DEEP SEA FISH RESOURCES DIVERSITY AND POTENTIAL IN THE WATERS OF WESTERN SUMATERA OF THE EASTERN INDIAN OCEAN

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ABSTRACT

The availability of data and information on the diversity and potential of fish resources provide important aspects for exploitation and management. Most of the deep sea regions provide the most widely habitat, but until recently information on its biodiversity and potential is very little. Data analyzed were parts of the results of exploratory trawling using the R/V Baruna Jaya IV carried out in June to July 2005. The most importance species in term of numbers were the lantern fish, *Diaphus* sp.1, the rat tails macrourid, *Caelorinchus divergens,* the neoscopelids, *Neoscopelus macrolepidotus*, the spinyfins, *Diretmoides pauciradiatus*, the alepocephalid, *Bajacalifornia erimorensis,* and the trachichthyds *Hoplostetus crassispinus*. Analysis of fish resources indicated that the lowest density of about 0.08 tonnes km^{-2} was observed in the depth zone of 751 to 1,000 m in the waters of the north western part of Simeuleu and the highest density of 17.7 tonnes km^{-2} was occurred in the depth zone 500 to 750 m in the waters of the western part off Banda Aceh. In relation with the environmental aspects such as the huge pressure and scarcity of food supply, it is likely that the deep sea fishes might have a very high sustainment for survive. The most interesting aspect is that the chemical substances of their flesh, such as proteins, lipids and others will need further pharmacological analysis and research. It is advised that exploitation of deep sea fish resources nowadays shoud be directed to get the benefit from the resources diversity and bioactive substances rather than catching fish for consumption.

KEYWORDS: **deep sea fish, diversity index, catch rate, catch composition, stock density, Western Sumatera, Eastern Indian Ocean**

INTRODUCTION

The demersal resources are a group of fishes that most of their life cycle living at or around the bottom waters. Characteristics of demersal fish behaviour compared with those pelagics fish are forming a relatively smaller school, lower movement, and relatively shorter migration ranges. Catch compositions of the most economically important demersal fish in the continental shelf area and relatively shallow waters are usually consisted of red snappers, silver bellies, white pomfrets, groupers, croackers, and catfish (Saeger *et al.*, 1976). The fishing gears used for the demersal fish exploitation are trawl, bottom long line, bottom gill net, traps and hook and line. The shallow waters demersal fish has been widely known and easily found in most landing places and fish market, however, most of the deepsea demersal fish are rarely encountered while some fishes provide as identified new species that have not even been found in the literatures. As demersal fish had a relatively short distance migration range, their fishing grounds in the Indian Ocean untill recently are still limited to the narrow continental shelf areas. Based on the available marine charts, the fishing areas are considered not more than 100 m isodepth. In relation with the relatively limited capability in both fishing gears and fishing fleets of most Indonesian fishers, it is believed that the deepsea demersal fish resources at the depth range more that 100 m are considered untapped. The fish resources include deep sea shark and rays, groupers, snappers (*Etelis* sp.) and some conger eels (Wibowo, 2005). Some deep sea fish that have been found during the exploratory bottom long lining in the Sunda Strait were *Gepyroberix* sp., and *Peristedion* sp. (Hufiadi *et al.*, 2003). The first fish species can be considered as food fish, while the later has been known as a very poisonous fish.

In relation with the fish resources potential, information on this aspect regarding the deep-sea fish resources in Indonesian waters is still very scare compared to the similar aspect on the shallow demersal fishes that have been widely reported (Losse & Dwiponggo, 1977; Dwiponggo & Badrudin, 1978; 1979; 1980; Badrudin & Sumiono, 2002; Badrudin *et al.*, 2002; 2004; 2004a; 2005).

Most of the deep sea region provides the most widely habitat with little information on its biodiversity. Ninety percent of the ocean volume consisted of deep water which are dark, cold. Mean while information on the aspects of life is still very rare (Nybakken, 1986). The main environmental factors affecting deep-sea region are light, hydrostatics pressure, salinity, temperature, oxigen, and food supply. These factors will undoubtedly

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affect the behaviour, life, survival, sustainment and diversity of most organisms including fish.

This paper provides information that can be used as a benchmark for further research and assessment activities in both similar marine waters or other marine areas with similar waters characteristics and biophysical conditions. Results of the anaylisis presented in this paper provide a complementary information found in the results of the exploratory trawling carried out by the R/V Baruna Jaya IV (Anonymous, 2006).

MATERIALS AND METHODS

Data analyzed were parts of the results of exploratory trawling using the R/V Baruna Jaya IV, carried out in the framework of The Japan-Indonesia Deep Sea Fisheries Resources Joint Exploration Marine Research 2004, with one of the main objectives is to study the catch per unit area as an index of abundance of the deepsea demersal fish resources in the Indian Ocean Southern Java and Western Sumatera (Anonymous, 2006).

A total of 50 trawl fishing stations was done completly during June to July 2005. The catches of each species or species group were weighted, counted, and recorded in the fishing log sheet. The combined data for analysis were inputted in the form of Excel format. Trawl sampling sites include the waters of SE Enggano (S-1 area), Western off Bangkulu (S-2 area), NW of Simeuleu (S-4 area), and Western off Banda Aceh (S-5 area). Due to some technical problems (Anonymous, 2006), trawling activity in the S-3 area has been cancelled (Figure 1). Exploratory fishing covered the depth range of 250 to 1,200 m, while data analysis was limited only to the exploratory results carried out in the western Sumatera of the Indian Ocean. These data were grouped into three depth fishing zones, the <500 m, 500 to 750 m, and 751 to 1,000 m. Estimation of stock density and standing stock size was carried out by using the swept area method following Saeger *et al.* (1976) with the assumption that the constant mouth openning of the trawl was 50% of the head rope length and escapement factor was 75%. Species identifications were done following Nakabo (2002).

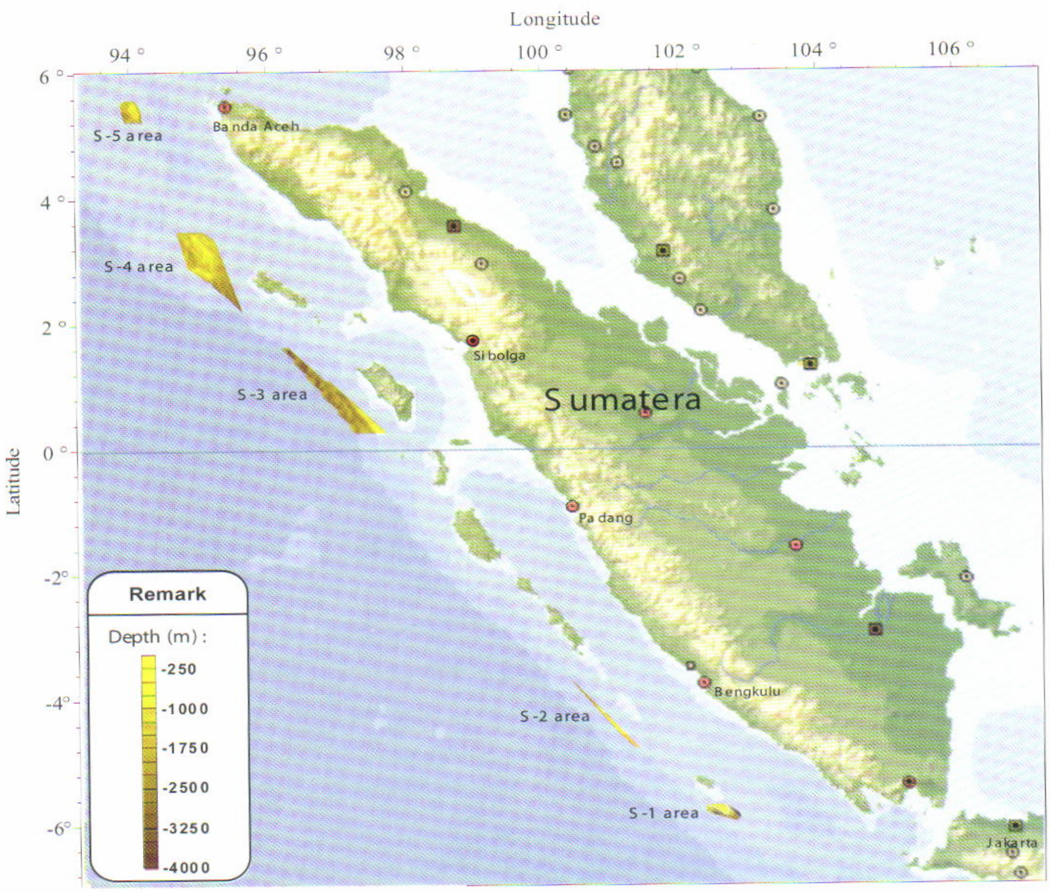

Figure 1. Deep sea trawl sampling sites (S-1 = SE Enggano; S-2 = W-off Bengkulu; S-3 = W of Nias, where trawling site has been cancelled; and S-4= NW Simeuleu; S-5 = W off Banda Aceh).

Calculations of diversity indices were limited to:

1. Richness Index of Margaleff:

   $R_1=(S-1)/\ln(n)$ .... (1

   where:
   S = number of species
   N = total number of individual fish of all species

2. Diversity Index of Shannon:

   $H=\sum[(n_i/n)\ \ln\ (n_i/n)]$ .... (2

   where:
   n = total number of individual fish of all species
   n_i = number of i [th] species

3. Diversity Index of Simpson:

   $\lambda=\sum[(n_i(n_i-1)/(n(n-1))$ .... (3

following the procedure explained in Ludwig & Reynold, (1988).

RESULTS AND DISCUSSION

Total Catch

A wide range of marine organisms was found in the catch. These included fishes group of both bony fish and elasmobranch. Other groups were crustaceans, cephalopods, echinoids, asteroids, ophiuroids, holoturoids, and anthozoa. A total of more than 550 species was found in the catch, of which until now some species were still unknown and not yet found in the literatures. The following analysis will only be limited to the fish resources.

Diversity

Biological diversity or biodiversity is the diversity of living things. The greater the variety of animal, the greater the biodiversity. The number of species and the number of individuals of each species are used to estimate biodiversity index. Biodiversity can vary with location, habitat, season, and other factors as well as with the means of estimation.

The Waters of the SE Part of Enggano

It is likely that within the depth range of 250 to 1,000 m in this waters, the number of species seems to increase toward the deeper waters. This is reflected in the Richness index, where the index in the depth zone 750 to 1,000 m is 40.0% higher than the index in the depth zone 500 to 750 m. Similary the index in the later depth zone was 40.5% higher than the index in depth zone <500 m.

This phenomenon is also happened to the Shannon index, where the values seems to decrease toward the deeper waters. In other words, the greater the depth zone the smaller the diversity. The highest index, H=2,171, occurred in the depth zone of <500 m, while in the respective deeper zones these value were 37.5 and 11.4% decreased (Table 1). The value of Simpson index reflects the domination of certain species. This index is also known as the index of domination. It seems that within the waters of Enggano, the species domination occurred in the deeper waters. The three fish groups abundantly found in the depth zone of 750 to 1,000 m, were the macrourids, the melanonids and the ophidiids. From a total of 759 fish caught, their percentage was around 50%. The most abundant macrourid species was *Caelorinchus divergens* reaching to about 12.5%, while the other members of family Macrouridae with the total percentage of almost 19% consisted of

Table 1. Richness index (R_1), Shannon index (H), and Simpson index (λ) of deep sea fish resources in the waters of Western Sumatera, Eastern Indian Ocean

Area	Index/Depth	< 500 m	500-750 m	750-1,000m
Enggano	R_1	6.47	9.09 (+40.5%)	12.82 (+40%)
	H	2.171	1,357 (-37.5%)	1,203 (-11.4%)
	λ	0.233	0.317 (+36.1%)	0.049 (-84.5%)
Bengkulu	R_1	-	8.36	10.00 (+19.6%)
	H	-	0.344	0.498 (+44.8%)
	λ	-	0.043	0.067 (+55.8%)
Simeuleu	R_1	3.036	15,061 (+396.1%)	15,403 (+2.3%)
	H	0.401	2,394 (+497.0%)	1,956 (-18.3%)
	λ	0.489	0.089 (-81.8%)	0.044 (-50.6%)
Banda Aceh	R_1	4.397	7,338 (+ 66.9%)	9,232 (+25.8%)
	H	0.609	1,812 (+198.0%)	1,019 (-43.8%)
	λ	0.839	0.281 (-66.5%)	0.255 (-9.3%)

Caelorinchus sp.1, *Gadamus colletti*, *Ventrifossa* sp.1, *Nezumia* sp.2, *Nezumia* sp.1, and *Pseudonezumia japonica* (Table 2).

The Waters of the Western Part off Bengkulu

Due to the limited area of the trawlable ground, number of trawl haul allocated in this waters was only two hauls in the 500 to 750 m depth zone and another two hauls in the 750 to 1,000 m depth zone. As in the Enggano area, the diversity indices including Richness, Shannon as well as Simpson index seem to increase toward the deeper waters. Richness index in the 750 to 1,000 m depth zone was about 19.6 (20%) higher than in the 500 to 750 m depth zone. Similarly, the Shannon index in the depth zone 750 to 1,000 m was 45% higher, while the Simpson index was 56% higher than in the depth zone 500 to 750 m (Table 1). The most abundance species in each of the two depth zone in the western part off Bengkulu as represented by the highest percentage was placed by the macrourid *Caelorinchus divergens*. This benthopelagic species seems to have either a wider range of depth distribution or the bottom habitat in this area are similar. The percentage of this species in the two depth zones was 11% and 19% respectively (Table 2).

The Waters of the NW Part off Simeuleu

Species diversity in the <500 m depth zone was rather poor compared with diversity in the deeper zone. As reflected by the Richness index which is only 3.0, the Richness index in the deeper waters of 15,061 was more than five times higher, an increase of about 396%. Similar phenomenon with the value of Shannon index, where in the <500 m depth zone the value of H=0.4, in the 500 to 750 m depth zone was six times higher as there was an increase to about 496% (almost 500%), while in the 750 to 1,000 m depth zone was five times higher (Table 1) compared with the <500 m depth zone.

The occurring Simpson diversity index is likely consistence with the Richness index, where the higher the value of the index the lower the diversity. The lower value of the Simpson index occurred in the 750 to 1,000 m depth zone, mean higher diversity occurred as indicated by the higher Richness index. The lowest value of Simpson index occurred in the 750 to 100 depth zone mean that

Table 2. The dominant families and species of the deep sea fish in the Western Sumatera (% of N)

Depth ranges (m)	< 500	500-750		750-1,000	
SE Enggano					
Myctophidae		Neoscopelidae		Macrouridae	
Diaphus sp.1	43.9	*Neoscopelus macrolepidotus*	53.1	*Caelorinchus divergens*	12.5
Ostracoberycidae		Caproidae		*Caelorinchus* sp. 1	5.5
Ostracoberyx dorgenys	16.8	*Antigonia sp.*	17.5	*Gadamus colletti*	3.4
Acropomatidae		Myctophidae		*Ventrifossa* sp. 1	3.0
Synagrops japonicus	5.6	*Diaphus* sp. 1	3.3	*Nezumia* sp. 2	2.6
Grammicolepididae		Moridae		*Nezumia* sp. 1	2.2
Xenolepidichthys dalgleishi	5.4	*Halargyreus* sp.	2.6	*Pseudonezumia japonica*	2.0
Total catch (N)	**3,103**		**1,586**		**759**
Western off Bengkulu					
		Macrouridae		Macrouridae	
		Caelorinchus divergens	11.1	*Caelorinchus divergens*	19.3
		Gadamus colletti	5.8	*Gadamus colletti*	1.5
		Neoscopelidae		*Nezumia* sp. 1	1.9
		Scopelengys tristis	9.9	Alepocephalidae	
		Neoscopelus macrolepidotus	7.0	*Rouleina guentheri*	11.9
		Sternoptychidae		*Bajacalifornia erimoensis*	6.3
		Sternoptyx sp.	4.7	Alepocephalidae sp. 1	4.1
		Alepocephalidae		*Talismania* sp.	1.5
		Rouleina guentheri	4.7	Ipnopidae	
		Bajacalifornia erimoensis	4.1	*Bathypterois atricolor*	5.2
Total catch (N)			**171**		**270**

Table 2. Countinous

Depth ranges (m)	< 500	500-750		750-1,000	
NW part of Simeuleu					
Ostracoberycidae		Diretmidae		Ophidiidae	
Ostracoberyx dorgenys	68.4	*Diretmoides pauciradiatus*	21.9	*Lamprogrammus niger*	11.4
Grammicolepididae		Macrouridae		*Glyptophidium* sp.	6.2
Xenolepidichthys dalgleishi	10.4	*Caelorinchus divergens*	10.4	Ophidiidae sp.1	2.3
Triacanthodidae		Berycidae		Macrouridae	
Tydemania navigatoris	8.5	*Beryx splendens*	9.6	*Caelorinchus divergens*	10.4
Berycidae		Ophidiidae		Melanonidae	
Beryx splendens	6.9	*Glyptophidium* sp.	9.5	*Melanonus zugmayeri*	6.5
		Trachichthyidae			
		Hoplostethus crassispinus	8.9		
Total catch (N)	**376**		**2,071**		**1,348**
Western off Banda Aceh					
Myctophidae		Ostracoberycidae		Diretmidae	
Diaphus sp.1	91.5	*Ostracoberyx dorgenys*	43.1	*Diretmoides pauciradiatus*	47.2
Phosichthyidae		Diretmidae		Nettastomatidae	
Polymytme elongatus	2.0	*Diretmoides pauciradiatus*	26.9	*Nettastoma solitarium*	13.6
Chloropthalmidae		Trachichthyidae		Macrouridae	
Chlorophthalmus sp.1	1.5	*Hoplostethus rubellopterus*	14.4	*Caelorinchus divergens*	9.3
		Nettastomatidae			
		Nettastoma solitarium	3.9		
		Paralepididae			
		Notoleptis rissoi	2.8		
Total catch (N)	**2,281**		**3,558**		**920**

diversity in this waters was relatively low but the domination index was high, which mean that the fish community was dominated by a small number of species. The most abundance species in the <500 m depth zone was only three species, while in the 500 to 750 m depth zone was 12 species and in the deeper zone was 14 species. This information indicates that the deep sea fish community in the <500 m depth zone was dominated by only three species. As already mention earlier that the very abundance species in the <500 m depth zone was only one. This species was *Ostracoberyx dorgenys* of the family Ostracoberycidae with the percentage number reaching to about 68% (Table 2). Comparing with the Enggano area, this species provides the second most abundance in the same depth zone, while in the other deeper zone of both Enggano and off Bengkulu area it was hardly ever found. It is likely that the depth distribution of this species might be relatively limited up to the depth of less than 750 m.

In the 500 to 750 m and 750 to 1,000 m depth zone the percentage of the most abundance species was not as high as the percentage in the <500 m depth zone. This appearence indicated that the habitat of fish community in the deeper zone was slightly different compared with the shallower depth zone.

The five most abundance species found in the 500 to 750 m depth zone were the spinyfins, *Diretmoides pauciradiatus* (Diretmidae), the macrourid, *Caelorinchus divergens*, the alfonsinos, *Beryx splendens*, the ophidiid, *Glyptophidium* sp., and the slimeheads, *Hoplostethus crassispinus* of the family Trachichthyidae. The respective percentage compositions of these species were almost 22%, each of the following three species of about 10% and the last species of almost 9%. The four most abundance species in the 750 to 1,000 m depth zone were the ophidiid, *Lamprogrammus niger*, the macrourid, *Caelorinchus divergens*, the melanonid or pelagic cod, *Melanonus zugmayeri* and the other ophidiid, *Glyptophidium* sp., with a lower percentage of about 11, 10, almost 7, and 6% respectively (Table 2).

The other species found in these two deeper depth zone with different percentage ranging from about 4 to 0.5% were the slimeheads, *Hoplostethus crassispinus*, similar with the orange roughy, *H. atlanticus* in the southern Australia (Anonymous, 1992), the ipnopids, *Bathypterois atricolor*, the spinyfins, *Diretmoides pauciradiatus*, two species of the alepocephalids, *Bajacalifornia erimoensis* and *Rouleina guentheri*, the viperfishes, *Chauliodus sloani*, the neoscopelids, *Neoscopelus macrolepidotus*, and two species of the myctophids, *Lampadena* spp.

The Waters of the Western Part off Banda Aceh

As already mentioned earlier that the Richness index always increased toward the deeper waters in each of the preceding areas, the similar appearences were also happened to the deep sea fish community in northest part of the waters of western Sumatera. Difference with the pattern of Shannon index in the Enggano area where the highest index occurred in the <500 m depth zone, and was decreasing toward the deeper zone, the highest index of H=1.8 in the Western part off Banda Aceh occurred in the 500 to 750 depth zone (Table 1). While the pattern of the Richness index in this area which increased toward the deeper waters. This is in line with the occurring reversed pattern of Simpson index that seems to be a normal phenomenon in ecology.

The most abundance species in each of the three depth zone was one species, three species, and two species respectively. The most abundance species in the <500 m depth zone in this waters was occupied by the mycthopid, *Diaphus* sp.1, where approximately 92% of the total number of individual fish in this depth zone was contributed by this species alone. The two abundance species were placed by the phosichtyds, *Polymytme elongatus*, followed by the green eyes, *Chlorophthalmus* sp.1 (Chloropthalmidae).

The first of the most abundance species in the 500 to 750 m depth zone was placed by *Ostracoberyx dorgenys*, followed by the spinyfins, *Diretmoides pauciradiatus,* and the slimeheads, *Hoplostethus rubellopterus* (Tabel 2). The four abundance species in this zone were *Nettastoma solitarium* (Nettastomatidae), *Notoleptis rissoi* (Paralepididae), *Caelorinchus divergens* (Macrouridae), and the deep sea hairtail, *Benthodesmus tenuis* (Trichiuridae).

As in the Simeuleu area, where the spinyfins, *Diretmoides pauciradiatus* provided the most abundance species in the 500 to 750 m depth zone, in the western part off Banda Aceh area this species respresented the most abundance species in the deeper zone of 750 to 1000 m. Based on this appearence, it is likely that the spinyfins would provide the major inhabitant of the deeper waters of the Eastern Indian Ocean.

Ranking of Importance

This rank of importance was tabulated based on the abundance data in term of frequency of occurence of the species in each depth zone in the four areas and the percentage to the total number on fish caught. The six species that were frequent to occurr in the catch were tabulated. The high rank of importance was based on the number of fish caught in each depth zone of the four areas. The myctophids, *Diaphus* sp.1, represented the first rank of important in the <500 m depth zone in the area of both SE Enggano and Western off Banda Aceh. This species was almost absence in the area close to the imaginary equator line, except in the area around Simeuleu at the 500 to 750 m depth zone with almost close to the lowest rank of important. The rat tails macrourid, *Caelorinchus divergens,* seems to be represented the main important fish within the depth zone of more than 500 m. It seems that this species provides a relatively cosmopolitant fish as the fish often presented in the catch in each of the four areas. The neoscopelids, *Neoscopelus macrolepidotus* was likely forming a southern waters inhabitant, as no record of the catches in the northern area of S-5, while in the S-4 area the importance was the lowest rank of the 750 to 1,000 m depth zone and in the 500 to 750 was close to the lowest rank. The spinyfins, *Diretmoides pauciradiatus* represented the deeper waters fish similar with the macrourid, *Caelorinchus divergens*. It is likely that this species prefers to inhabit in the waters of the northern part of the equator. The alepocephalid, *Bajacalifornia erimorensis* might prefer to inhabit in the deepest depth zone of 750 to 1,000 m, and in the shallower zone of the northern and southern waters close to the equator, while the slimeheads, *Hoplostetus crassispinus* might represent the northern inhabitant of the western Sumatera waters.

Catch Rates

Catch rate which is equivalent with the catch per unit of effort provides one of the indices of abundance of fish resources. Fluctuation of catch rates can be assummed as the response of the fish communities against some influencing factors both internal and external. In the exploited fisheries, especially in the shallow coastal waters, fishing pressure provides the most influencing factor. However, what is the most influencing factor affecting the fluctuation of fish abundance in the deep-sea is not known. The availability of data and informations on the catch rates in a certain waters in both spatial and temporal provide one of the

Table 3. Ranking of importance of the six abundance species in the waters of Western Sumatera, Eastern Indian Ocean

Area code, depth zones (m)	Myctophidae *Diaphus* sp.	Macrouridae *Caelorinchus Divergens*	Neoscopelidae *Neoscopelus macrolepidotus*	Diretmoidae *Diretmoides pauciradiatus*	Alepocephalidae *Bajacalifornia erimorensis*	Trachichthydae *Hoplostetus crasipinus*
S-1						
<500	1	-	-	-	-	-
500-750	3	8	1	1	-	-
750-1,000	-	1	7	7	6	-
S-2						
<500	-	-	-	-	-	-
500-750	-	1	3	-	8	-
750-1,000	-	1	7	-	3	-
S-4						
<500	-	-	-	-	-	-
500-750	17	2	14	1	15	5
750-1,000	-	2	19	7	5	8
S-5						
<500	1	-	-	-	-	-
500-750	-	6	-	2	-	3
750-1,000	6	3	-	1	7	4

most important aspects needed for fish resources exploitation and fisheries development.

In the waters of south eastern part of Enggano both the minimum of 5.5 kg per hr and the maximum of 330.1 kg per hr were obtained from the depth zone of 500 to 750 m. The average catch rate of the following three depth zone of <500 m, 500 to 750 m, and 751 to 1,000 m were 81.0, 121.7, and 103.2 kg per hr, respectively (Table 4). Catch rate data in the waters of western part off Bengkulu area were based on only two trawl hauls from the depth zone 500 to 750 m and two trawl hauls in the depth zone 751 to 1,000 m. The respective minimum catch rates were 7.5 and 17.5 kg per hr, while the maximum were 18.1 and 20.5 kg per hr, with the average of 12.8 and 19.0 kg per hr.

Fifty percent of the total number trawl hauls in the Western Sumatera of the eastern Indian Ocean during this cruise were carried out in the waters of North Western Simeuleu. The minimum catch rate of only 3.3 kg per hr occurred in the depth zone 751 to 1,000 m, while the maximum catch rate of 90.1 kg per hr was observed in the depth zone 500 to 750 m. During this cruise, the minimum catch rate in this area provided the lowest catch rate of the whole depth zone in the four areas of western Sumatera. The average catch rates from the three depth zone were 43.4, 45.7, and 25.8 kg per hr repectively (Table 4).

In the western part off Banda Aceh, the lowest catch rates were found in the the depth zone <500 m, while the highest catch rates occurred in the 500 to 750 m depth zone. The respective average catch rates in the western off Banda Aceh were 8.4, 110.0, and 84.8 kg per hr (Tabel 4). Based on these catch rates data, through some further calculations procedures and asumptions, a number of stock parameters such as stock density (Shindo, 1973), standing stock size (Saeger *et al.*, 1976) as well as potential yield (Gulland, 1983) of the deep sea fish resources in the western part of Sumatera may be estimated.

Stock Density and Standing Stock Size

In the waters of the South Eastern part of Enggano the estimated density of fish varied from the minimum of 0.6 to 0.8 tonnes km^{-2} to the maximum of 3.3 to 9.9 tonnes km^{-2}, with the average of 2.3 to 3.8 tonnes km^{-2}. Based on these figures, the estimated standing stock size (biomass) in this waters was about 3,176 tonnes, derived from the following depth zone of <500 m, 500 to 750 m, and 751 to 1,000 m of about 700; 1,179; and 1297 tonnes, respectively (Table 5).

Due to the limited number of trawl hauls in the western part off Bengkulu waters which was only covered two depth zone of 500 to 750 m and 751 to 1,000 m, the estimated mean density of fish was between 0.4 to 0.6 tonnes, with the total biomass of about 62.5 tonnes, which was originated from the two depth zone of about 7.5 and 55 tonnes respectively. Based on 25 trawl fishing stations carried out in the north western part off Simeuleu, it was found that a relatively wider range of fish

Table 4. Catch rates of deep sea fish resources in each depth zone in the waters of Western Sumatera (Indian Ocean)

Items/Depth zone	<500 m	500-750 m	751-1,000 m	Total
South-Eastern part of Enggano				
No. of Station (n)	3	3	4	10
Catch rates (kgs per hr)				
Minimum	27.3	5.52	31.0	5.5
Maximum	124.4	330.1	202.5	330.1
Mean	81.0	121.7	103.2	102.1
Std. Dev. (s)	49.3	180.9	72.0	99.1
Coef. Var. (%)	60.9	148.6	69.8	97.0
Western part off Bengkulu				
No. of Station (n)	-	2	2	4
Catch rates (kgs per hr)				
Minimum	-	7.5	17.5	7.5
Maximum	-	18.1	20.5	20.5
Mean	-	12.8	19.0	15.91
Std. Dev. (s)	-	7.5	2.2	5.7
Coef. Var. (%)	-	58.4	11.4	36
North Western part of Simeuleu				
No. of Station (n)	1	12	12	25
Catch rates (kgs per hr)				
Minimum	-	8.8	3.3	3.3
Maximum	-	90.1	81.5	90.1
Mean	43.4	45.7	25.8	36.1
Std. Dev. (s)	-	29.7	22.4	27.2
Coef. Var. (%)	-	65.1	86.9	75.0
Western part off Banda Aceh				
No. of Station (n)	3	4	4	11
Catch rates (kgs per hr)				
Minimum	5.2	24.6	23.8	5.2
Maximum	13.2	270.4	188.5	270.4
Mean	8.4	110.0	84.8	73.1
Std. Dev. (s)	4.2	114.4	75.2	86.5
Coef. Var. (%)	50.4	104.0	88.7	118

densities in each depth zone have been observed. The minimum density in this waters was between 0.08 to 0.24 tonnes km^{-2} with the maximum between 2.4 to 2.7 tonnes km^{-2}. The estimated total biomass in this area was about 4,827 tonnes. This was contributed from the previous three zones of 455; 2,525; and 1847 tonnes respectively. Similar with the area off Simeuleu, in the western part off Banda Aceh, the northest fishing area during this cruise, a relatively wider range of fish density has also been detected. The minimum density within the three depth zones was 0.2 tonnes km^{-2}, while the maximum density was 17,714 tonnes km^{-2}. The average density beginning from the shallower to the deeper depth zones were 0.26, 5.7, and 2.5 tonnes km^{-2} respectively. The total biomass in this area was about 4,491 tonnes. This figure was cummulated from the three depth zone of 90; 2,905; and 1,497 tonnes respectively. Other information regarding the density and the standing stock size of the deep sea fish in the western part of Sumatera of the Indian Ocean is presented in Table 5.

The Russian investigation in the western tropical Pacific Ocean and the seas on the Indo-Australian Archipelago produced a wealth of mesopelagic fishes. The biomass of these fishes in the entire water column to 1,000 metres had been measured. In the Kuroshio zone the density of fish were 5.0 to 6.0 mg m^{-3}; equatorial waters, 3.1 to 8.1 mg m^{-3}; central water mass 0.6 to 2.0 mg m^{-3}. Their investigation barely extended to the bathypelagic fish fauna. In the waters column from 1,000 to 4,000 m, the comparable biomass is likely to fall to a tenth of the mesopelagic value. Eventhough these results could not directly be compared with the present finding due to the differences in the method of measurements, the following estimation of demersal fish from the western of the North Atlantic waters has been reported by Heidrich & Rowe in 1977 (Marshall, 1979). Based on 116 trawl

Table 5. Estimated mean stock density (tonnes km^{-2}) and standing stock size (tonnes) in the waters of Western Sumatera

Items/Depth zone	< 500 m	500-750 m	751-1,000 m	Total
South-Eastern part of Enggano				
No. of Station (n)	3	3	4	
Stock density	2,271	3,807	3,126	
Trawlable area (km^2)	308.24	309.76	414.96	1,032.96
Standing Stock	700.0	1,179.3	1,297.2	3,176.5
Western part off Bengkulu				
No. of Station (n)	-	2	2	
Stock density	-	0.408	0.559	
Trawlable area (km^2)	-	18.37	98.31	116.68
Standing Stock (tonnes)	-	7.5	55.0	62.5
North-Western part off Simeuleu				
No. of Station (n)	1	12	12	
Stock density	2,079	1,349	0.760	
Trawlable area (km^2)	218.70	1,871.97	2,429.85	4,520.51
Standing Stock (tonnes)	454.7	2,525.3	1,846.7	4,826.7
Western off Banda Aceh				
No. of Station (n)	3	4	4	
Stock density	0.263	5,695	2,484	
Area (km^2)	341.72	510	602.46	1,454.18
Standing Stock (tonnes)	89.9	2,904.5	1,496.5	4,490.9

hauls, the fish which were identified and weighed, estimates of absolute abundance were obtained from a series of exposures in a pair of cameras. The density of fish, expressed in weight per square metre of bottom over areas between 497 to 2,780 m, varied from 0.63 to 5.78 g m^{-2} (Marshall, 1979). This means that the estimated density of the deep sea fish in that area was between 6.3 to 57.8 tonnes km^{-2}. Comparing with the density of deep sea fish in other part of the world ocean, particularly in the North Atlantic waters, it can be stated that the density of fish in the western part of Sumatera of the eastern Indian Ocean during the survey period was relatively low.

From experimental fishing using bottom long line in the waters of Semangka Bay, Lampung, three species of deepsea fish that never been seen before in any other part of the Sunda shelf were *Gepyroberix* sp., one species from the family of Triglidae and one species from family of Macrouridae (Hufiadi *et al.*, 2003). The colour of the first two species was reddish and bright red. It was informed that *Gepyroberix* sp. has been normally consumed in Japan. The species of *Peristedion* sp. of the family of Triglidae provides a very poisonous fish (Figure 2 and 3). In general, it is likely that until recently the exploratory trawling of the deepsea demersal fish are still considered as one of the scientifics purposes rather than searching fish resources for direct human consumption. Some implications from the environmental aspects such as a very huge pressure and scarcity of food supply, it is likely that the deep sea fishes would have a very high sustainment for survive. The most interesting biological aspect is that the chemical substances of their flesh, such as protein, lipid and other biochemical substances which will need further pharmacological laboratory analysis and research. It was reported by the crews of the research vessel during this cruise that they were hardly ever to sleep for the whole night after they consumed the 'boiled' alepochepalid fish (*Bajacalifornia erimorensis*). This aspect seems to be important for the future frontier research in the framework of the exploitation of fish resources biodiversity.

Catch Composition

Catch composition in the SE off Enggano

The availability of catch composition data provide one of the basic information needed for the development of resources exploitation. In each depth stratum there were at least three species from three different families dominated the catch. In the depth stratum of <500 m, these species were *Plesiobatis* sp. (Plesiobatididae), *Diaphus* sp.1 (Myctophidae), and *Ostracoberyx dorgenys* (Ostracoberycidae). These three species amounted to about 60% of the total catch in the stratum, while the rests consisted of more than 10 species (Table 6).

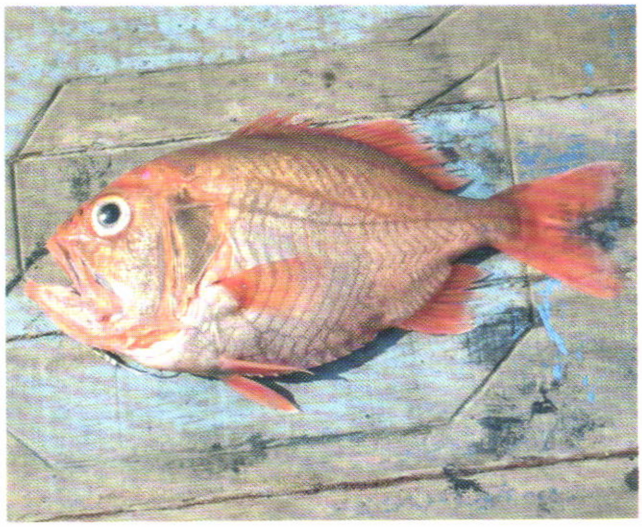

Figure 2. *Gepyroberix* sp. deep sea fish species caught by bottom long line in the waters of Semangka Bay, Lampung.

Figure 3. *Peristedion* sp. (Triglidae), a very poisonous deep sea fish caught by bottom long line in the waters of Semangka Bay, Lampung.

The *Diaphus* sp.1 is one of the species of Myctophidae. The myctophid which is also known as the lantern fishes provides the most diverse mesopelagic fish in both number of species and individuals (Marshall, 1979). It was likely that an acoustically detected large schooling traces found in the Bay of Tomini at the depth of more than 200 m during the east monsoon in 2003 provide one the examples (Anonymous, 2005).

The three dominant species found in the 500 to 750 m depth stratum were *Mitsukurina owstoni* (Mitsukuiridae), *Setarches guentheri* (Scorpaenidae), and *Plesiobatis* sp. (Plesiobatididae), which amounted to about approximatelly 81% of the total catch. Within the stratum of 750 to 1,000 m, there were also three dominant species, *Mitsukurina owstoni* (Mitsukuiridae), *Hexatrygon longirostra* (Hexatrygonidae), and *Plesiobatis* sp. (Plesiobatididae) that amounted to about 65% of the total catch in this stratum. It can be stated that the species of *Plesiobatis* sp., provides the most wider depth range distribution as the fish species always occurred in each depth stratum. Other species that were likely to be found substantially in the depth strata were the family of Macrouridae and Alepocephalidae.

Catch composition in the western part off Bengkulu

In the western part off Bengkulu area the trawl samples covered only two depth strata, the 500 to 750 m and the 750 to 1,000 m as the trawlable ground was only found within the depth range of 500 to 1,000 m.

The most dominated fish families found in the catch were Ophidiidae, Marouridae, and Chimaeridae. In the depth stratum of 500 to 750 m, the *Ophidiidae* sp.1 and *Lamprogrammus niger*,

Table 6. Percentage catch composition of deepsea fish in the south eastern part of Enggano island

Depth ranges (m)	< 500	500-750		750-1,000	
Plesiobatididae		Mitsukurinidae		Mitsukurinidae	
Plesiobatis sp.	27.2	*Mitsukurina owstoni*	41.1	*Mitsukurina owstoni*	36.3
Plesiobatis daviesi	4.3	Scorpaenidae		Hexatrygonidae	
Myctophidae		*Setarches guentheri*	26.9	*Hexatrygon longirostra*	15.9
Diaphus sp.1	16.6	Plesiobatididae		Plesiobatididae	
Ostracoberycidae		*Plesiobatis* sp.	12.8	*Plesiobatis* sp.	12.5
Ostracoberyx dorgenys	16.0	Neoscopelidae		*Plesiobatis daviesi*	4.5
Grammicolepididae		*Neoscopelus macrolepidotus*	4.8	Macouridae	
Xenolepidichthys dalgleishi	5.8	Torpedinidae		*Caelorinchus divergens*	6.3
Squatinidae		*Torpedo tokionis*	3.2	*Caelorinchus* sp.1	1.8
Squatina tergocellatoides	3.5	Moridae		Centrophoridae	
Macrouridae		*Halargyreus* sp.	1.4	*Centrophorus* sp.2	3.6
Ventrifossa sp.1	3.2	Alepocephalidae		Melanonidae	
Ventrifossa sp.2	2.1	*Alepocephalus bicolor*	1.4	*Melanonus zugmayeri*	2.7
Trichiuridae		*Xenodermichthys nodulosus*	0.9	Alepocephalidae	
Benthodesmus tenuis	2.6	Trichiuridae		*Bajacalifornia erimoensis*	2.1
Xiphiidae		*Benthodesmus elongatus*	0.1	*Alepocephalus bicolor*	1.1
Xiphus gladius	2.4	Miscellaneous	7.4	*Talismania* sp.	0.7
Zeidae				Ophidiidae	
Zenopsis conchifer	2.2			*Lamprogrammus niger*	2.0
Acropomatidae				Macrouroidae	
Synagrops japonicus	2.1			*Squalogadus modificatus*	1.6
Miscellaneous	12.0			Miscellaneous	8.5
Total (%)	**100.0**		**100.0**		**100.0**
Total catch (kgs)	**242.9**		**365.0**		**412.8**

Table 7. Percentage catch composition of deep sea fish in the westhern part off Bengkulu

Depth ranges (m)	500-750	750-1,000	
Ophidiidae		Macrouridae	
Ophidiidae sp.1	24.3	*Caelorinchus divergens*	33.9
Lamprogrammus niger	2.6	*Nezumia* sp.1	1.2
Macrouridae		*Ventrifossa* sp.1	1.0
Caelorinchus divergens	21.4	Chimaeridae	
Gadamus colletti	3.1	*Chimaera* sp.	23.4
Barbourisiidae		Congridae	
Barbourisia rufa	6.9	Congridae sp.1	5.4
Alepocephalidae		Muraenesocidae	
Bajacalifornia erimoensis	6.8	Muraenesocidae sp.	4.8
Alepocephalus sp.1	2.9	Alepocephalidae	
Narcetes sp.	1.4	*Bajacalifornia erimoensis*	4.1
Talismania sp.	1.6	*Rouleina guentheri*	2.7
Neoscopelidae		Alepocephalidae sp.1	2.9
Neoscopelus macrolepidotus	5.5	Melanonidae	
Scopelengys tristis	3.0	*Melanonus zugmayeri*	2.9
Synaphobranchidae		Asteronesthidae	
Synaphobranchus sp.	2.8	*Heterophotus ophistoma*	2.4
Melanonidae		Neoscopelidae	
Melanonus zugmayeri	2.7	*Neoscopelus macrolepidotus*	1.8
Halosauridae		Diceratiidae	
Aldrovandia affinis	2.4	Diceratiidae sp.	1.3
Miscellaneous	12.6	Miscellaneous	12.2
Total (%)	**100.0**		**100.0**
Total catch (kgs)	**25.6**		**38.03**

Table 8. Percentage catch composition of deep sea fish in the north western part of Simeuleu island

Depth ranges (m)	< 500	500-750		750-1,000	
Ostracoberycidae		Trachichthyidae		Hexatrygonidae	
Ostracoberyx dorgenys	52.6	*Hoplostethus crassispinus*	28.9	*Hexatrygon longirostra*	15.6
Berycidae		Berycidae		Ophidiidae	
Beryx splendens	33.3	*Beryx splendens*	19.0	*Lamprogrammus niger*	15.3
Grammicolepididae		Diretmidae		Ophidiidae sp.1	2.2
Xenolepidichthys dalgleishi	7.8	*Diretmoides pauciradiatus*	17.3	Macrouridae	
Miscellaneous	6.3	Macrouridae		*Caelorinchus divergens*	13.5
		Caelorinchus divergens	9.8	Alepocephalidae	
		Centrophoridae		*Bajacalifornia erimoensis*	6.0
		Centrophorus sp.	3.2	*Narcetes* sp.	2.1
		Centrophorus moluccensis	1.8	*Talismania* sp.	1.9
		Muraenesocidae		*Rouleina guentheri*	1.7
		Muraenesox sp.	1.9	Trachichthyidae	
		Lophiidae		*Hoplostethus crassispinus*	5.7
		Lophiodes sp.	1.6	Centrophoridae	
		Plesiobatididae		*Centrophorus* sp.2	5.2
		Plesiobatis sp.	1.3	Diretmidae	
		Hexatrygonidae		*Diretmoides pauciradiatus*	3.5
		Hexatrygon longirostra	1.2	Macrouroididae	
		Alepocephalidae		*Squalogadus modificatus*	3.4
		Alepocephalus bicolor	1.0	Melanonidae	
		Bajacalifornia erimoensis	0.8	*Melanonus zugmayeri*	2.9
		Miscellaneous	12.2	Congridae	
				Congridae sp.1	2.2
				Rajidae	
				Dipturus sp.	2.0
				Miscellaneous	16.8
Total %	**100.0**		**100.0**		**100.0**
Total catch (kgs)	**43.4**		**548.7**		**309.4**

both of them made up to 27%, followed by *Caelorinchus divergens* of the family of Macrouridae. The last species of Macrouridae has also dominated the catch within the stratum of 750 to 1,000 m that reached to about 34%, while the second dominated species was the rat tails *Chimaera* sp. (Chimaeridae) amounted to about 23% (Table 7). The rest of the catch consisted of more than 15 species in each stratum.

Catch composition in the NW Simeuleu

More than 93% of the total catch in stratum <500 m contibuted by only three species. These were *Ostracoberyx dorgenys* (Ostracoberycidae), *Beryx splendens* (Berycidae), and *Xenolepidichthys dalgleishi* (Grammicolepididae) with the percentage of about 53, 33, and 8% respectively. The most dominant species found within the depth stratum of 500 to 750 m were *Hoplostethus crassispinus* (Trachichthyidae), *Beryx splendens* (Berycidae), *Diretmoides pauciradiatus* (Diretmidae), and *Caelorinchus divergens* (Macrouridae) with the respective percentage of about 29, 19, 17, and 10%. With the relatively lower percentage catch composition, the species of *Hexatrygon longirostra* (Hexatrygonidae), *Lamprogrammus niger* (Ophidiidae), and *Caelorinchus divergens* (Macrouridae) were substantially found in the catch (Table 8). The species of *Beryx splendens* was likely to have wide depth distribution as this species was found in both depth range of <500 m and 500 to 750 m. The similar case were also applied to the species of *Hoplostethus crassispinus* (Trachichthyidae), *Caelorinchus divergens* (Macrouridae), *Diretmoides pauciradiatus* (Diretmidae), *Centrophorus* sp. (Centrophoridae) and *Bajacalifornia erimoensis* (Alepocephalidae) that occurred in the deeper water of both the strata 500 to 750 m and 750 to 1,000 m. The species of *Hexatrygon longirostra*, the second dominant species within the stratum of 750 to 1,000 m in the waters around Enggano Island, provided the most dominated the catch within the same stratum in the waters around Simeuleu Island.

Table 9. Percentage catch composition of deep sea fish in the westhern part off Banda Aceh

Depth ranges (m)	< 500	500-750		750-1,000	
Myctophidae		Diretmidae		Alopiidae	
Diaphus sp.1	22.2	*Diretmoides pauciradiatus*	36.2	*Alopias superciliosus*	26.7
Plesiobatididae		Ostracoberycidae		Diretmidae	
Plesiobatis sp.	22.1	*Ostracoberyx dorgenys*	33.9	*Diretmoides pauciradiatus*	25.4
Zeidae		Trachichthyidae		Trachichthyidae	
Zenopsis conchifer	18.6	*Hoplostethus rubellopterus*	5.7	*Hoplostethus rubellopterus*	14.1
Polymixiidae		Macrouridae		Macrouridae	
Polymixia japonicus	8.0	*Caelorinchus divergens*	3.8	*Caelorinchus divergens*	7.9
Ostracoberycidae		Nettastomatidae		Centrophoridae	
Ostracoberyx dorgenys	6.2	*Nettastoma solitarium*	3.8	*Centrophorus* sp.2	6.4
Chlorophthalmidae		Plesiobatididae		*Centrophorus moluccensis*	5.7
Chlorophthalmus sp.1	4.6	*Plesiobatis* sp.	3.4	Nettastomatidae	
Caproidae		Centrophoridae		*Nettastoma solitarium*	4.3
Antigonia capros	2.6	*Centrophorus moluccensis*	3.1	Miscellaneous	9.5
Berycidae		Paralepididae			
Beryx splendens	2.4	*Notoleptis rissoi*	2.6		
Miscellaneous	13.3	Miscellaneous	7.5		
Total (%)	**100.0**		**100.0**		**100.0**
Total catch (kgs)	**25.3**		**439.9**		**339.0**

Catch composition in the western part off Banda Aceh

The catch composition in the western part off Banda Aceh seems to be the lesser diverse in catch composition compared with the previous areas of Western part of Sumatera. Similar with the composition in the previous areas where the catches in the depth stratum <500 m were dominated by the species of *Plesiobatis* sp. (Plesiobatididae) and *Diaphus* sp.1 (Myctophidae), in the North western part of Simeuleu Island the species of *Diaphus* sp.1 and *Plesiobatis* sp. provide the most dominant species found in the catches, with the respective percentage of each species of about 22%.

The third dominant species in this stratum was *Zenopsis conchifer* (Zeidae) of about 19%, followed by *Polymixia japonicus* (Polymixiidae) which percentage to about 8%. The other species in this stratum consisted of about more than 6 species, where each species contributed to only <6% (Table 9).

In the depth stratum 500 to 750 m, more than two-third of the catches were contributed by the species of *Diretmoides pauciradiatus* and *Ostracoberyx dorgenys* that reached to about 70% of the total catch in the stratum. The rests of the catches consisted of more than 7 species, each of the species contributed to only <5%. The first species of Diretmidae that was dominated in this stratum, has been the second dominant species in the depth stratum of 750 to 1,000 m, that contributed to about 25% of the total catch in this stratum. The first dominated species was contributed by deep sea shark, *Alopias superciliosus* of the family Alopiidae. The third dominant species amounted to about 14% of the total catch in this stratum was *Hoplostethus rubellopterus*.

CONCLUSION

From the analysis of only fish resources it was found that the highest mean catch rate of about 121.7 kgs per hr was occurred in the depth range of 500 to 750 m, in the south western part of Enggano area, while the lowest mean catch rate of 3,3 kgs per hr was occurred in the depth zone 751 to 1,000 m in the waters of North Western Simeuleu. The lowest density of about 0.08 tonnes km^{-2} was observed in the depth zone of 751 to 1,000 m in the north western part of Simeuleu, while the highest density of 17,714 (17.7) tonnes km^{-2} was occurred in the depth zone 500 to 750 m in the western part off Banda Aceh. By multiplying the estimated sea surface areas and the mean density in each depth zone and in the survey area, the total deep-sea fish standing stock size can be calculated.

As reflected by the Richness index of Margaleff, within the depth range of 250 to 1000 m in the waters of Western Sumatera, the number of species seems to increase toward the deeper waters. The six species of important in term of numbers of individual fish available were the lantern fish myctophids, *Diaphus* sp.1, the rat tails macrourid, *Caelorinchus divergens,* the neoscopelids, *Neoscopelus macrolepidotus*, the spinyfins, *Diretmoides pauciradiatus*, the alepocephalid, *Bajacalifornia erimorensis*, and the trachichthyds *Haplostetus crassispinus*.

In relation with the environmental aspects such as the very huge pressure and scarcity of food supply, it is likely that the deep sea fishes would have a very high sustainment for survive. In this aspect, the chemical substances of their flesh, such as proteins, lipids, and other biochemical substances will need further pharmacological laboratory analysis and research. These aspects seem to be important for the future frontier research. It is advised that exploitation of deep sea fish resources nowadays shoud be directed to get the benefit from the fish resources biodiversity and bio active substance rather than searching fish for direct human consumption.

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