAM TEC – GOLAR
Fresh Water Tank Capacity : 51.28 Ton
Manuver Equipment : Steering Gear Pilot
Ship Auto Motion
Joystick
Forward & Aft Thruster

## Navigation & Telecommunication

Communication Equipment : VHF Sailor Console
GMDSS Compact Sailor Console
Inmarsat C, Sailor
Inmarsat B, (Phone, Fax, Telex, Data)
SSB ICOM – M 710
Byru Satellite Phone
Navigation Equipment : Radar 72 Mil (Freq 9 GHz)
Radar Arpa 120 mil
Simrad Planning Station
Echo Sounder
Doppler Log (Speed Log)
GPS / DGPS
Navtec
Weather Station

## Deck Machinary

Deck Crane Hydraulic (Aft) : 3 Ton Capacity (12 meters)
Deck Crane Hydraulic (Fwd) : 2 Ton Capacity (6 meters)
Trawl / Try Net Winch : 13 mm diameter, 1500 m, 8 Ton SWL
Oceanography Winch : 4 mm diameter, 2500 m, 2.5 Ton SWL
CTD Winch : 8 mm diameter, 6000 m, 6 Ton SWL
Multipurpose Winch : 14 mm diameter, 10300 m, 8 Ton SWL
Capstan : 4 Ton

**Research Equipments:**

1. Sampling Equipment
   - Dregde
   - Box Core
   - Piston Core
   - Gravity Core
   - Grab Bottom Sampler
   - Plankton Net
   - Trawl Net
2. Bathymetric Survey
   - Hydrographic Echo Sounder SIMRAD EA 500
   - Multibeam Echo Sounder SIMRAD EM 1002
3. Sub Bottom Profile Survey
   - Sub Bottom Profiler DATASONIC CAP-6600 CHIRP II
4. Water Masss Circulation Survey
   - CTD Sea Bird 911 Pus
5. Current Profile and Pattern
   - Acoustic Doppler Current Profiler RD Instrument 77 kHz

Stock Assessment

## ANNEX II
# CRUISE PARTICIPANTS

**Physical Oceanography:**

1. Ir. Herlisman, M.Si
2. Dr. Simon Tubalawony
3. Muhammad Ramdhan, M. T.
4. Muhadjirin A., Md.
5. Bobby F. Talakua

**Bathymetry**

1. M. Hasanudin, M.T.
2. Priyadi Dwi Santoso, .ST.
3. Dhani Setiawan, S.T.

**Fisheries Accoustic**

1. Moh. Natsir, S.Pi
2. Priyadi D.S.
3. Dani Setyawan

**Shrimp and Demersal Fisheries**

1. Ir. Herlisman,M.Si
2. Drs.Bambang Sumiono,M.Si
3. Drs. Suprapto
4. Ir. Wedjatmiko
5. M. Natsir, S.Pi
6. M.Rijal,B.Sc
7. Agus Salim
8. Ali Kusnin
9. Constancio dos Santos Silva, AMPi
10. Ir.Fernando da Silva
11. Ir.Orlando Halek Kalis
12. Francisco Xavier Luis Pereira,S.st

**Cetacea**

1. Jotham Ninef, M.Sc

**Water Productivity**

1. Restu Nur Afi Ati, M.Si (Plankton)
2. Ir.Fernando da Silva (Plankton)
3. Jemmy Manan, S.Ik, DEA (Chlorophyll-a)
4. Salim Picalauhatta (Nutrient)
5. Suci Lestari (Nutrient)

**PAH and Heavy Metal Contamination**

1. Dr. Zainal Arifin
2. Dede Falahudin
3. M.Taufik Kaisupy
4. Herman Rahayaan

**Geochemical and Nutrient Analysis of Sediment Samples**

1. Dr. Daniel M. Alongi
2. Dr. Lindsay A. Trott

**IUU Fishing**

1. H. Chandra, M.T

**Surface Sediment**

1. M. Hasanudin, M.T.
2. Rubiman
3. Muhajirin

## ANNEX III

# CRUISE ACTIVITY

| Date | Time | Activities | Notes |
|---|---|---|---|
| 10-May 2010 | 14:00 | Departed from Kupang | |
| 10-May 2010 | 18:24 | Arrived at Station 1 | CTD<br>ADCP<br>PAH and H. Metal Sampling<br>Water Productivity Sampling |
| 10-May 2010 | 23:10 | Arrived at Station 2 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 11-May 2010 | 09:34 | Arrived at Station 3 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 11-May 2010 | 15:05 | Arrived at Station 4 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 11-May 2010 | - | Arrived at Timor Sea TRAWL station | Bottom TRAWL |
| 12-May 2010 | 07:06 | Arrived at Station 5 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 25-May 2010 | 15:05 | Arrived at Station 6 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 13-May 2010 | 10:00 | Arrived at Station 7 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |

| | | | |
|---|---|---|---|
| 13-May 2010 | 07:17 | Arrived at Station 8 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 13-May 2010 | 20:35 | Arrived at Station 9 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 14-May 2010 | 09:40 | Arrived at Station 10 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 14-May 2010 | 21:45 | Arrived at Station 11 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Water Productivity Sampling |
| 15-May 2010 | 07:17 | Arrived at Station 12 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Sediment Sampling<br>Water Productivity Sampling |
| 15-May 2010 | 15:38 | Arrived at Station 13 | CTD<br>ADCP<br>PAH and Heavy Metal Sampling<br>Sediment Sampling<br>Water Productivity Sampling |
| 18-May 2010 | 13:43 | Arrived at Station 14 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 19-May 2010 | 01:09 | Arrived at Station 15 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 19-May 2010 | 11:23 | Arrived at Station 16 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |

| | | | |
|---|---|---|---|
| 19-May 2010 | 22:34 | Arrived at Station 17 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 20-May 2010 | 08:38 | Arrived at Station 18 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 20-May 2010 | 23:40 | Arrived at Station 19 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 21-May 2010 | 14:46 | Arrived at Station 20 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 22-May 2010 | 01:49 | Arrived at Station 21 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 22-May 2010 | 13:36 | Arrived at Station 22 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 23-May 2010 | 01:23 | Arrived at Station 23 | CTD<br>Bottom TRAWL<br>ADCP<br>Water Productivity Sampling |
| 23-May 2010 | - | Steaming to Kupang | |

# REFERENCES


Alongi, D.M. (1997) Coastal Ecosystem Processes. CRC Press, Boca Raton

Alongi, D.M., Trott, L.A. and Mohl, M. (2010) Manganese reduction dominates benthic metabolism in the southern Great Barrier Reef. Continental Shelf Res. (in press)

Anonim, 1992. Munsell soil color chart, Macbeth Devision of Kolimorgen Instruments Corps Munsell Color. Rev. Edition. New York: 10p

Anonim A, 2004. SIMRAD EM 1002 Seafloor Information System (SIS) User Guide, Horten, Norway.

Anonim. 2004. Keputusan Menteri Lingkungan Hidup No.51 Tentang Baku Mutu Air Laut untuk kehidupan Biota Laut: 11p.

Anonim B, 2004. Neptune Bathymetric Post Processing User Guide, Horten, Norway

Anonim, 2005. Cfloor User Guide, Oslo, Norway

Antara news. 2010. Jakarta serius bahas pencemaran Laut Timor-Arafura. www.antaranews.com, accessed 11 April 2010.

Badrudin and H.R.Barus, 1991. Penyebaran dan komposisi ukuran hasil tangkapan udang di perairan pulau Timor, Nusa Tenggara Timur. Jurnal Penelitian Perikanan Laut No. 57. Balitkanlut, Jakarta: pp.1-10.

Budihardjo, S., Sudjianto and T.S Murtoyo, 1993. Penelitian pendahuluan potensi sumber daya ikan demersal di wilayah perairan Zona Ekonomi Eksklusif selatan Irian Jaya bulan November-Desember 1992. Jurnal Penelitian Laut No. 80. Balitkanlut, Jakarta : pp 82-93

Bez N, D Reid , S. Neville, Y. Verin, V Hjellvik, HD Gerritsen. 2007. Acoustic data collected during and between bottom trawl stations: Consistency and common trends. Canadian Journal of Fisheries and Aquatic Sciences Jan 2007; 64 (1) pp 166-180

Clark, C. O., J. E. Cole and P. J. Webster, 1999. Indian Ocean SST and Indian summer rainfall: predictive relationships and their decadal variability.

Connell D.W. 2006. Polycyclyic aromatic hydrocarbons (PAHs). In : basic concepts of environmental chemistry. Taylor and Francis Group. London.

Forstner, U., G.T.W. Wittmann. 1979. Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin Heidelberg, New York.

Fieux, M., C. Andrie, E. Charriaud, A. G. Ilahude, N. Metzl, R. Molcard, and J. C. Swallow, 1996. Hydrological and Chlorofluoromethane Measurements of the Indonesian Throughflow Entering the Indian Ocean. J. Geophys. Res., 101 (C5): 12,433 – 12,454.

Gloerfelt-Tarp, T. and P. Kailola. 1985. Trawled fish of the Southern Indonesia and Northern Australia. ADAB –GTZ-DGF Indonesia : 406 p.

Gordon, A., 1986. Interocean Exchange of Thermocline Water. J. Geophys. Res., 91, 5037 – 5046.

Gordon, A. L., A. Field, and A. G. Ilahude, 1994. Thermocline of the Flores and Banda Seas. J. Geophys. Res., 99, 18,235 – 18,242.

Grey, D.L. and W. Dall. 1983. A Guide to the Australian Penaeid Prawn. Department of Primary Production. Darwin, Northern Territory.

Grigoriadou A, J Schwarzbauer, A Georgakopoulos. 2008. Organic geochemical parameters for estimation of petrogenic inputs in the coastal area of Kavala City, Greece. *Soils sediments* (8):253–262.

Hamilton, W. 1979. Tectonics of the Indonesian Region. Geol. Survey, Professional Paper No 1078. US Gov. Printing Office, Washington, 1979, 345 p

Hutagalung H.P. 1997. Filter methods of seawater samples. In : Analysis method for seawater, sediments, and biota. Second book. Horas P.H, Deddy S, S. Hadi R (eds).,Research and Development Center for Oceanography, LIPI, Jakarta. pp.175.

Hasanudin, M. 2009. Pemetaan dasar laut dengan menggunakan *multibeam echosounder*, OSEANA:37:1, p.19-26.

Hiller E, Z Lenka, M Sirotiak, I Jurkovic. 2010. Concentrations, distributions, and sources of polychloronated biphenyls and polycyclic aromatic hydrocarbons in bed sediments of the water reservoirs in Slovakia. *Environ monit assess* : doi 10.1007./s10661-010-1431-6.

IHO, (2002). IHO standards, for Hydrographic Surveys 4th Edition, Special Publication no 44

Irwin R.J. 1997. Environment contaminant encyclopedia chrysene entry.national service. http://www.nature.nps.gov/hazardssafety/toxic/chrysene.pdf [ 9 July 2010].

Ilahude, A. G., and A. L. Gordon, 1996. Thermocline Stratification within the Indonesian Seas. J. Geophys. Res., 101 (C5): 12,401 – 12,420.

Jinshu Z , B.J Richardson, O Shouming, Z Jianhua. 2004. Distribution and sources of polycyclic aromatic hydrocarbon (PAH) in marine environment of China. *Chinese j ocean limn* vol.22 (2):136-145.

Jun Luo X, S Jun Chen, B.I Xian Mai, G Ying Sheng, J Mo Fu, E.Y Zeng. 2008. Distribution, source apportionment, and transport of PAHs in sediments from the Pearl River delta and the Northern South China Sea. *Arch environ contam toxicol* (55):11–20.

Kailola PJ, Tarp TG. 1984. Trawled fishes of southern Indonesia and northwestern Australia. Australian Development Assistance Beureau. Directorate General of Fisheries – Indonesia.

KLH. 2004. State Environment Minister's decision no. 51 year 2004 . http : www.klh.go.id

KLH. 2010. State Environment Minister's decision draft in year 2010 http : www.klh.go.id

Kompas .2009. Pencemaran laut Timor-Arafura oleh minyak mentah, lewati ZEE. www.kompas.com, accessed 12 April 2010.

MacLennan DN, Simmonds EJ. 1992. Fisheries acoustics. Chapman & Hall. London. 325 p.

Molcard, R., M. Fiuex, and A. G. Ilahude, 1996. The Indo – Pacific Throughflow in the Timor Passage. J. Geophys. Res., 101 (C5): 12,411 – 12,420.

Mansoor.M.I., H. Kohno, Ida, H.T. Nakamura, Z. Asnan & S. Abdullah. 1998. Field guide to important commercial marine fishes of the South China Sea. SEAFDEC MFRDMD/SP/2

Morgan, J.R & M.J. Valencia, 1986. The natural environment setting *In* Morgan,J.R & M.J. Valencia (Eds.): Atlas for Marine Policy in Southeast Asean Seas. Univ of California Press. Berkeley.Los Angeles. London: 144p.

Morrison, R.J., and J.R Delaney, 1996. Review : marine pollution in the Arafura and Timor Seas. Mar Poll Bull. 32 : 327-334.

Mostafa AR, A.O Barakat, Y Qian, T.I Wade. 2003. Composition, distribution and sources of polycyclic aromatic hydrocarbons in sediments of the western harbour of Alexandria, Egypt. *Soils & sediments* 3 (3) : 173 – 179.

Munawir K. 2007. Distribusi kadar polisiklik aromatik hidrokarbon (pah) dalam air, sedimen dan beberapa sampel biota di perairan teluk klabat Bangka. Oseanologi dan limnologi di Indonesia. Pusat Penelitian Oseanografi, Pusat Penelitian Limnologi LIPI, (33/3): 441-453.

Munawir, K.,2008. Levels of PAHs in the coastal bays of Lampung, Lampung Province. *In* The dynamics of coastal ecosystems Lampung bay in relation to spatial structure. Pramudji (ed.). Research Center for Oceanographic. Indonesian Institute of Sciences. Jakarta.

Munawir K. 2008. Kadar PAH di pesisir kepulauan Raja Ampat, propinsi Papua. In: " EWIN Teluk Mayalibit, Raja Ampat", Unpublished report by Susetiono. Pusat Penelitian Oseanografi, LIPI. Jakarta.

Naamin, N. 1984. Dinamika populasi udang jerbung (*Penaeus merguiensis* de Man) di perairan Arafura dan alternatif pengelolaannya. Disertation. Fakultas Pasca Sarjana IPB: 281p.

Naamin *et al.*, 1992. Pedoman teknis pemanfaatan dan pengelolaan sumber daya udang penaeid bagi pengembangan perikanan. Seri Pengembangan Penelitian Perikanan No. PHP/KAN/PT/22/1992. Badan Litbang Pertanian: 92p.

Nakabo, T., 2000. Fishes of Japan with pictorial keys to the species. Second Edition. Tokai University Press. 2-28-4, Tomigaya, Shibuya-ku, Tokyo.

Natsir M, Sadhotomo B, Wudianto. 2005. Pendugaan biomassa ikan pelagis di perairan Teluk Tomini dengan metoda akustik bim terbagi. Jurnal Penelitian Perikanan Indonesia (JPPI). Vol. II No. 6 Tahun 2005: pp 101-107

NASA [National Aeronautics and Space Administration].2009. Oil slick in the Timor Sea. http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=40123, accessed 21 July 2010.

Nemr EA, E.A Sikaily, A Khaled, O.T Said, A.A Abd-Alla. 2004. Determination of hydrocarbons in mussels from the Egyptian Red sea coast. *environ monit assess (*96): 251–261.

Nemr El A, A Khaled, E.A Sikaly , O.T Said, A.A Abdallah. 2006. Distribution and sources of polycyclic aromatic hydrocarbons in surface sediments of the Suez Gulf. *Environ monit asses*:doi 10.1007/s10661-005-9009-4.

Nizzetto L, R Lohmann, R Gioia, A Jahnke, C Temme, J Dachs, P Herckes, A Di Guardo, K.C. Jones. 2008. PAHs in air and seawater along a North–South Atlantic transect: trends, processes and possible sources. *Environ sc. Technol*(*42)* (5):1580–1585.

Opuene K, I.E Agbozu, O.O Adegboro. 2008. A critical appraisal of PAH indices as indicators of PAH source and composition in Elelenwo Creek, Southern Nigeria. *Environmentalist* (29): 47-55.

Ramm, D.C., 1996. Sustainable groundfish yields in the Arafura Sea. Report on a scientific exchange visit to Institute of Oceanography, National Taiwan University. 6 p.

Reddy C.M, J.G. Quinn. 1999. GC-MS analysis of total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in seawater samples after the North Cape oil spill. *Mar Poll Bull* (38):126-135.

Saha, M. et al. 2009. Sources of sedimentary PAHs in tropical Asian waters: differentiation between pyrogenic and petrogenic sources by alkyl homolog abundance. Marine Pollution Bulletin. 58 :189–200.

Shepard, F. P., 1954, Nomenclature based on sand-silt-clay ratios: Journal of Sedimentary Petrology, v. 24, p. 151-158

Strickland, J.D.H. & T.R. Parsons, 1968. A Practical Hand Book of Seawater Analysis.*Fish. Sea.Res. Bull*. 167 Canada : 1-311.3

Shevelev MS, VS Mamylov, SV Ratushny, EN Gavrilov. 1998. Technique of Russian bottom trawl and acoustic surveys of the Barents Sea and how to improve them. NAFO Scientific Council Studies, No. 31: p. 13-19

Shindo, S. 1973. General review of the trawl fishery and the demersal fish stocks of the South China Sea. FAO. Fish. Tech. Paper. (120) : 49p.

Smet, M.E.M, 1989. A Geometrically Consistent Plate-Tectonic Model for Eastern Indonesia, Netherlands Journal of Sea Research, Netherlands Institute for Sea Research. Texel, Netherlands. pp 174.

Sparre, P. & S.C. Venema. 1999. Introduksi pengkajian stok ikan tropis. Translation from Introduction to tropical fish stock assessment. Part 1. Manual. Oleh Pusat Penelitian dan Pengembangan Perikanan. Jakarta : 438 p.

Sumiono,B & R. Basuki. 1991. Pengusahaan udang penaeid di perairan pantai selatan Timor Timur. Jurnal Penelitian Perikanan Laut No.57. Balitkanlut, Jakarta: pp. 53-62

Saha M *et al*. 2009. Sources of sedimentary PAHs in tropical asian waters: differentiation between pyrogenic and petrogenic sources by alkyl homolog abundance. *Marine Poll Bull* (58 ):189–200.

Sisovic A, I Beslic, K Sega, V Vadjic. 2002. Pah mass concentrations measured in $pm_{10}$ particle fraction. http://www.sciencedirect.com [9 July 2010]

Tim Survei Baruna Jaya I, 1991. Penelitian sumber daya perikanan dan karakteristik lingkungan perairan ZEE Selatan Timor (Agustus-September 1991). Laporan Pelayaran KAL Baruna Jaya-I. Balitkanlut, Jakarta (Unpublished).

Tim Survei Baruna Jaya I,1993. Penelitian potensi, penyebaran udang dan ikan demersal laut-dalam serta teknologi penangkapannya di perairan Kai, Tanimbar dan ZEE Laut Timor. Laporan Pelayaran KAL IV-02 Baruna Jaya-I. BPPT-Balitkanlut- Dishidros TNI AL (Unpublished).

Tomascik, T., A. J. Mah, A. Nontji, and M. K. Moosa, 1997 a. The Ecology of the Indonesian Seas. Part One. The Ecology of Indonesian Series. Vol. VII. Periplus Editions (HK) Ltd.

Tubalawony, S., 2002. Karakteristik Fisik Kimia dan Klorofil-a Laut Timor. Tesis. Institut Pertanian Bogor, unpublished.

Tjelmeland S. 2002. A model for the uncertainty around the yearly trawl-acoustic estimate of biomass of Barents sea cappelin, *Mallotus villosus* (Muller). ICES Journal of Marine Science, 59:  p. 1072-1080

Unar, M. 1978. Survai udang di perairan Teluk Waworada dan pantai Selatan Timor. Prosiding Seminar Ekosistem Hutan Mangrove. Jakarta, 27 Pebruari-1 Maret 1978. KLH-MAB-LON LIPI: 201-212.

US EPA [United State Environmental Protection Agency]. EPA1986. Method 8100 Polynuclear Aromatic Hydrocarbons. http://www.epa.gov/sam/pdfs/EPA-8001.pdf.

Wagey, T. and Arifin, Z. (ed). 2008. Marine biodiversity review of the Arafura and Timor Seas. Ministry of Marine Affairs and Fisheries, Indonesian Institute of Sciences, United Nation Development Programe, and Census of Marine Life, Jakarta.

Wenchuan, Q., M. Dickman, F. Chengxin, W. Sumin, S. Chenwei, Z. Lu, and Z. Huixian, 2002. Distribution, sources and potential toxicological significance of polycyclic aromatic hydrocarbons (PAHs) in Taihu Lake sediments, China. Hydrobiologia 485: 163–171

Wentworth, C. K. 1922, A scale of grade and class term for clastic sediment. Jour. Geol. 30: 337-392

Wikipedia.2010. Timor sea. http://en.wikipedia.org/wiki/Timor_Sea, accessed on 21 July 2010.

Wyrtki, K., 1961. Physical Oceanography of the Southeast Asean Waters, NAGA Rep. 2. Scripps Inst. of Oceanography, La Jolla, Calif.

Van Haren, Hans. 2005. Cruise Report: Towed ADCP. Bay of Biscay, with R/V Pelagia. Royal Netherlands Institute for Sea Research (NIOZ), Den Burg.

Wagey, T and Arifin, Z. 2008. Marine Biodiversity Review of The Arafura and Timor Seas. Ministry of Marine affairs and Fisheries (DKP), Indonesian Institute of Sciences (LIPI), UNDP and Census of Marine Life.

Wikipedia.2010. Timor sea. http://en.wikipedia.org/wiki/Timor_Sea, accessed 21 July 2010.

Wenchuan Q, M Dickman, F Chengxin, W Sumin, S Chenwei, Z Lu, Z Huixian. 2002. Distribution, sources and potential toxicological significance of polycyclic

Yunker, M.B., R.W. Macdonald, R Vingazan, R.H. Mitchell, D. Goyette, and S. Sylvestre, 2002. PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH sources and composition. Org Geochem. 33 : 489-515.

Yunker, M.B. 1995. Composition and origins of polycyclic aromatic hydrocarbons in the Mackenzie River and on the Beaufort Sea Shelf. Arctic. 48 : 118-129.

Zakaria M, H Takada, A Machinchian, M Sakari. 2009. Coastal marine pollution of polycyclic aromatic hydrocarbons (PAH) in the Asian waters. Proceeding the Asian International Conference, Conservation on the coastal environment: 070-080

.

**This book is published by :**

**Arafura and Timor Seas Ecosystem Action (ATSEA) Program**
Jl. Pasir Putih I, Ancol Timur, Jakarta Utara - 14430, Indonesia

**2011**

ISBN 978-979-3692-26-5
9 789793 692265