Deepwater (150-500m) Demersal Resources Exploration in the Exclusive Economic Zone of Malaysia Using Beam Trawl

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Abstract: The objective of this survey is to investigate the species diversity and the distribution of unexploited demersal resources at a depth between 150-500 m using beam trawl. The survey covered 16 stations between latitude 04.30° longitude 109.30° (off Sarawak) to latitude 08.00°N longitude 117.00° (off east-coast Sabah). 160 species of fish and invertebrates under 79 families were identified. The dominant species caught were deep sea pink shrimp, (*Pandalus* sp)., sea cucumber, (Holothuroidea), gastropods, benthic fishes: *Polymixia* sp. (beardfish), *Malakichthys elegans*, *Setarches guentheri* (deepwater scorpion fish), *Chloropthalmus* sp. (greeneye), *Cubiceps cf. whiteleggii* (flathead), *Bembrops caudimacula* (duckbill), nephrops: (*Metanephrops formosanus*, *M. andamanicus* and *M. chinensis* and others). At a towing speed of 3 NM/hr, the average catch rate was 16.06 kg/hr, where fish contributed 9.46 kg/hr (59%) and invertebrate 6.60 kg/hr (41%). The average density was 724 kg/km^2(fish 436 kg/km^2 and invertebrate-288 kg/km^2) at catchability coefficient, q=1.0. The water off Sabah was more productive (density 964 kg/km^2) than off Sarawak (486 kg/km^2). The estimated area within the depth range 150-500 m for Sarawak (24,695 km^2) was almost 5 times larger than the area off Sabah east coast (5,488 km^2) but the biomass distribution was only in a ratio of 3:2.

Keywords: beam trawl, catch rate, fish, invertebrate, density, biomass

Abstrak: Objektif survei adalah untuk mengetahui kepelbagaian spesies dan taburan sumber demersal yang belum diterokai di kedalaman 150-500 m dengan menggunakan "beam trawl". Survei ini melibatkan 16 stesen merangkumi kawasan di antara latitud 04.30° longitud 109.30° (luar pantai Sarawak) ke latitud 08.00°N longitud 117.00° (luar pantai barat Sabah). Sebanyak 160 spesies ikan dan invertebrata di bawah 76 famili telah dikenalpasti. Spesies dominan adalah udang jingga laut dalam, (*Pandalus* sp)., mentimun laut (Holothuroidea), gastropoda, ikan-ikan dasar: *Polymixia* sp., *Malakichthys elegans*, *Setarches guentheri*, *Chloropthalmus* sp., *Cubiceps cf. whiteleggii*, *Bembrops caudimacula*, nephrops: (*Metanephrops formosanus*, *M. andamanicus* dan *M. chinensis* dan lain-lain). Pada kelajuan tunda 3 BN/jam, kadar purata tangkapan adalah 16.06 kg/jam, di mana ikan menyumbangkan 9.46 kg/jam (59%) dan invertebrata 6.60 kg/jam (41%). Purata kepadatan adalah 724 kg/km^2 (ikan 436 kg/km^2 dan invertebrata 288 kg/km^2) pada koefisien tangkapan, q = 1.0. Perairan Sabah adalah lebih produktif (kepadatan 964 kg/km^2) berbanding dengan perairan Sarawak (486 kg/km^2). Anggaran luas kawasan pada julat kedalaman 150-500 m di peraiaran Sarawak (24,695 km^2) adalah hampir 5 kali ganda lebih besar daripada kawasan perairan pantai timur Sabah (5,488 km^2) tetapi taburan biomas cuma bernisbah 3:2.

Introduction

The United Nations Convention on the Law of the Sea, 1982 (UNCLOS or the 1982 Convention) came into force on the 16 of November 1994. The Government of Malaysia formally declared Malaysia's proclamation of the Exclusive Economic Zone (EEZ) on 25 of April 1980 (Tunku Sofiah, 1996). Malaysia then signed the UNCLOS on 10 December 1982 and ratified it fourteen years later on 14 October 1996 (Juita, 1999). During the period leading to Malaysia's ratification of the LOSC in 1996, many written national laws of the sea were established among them are; the declaration of Malaysia's (EEZ) of 200 nautical miles vide the Exclusive Economic Zone Act, 1984; and proclamation of the legislation pertaining to conservation, management and development of maritime and estuarine fishing and fisheries provided for in the Fisheries Act, 1985.

The total area of the Malaysian EEZ is 548,800 km^2, of which 46% or approximately 250,000 km^2 is the combined EEZ off the coast of Sarawak, Sabah and the Federal Territory of Labuan. The first fishery resources survey in the EEZ of Malaysia was conducted from 1985 to 1987 (Anon., 1988) followed by the second survey from 1996 to 1997 (Anon., 2000). These two surveys covered areas in the west and the east coast of Peninsular Malaysia as well as in the South China Sea area off Sarawak and Sabah. A third survey was conducted in 2004 to 2005 off Sarawak with the objective of assessing the fishery resources in the area of 30 NM offshore, which have been exploited by deep-sea fishing vessels (Hadil *et al.*, 2008).

Otter trawl and beam trawl were the sampling gears deployed in the earlier study on the deep water fauna of South China Sea (Yeh *et al.*, 2006) in waters adjacent to the Taiwan Strait. Diversity of deep water fauna was found to be affected by factors such as depth (Yeh *et al.*, 2006), water productivity (Snidvongs, 1999; Liu *et al.*, 2002) and food supply (Gartner *et al.*, 1997). In deep water environment, species and communities often change with increasing depth (Gage and Tyler, 1991; Cartes *et al.*, 2004; 2007). Dominant deep water species such as *Pandalus* sp. tend to have a wide range of habitats (Pequegnat, 1970; Toriyama and Hayashi, 1982). But some fishes will thrive in the whole range of water depth because these fishes were carnivores and scavenger that feed on small invertebrates and decay matters (Gartner *et al.*, 1997, Drazen *et al.*, 2009).

The distribution patterns of deep-sea benthic fauna at depth >150 m of the Malaysian EEZ waters off Sabah and Sarawak is unknown. It was timely that research initiative was taken in to explore and obtain quantitative data of this deep water fauna. In 2010 the training and research vessel, *MV SEAFDEC 2* was deployed to explore the deep waters of Malaysian EEZ for the first time. This initial exploration in Malaysian EEZ waters was conducted from the 28th June to 11th August 2010. The main purpose of this exploration is to investigate the species diversity and distribution as well as the commercial potential of deep sea fish resources at bathymetric distribution or depths between 150 m to 500 m using beam trawl. This life-adaptive zone was termed as mesobenthal and; Allen and Smith 1988 based on hydrographic conditions. (Hedgpeth 1957). The objective of this study was first to document the knowledge of the spatial pattern of demersal and benthic fauna in this area. Second, it tries to show, in terms of relative biomass, species composition and biodiversity, the characteristics of this particular area of transition, which marks the beginning of the deep-sea ecosystem. The Swept Area Method (Sparre and Venema, 1998) was used to estimate demersal fish density and biomass.

Materials and Methods

The Training and Research Vessel, MV SEAFDEC 2 from SEAFDEC Training Department (TD), Bangkok was deployed for this survey. The sampling methodology for this survey was adopted from the standard operating procedures designed by SEAFDEC TD (Sayan *et al.*, 2007). The sampling gear used in this exploration was a beam trawl which was specifically designed for the research vessel MV SEAFDEC 2 as explained in the SOP. Appendix 1 shows the detail design of the beam trawl net. The beam or the frame (Appendix 2) with a length of 4.0 m that opened the net was made of steel.

The exploration was conducted covering the Malaysian EEZ off Sarawak and east coast Sabah between latitude 04.30° to 08.00°N and longitude 109.30° to 117.00°E as shown by Fig. 1 and 2. The estimated area coverage was 8,800 NM^2 (30,222 km^2). Sixteen stations were successfully trawled following a bathymetric-stratified sampling strategy (Fig. 1). Sampling stations were planned based on the 30 NM by 30 nautical miles (NM) grid square (Fig. 2) at different depths range: 150-300 m; 301-400 m and 401-500 m with at least one station in one grid square. The towing speed for beam trawl was maintained at 3 knots. Warp length released was between 1.5 to 2.5 times of the sea depth. Gear selectivity was assumed to be constant because the same beam trawl for each station was used. From the 11th July to 4th August 2010, sampling using beam trawl involved 16 one-hour trawling operations: 9 off Sabah and 7 off Sarawak (Fig. 1 and Appendix 3). Attempt to cover more sampling stations were hindered by bad weather conditions.

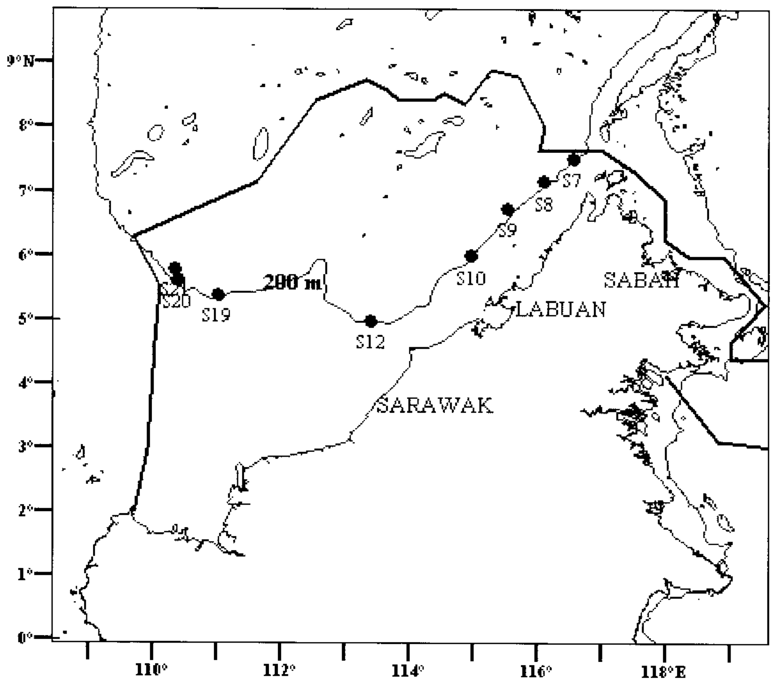

Figure 1: The sampling stations for beam trawl at the edge of the 200 m

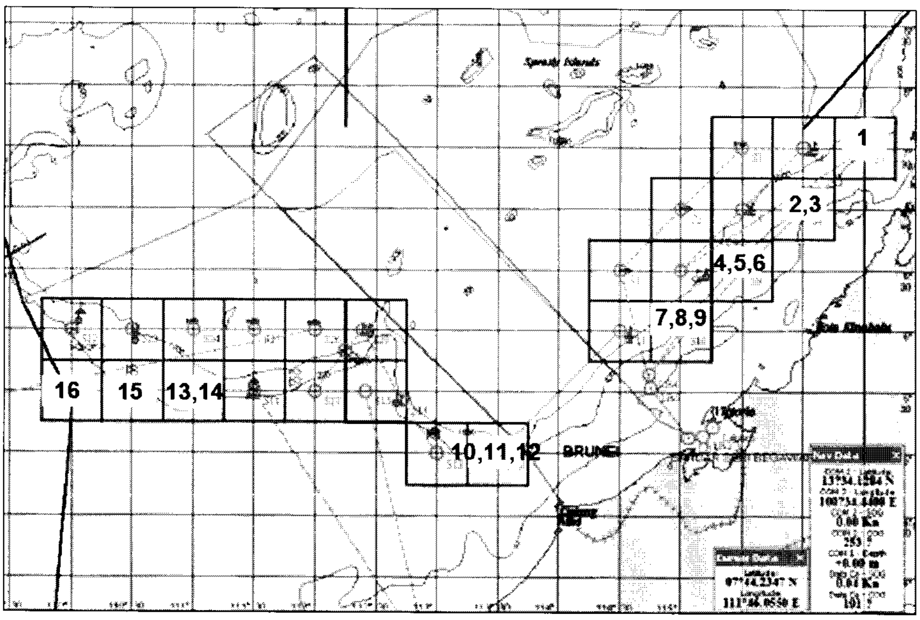

Figure 2: Sampling sites for the deep water expedition, the box refers to the grid where each beam trawl operation has been carried out

Once the beam trawl net was hauled up, large matters such as rocks, dead woods and other debris were removed; samples collected were then screened through 10.0, 5.0, 2.5, 1.0 and 0.5 mm-mesh size sieves with running water. The specimens were sorted on the deck into fishes, crustaceans, molluscs and other invertebrates. For each haul, data were noted and standardized to 1 hour of haul. In the laboratory inside the vessel, the sorted specimens were measured for their total length (mm), body weight (g) and the number per species were recorded for every haul. The specimens were photographed and identified to the lowest taxonomic level as possible using identification keys by Abu Khair and Mohd Azmi (1996); Mansor *et al.* (1998); Carpenter and Niem (1999); Carpenter and Niem (2001a); Carpenter and Niem (2001b); Nakabo (2002); Froese and Pauly (2007) and Eschmeyer (2007); Sukramongkol *et al.* (2007); SEAFDEC (2008). Shannon-Weaver index, H' (Poole 1974) was chosen to determine the fish diversity (Putman, 1994) by trawl station.

The fish specimens were placed in punctured plastic bags and submerge in 10% formalin solution (McAllister, 1965). The crustacean specimens were immersed in 80% ethanol (Wilson, 2010). These specimens were then labeled, sealed and stored in separate plastic drum containers. All specimens from this exploration were kept at Fisheries Research Institute(FRI), Bintawa Kuching and Marine Fisheries Research & Development Management Department (MFRDMD), Chendering Kuala Terengganu and will be used for taxonomic reference.

The Swept Area method (Sparre and Venema, 1998) was used to estimate fish density and biomass based on the weight of catch per haul (kg/hr) or catch rate data obtained from the trawl hauls. The distance (d) between the starting and the ending point of each haul after one hour of trawling was estimated using the ship speed. Thus the swept area (a) is computed as:

$$a = d*BL \text{ where } BL = \text{length of the beam} = 4 \text{ m}$$

If the weight of catch per haul is Cw, then Cw/t is the catch per hour (catch rate) when t is the duration of the trawl haul. If "a" is the area swept by the trawl haul, then a/t represents the area swept per hour. In this exploration, the swept area was covered by trawling for duration of one hour with an effective beam mouth opening of 4.0m. The weight of catch per unit area or the density is:

$$(Cw/t)/(a/t) = Cw/a \text{ kg per sq.km}$$

The mean weight of catch per unit area (Cw/a) divided by q (catchability coefficient) gives the average biomass per unit area. The catchability coefficient represents the amount of the fish caught by the trawl relative to the amount that escaped being caught. When q = 1.0, all the fish in the path of the trawl was assumed to be caught. Thus biomass, B, of the whole area survey, A, is:

$$B = (Cw/a)/q*A$$

The biomass for the whole area, 30,221.75 km^2 was calculated using average density on the assumption that the resources were evenly distributed..

Results and Discussion

Species composition

A total of 33,861 individuals (total weight 229.62 kg) of deep water demersals belonging to 160 species of fish (133) and invertebrate (27) under 79 families were collected and identified from the catches of the beam trawl operation (Appendix 4). Samsudin *et al.* (2006) reported that by using otter trawl, MV SEAFDEC 2 successfully sampled 72 species of fish from 45 families for 3 trawl stations within 134 to 174 m depths. Yeh *et al.* (2003) using both otter and beam trawls sampled the deep waters (up to 3,750 m) of the South China Sea basin adjacent to the Taiwan Strait from August 2002 to July 2004. They managed to identify 121 species of demersal fishes belonging to 37 families of which 17 were also recorded by this exploration.

Fig. 3 and 4 show the dominant species caught in term of weight and numbers respectively. Within the investigated depth range, deep water caridean pink shrimp *Pandalus* sp. predominates in all depth strata and were caught nearly at all the trawl stations (Appendix 5). And in term of total abundance (Table 1), *Pandalus* sp. was the most dominant species caught at 18.9% (total weight-43.53 kg). The other dominant species were sea cucumber, Holothuroidea (6.9%), gastropods (3.3%), benthic fishes: *Polymixia* sp. (beardfish)-5.5%, *Malakichthys elegans* (3.9%), *Setarches guentheri* (deepwater scorpionfish)-3.5%, *Chloropthalmus* sp.(greeneye)-3.2%, *Cubiceps cf. whiteleggii* (flathead)-2.9%, *Bembrops caudimacula* (duckbill), nephrops: *Metanephrops formosanus, M. andamanicus* and *M. chinensis* and others (Fig. 3). In term of frequency of occurrence in all the stations surveyed (Table 1), *Pandalus* sp. was caught at 11 stations (68.75%). Eventhough the percentage abundance was not substantial (2.5%), *Metanephrops formosanus* appeared in the catches quite frequently at 62.5% occurrence (Table 1). This was followed by *Chlorophthalmus* sp., *Bembrops caudimacula* and *Chrionema chlorotaenia* all at 50% occurrence. Others were presence at <50% of the stations surveyed. Subsequently, *Pandalus* sp. was also numerically dominant (>29,000 tails) in term of total numbers caught (Fig. 4), followed by *Setarches guentheri* (>400 tails), *Polymixia* sp., *Champsodon longispinnis, Samariscus* sp., *Neoscopelus microchir* (lanternfish), *Malakichthys elegans* and others.

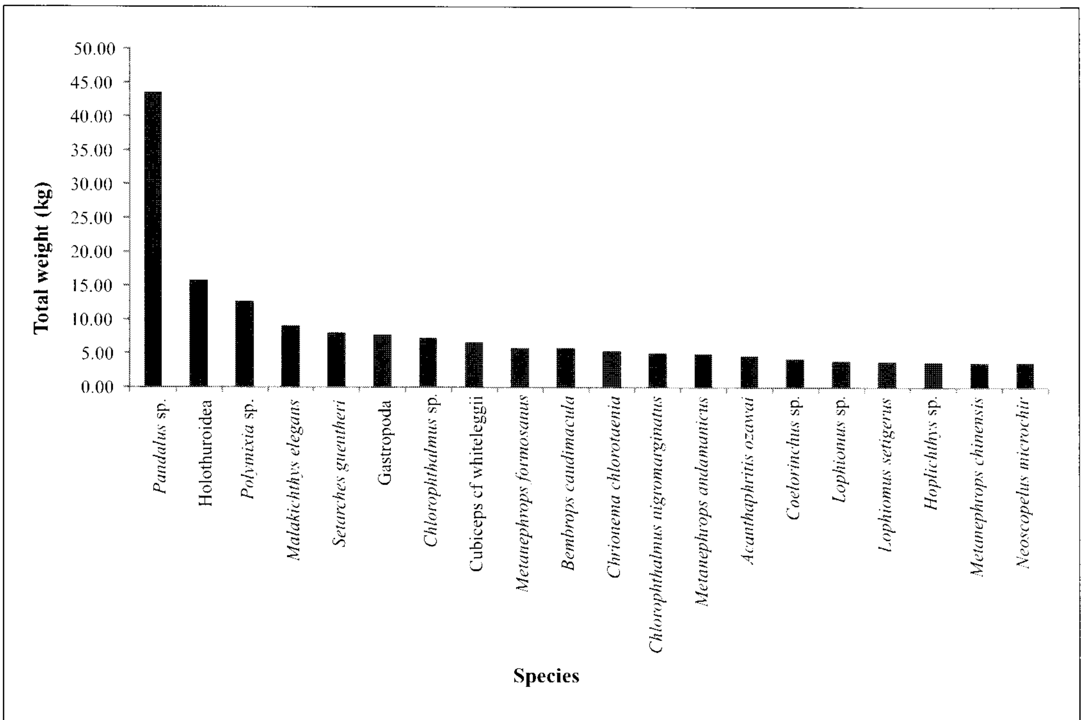

Figure 3: Dominant species caught in term of total weight

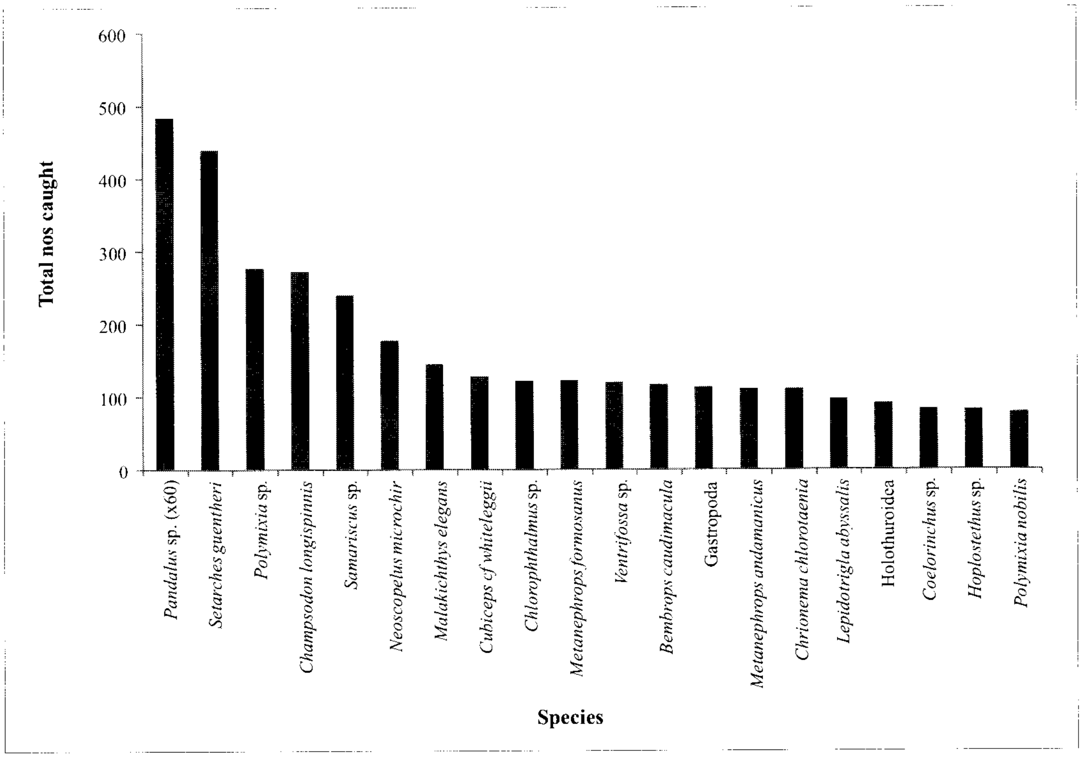

Figure 4: Dominant species caught in term of total number of tails

Table 1: Percentage abundance and occurrence of the major species caught by beam trawl at 16 trawl stations within the water depth of 150 to 500 m

Species	Total weight (kg)	Abundance	Percentage Occurrence
Pandalus sp.	43.53	18.9	68.75
Holothuroidea	15.77	6.9	43.75
Polymixia sp.	12.67	5.5	37.50
Malakichthys elegans	9.03	3.9	31.25
Setarches guentheri	7.99	3.5	43.75
Gastropoda	7.70	3.3	12.50
Chlorophthalmus sp.	7.27	3.2	50.00
Cubiceps cf whiteleggii	6.68	2.9	6.25
Metanephrops formosanus	5.81	2.5	62.50
Bembrops caudimacula	5.80	2.5	50.00
Chrionema chlorotaenia	5.39	2.3	50.00
Chlorophthalmus nigromarginatus	5.03	2.2	31.25
Metanephrops andamanicus	4.90	2.1	18.75
A canthaphritis ozawai	4.59	2.0	31.25
Coelorinchus sp.	4.19	1.8	37.50
Lophiomus sp.	3.86	1.7	18.75
Lophiomus setigerus	3.82	1.7	43.75
Hoplichthys sp.	3.69	1.6	25.00
Metanephrops chinensis	3.63	1.6	12.50
Neoscopelus microchir	3.61	1.6	37.50

Species diversity

The number of species caught per station is shown by Fig. 5 and Appendix 3. Species richness (Putman 1994) at Station 8 recorded the highest number of species caught at 45; followed by station 11 (39 species), station 14 (34 species), station 13 and 10 (31 species each) and station 3 recorded the least number of species caught at 14. The trawl stations' specific richness varied from 14 to 45 species (Fig. 6). The highest frequency at 6 stations was attained by the range 28-34 species; followed by 14-20 and 21-27 species. The 31-41 and 42-48 species range was recorded from only one station each.

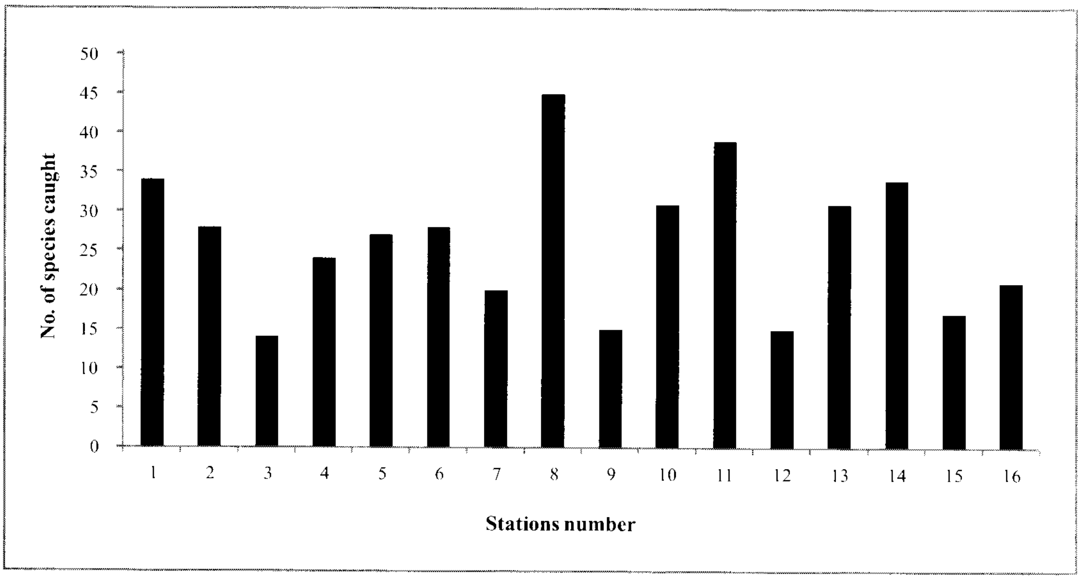

Figure 5: Number of species caught by beam trawl at various stations

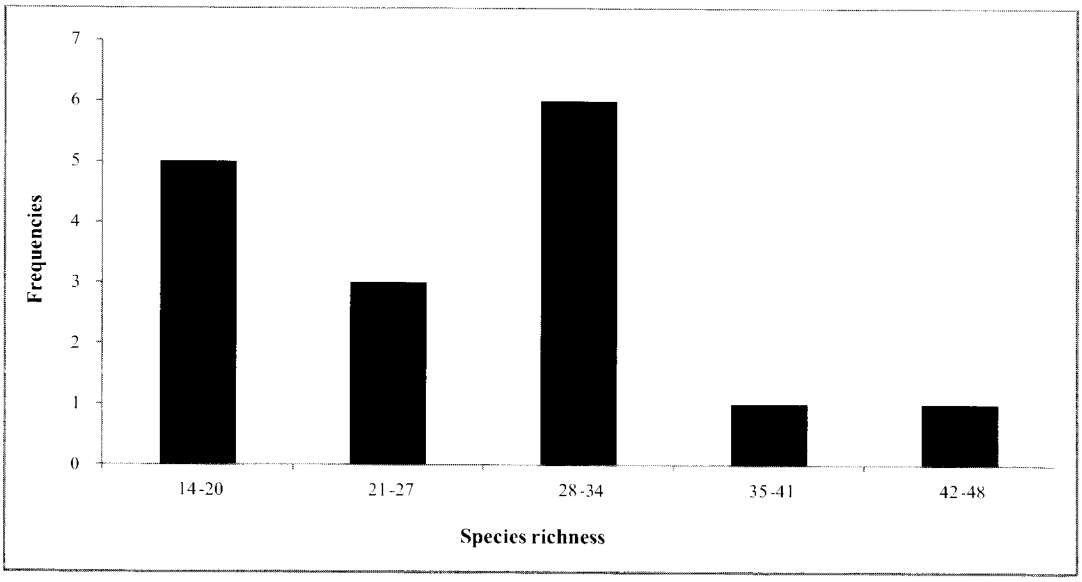

Figure 6: Distribution of species richness in term of occurrence in the catch of the 16 trawl stations

Fig. 7 shows that at depth stratum 150-300 m, catches at trawl station 10 was the most diverse with Shannon index > 1.3 and the least diverse was at station 5 (index <0.2). The average diversity index for the 6 sampling stations was at 0.78+/-0.395. For depth stratum 301-400 m (Fig. 8) the average diversity index was 0.83+/- 0.392 with the highest diversity index (>1.2) portrayed by catches from station 8 with the lowest diversity index given by station 2, less than 0.2. At the deepest stratum explored (Fig. 9), the highest diversity index at >1.0 was obtained from station 16 catches and the lowest at 0.3 was from station 3 and the average was 0.87+/-0.340. Predictive equation for determining species diversity from the number of species in a haul (only in trawl) could be obtained by regression analysis (Bechtel and Copeland, 1970). Fig. 10 to 13 give the regression lines of species diversity, H' versus species number, s of the beam trawl catches for stratum 150-300 m, stratum 301-400 m, stratum 401-500 m and overall survey area respectively. The 4 predictive equations were:

Stratum 150-300m- $H' = -0.0135s + 1.144$ with correlation coefficient, $r^2 = 0.050$;
Stratum 301-400m- $H' = 0.029s - 0.222$, $r^2 = 0.436$;
Stratum 401-500m - $H' = 0.028s + 0.293$, $r^2 = 0.225$ and
Overall area- $H' = 0.006s + 0.646$, $r^2 = 0.028$,

where H' is the predictive species diversity and s is the number of species in a haul

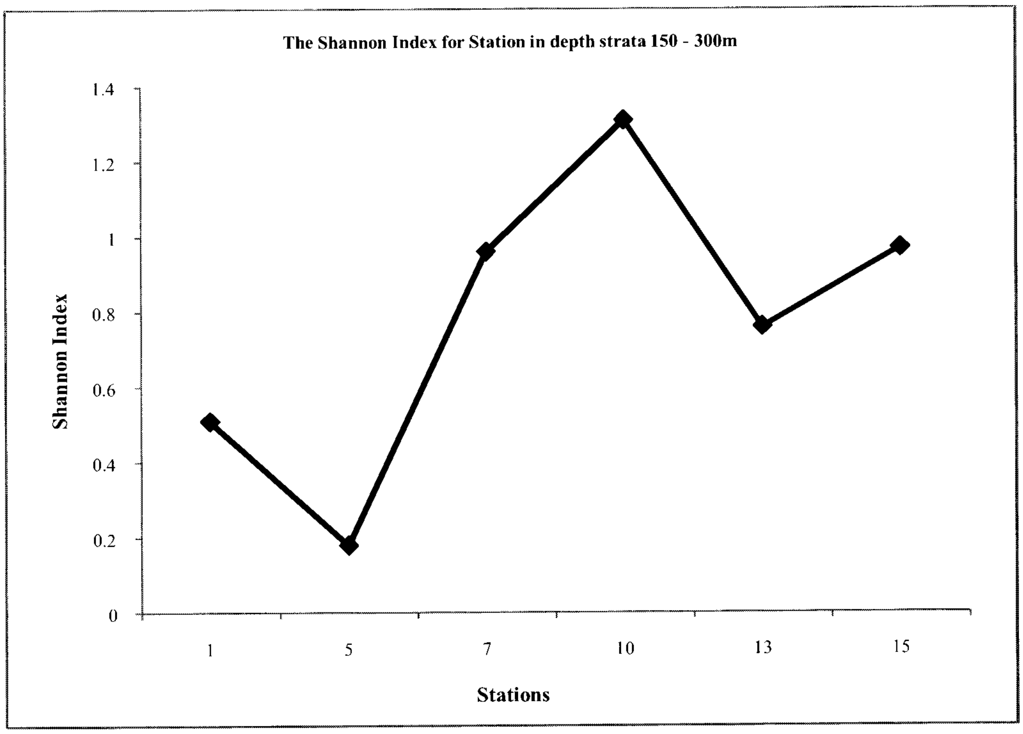

Figure 7: Diversity index (Shannon's) for trawl stations in the depth stratum 150-300 m

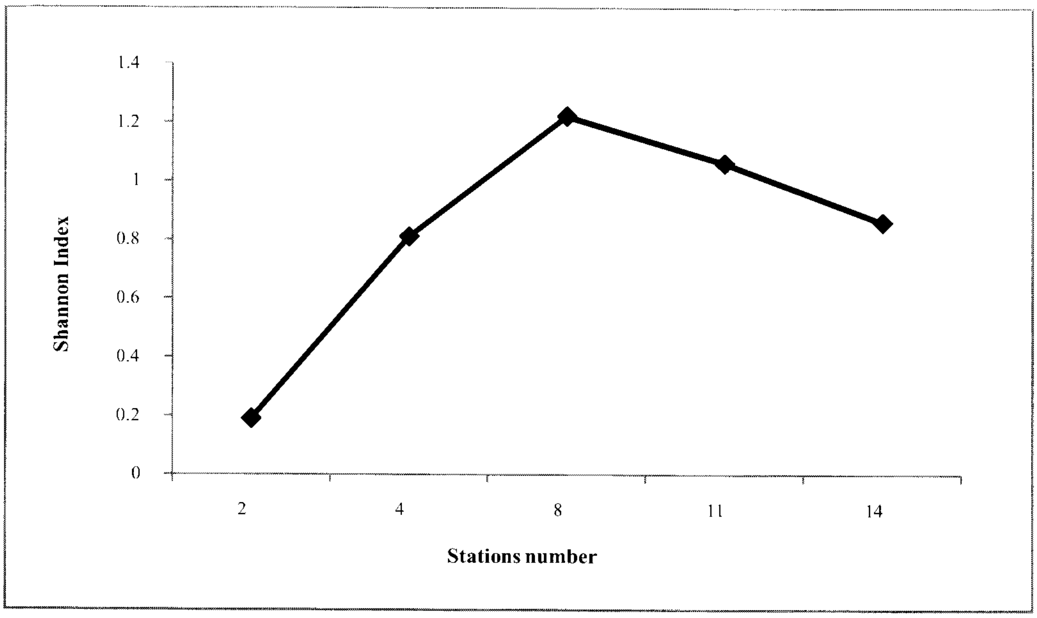

Figure 8: Diversity index (Shannon's) for trawl stations in the depth stratum 301-400 m

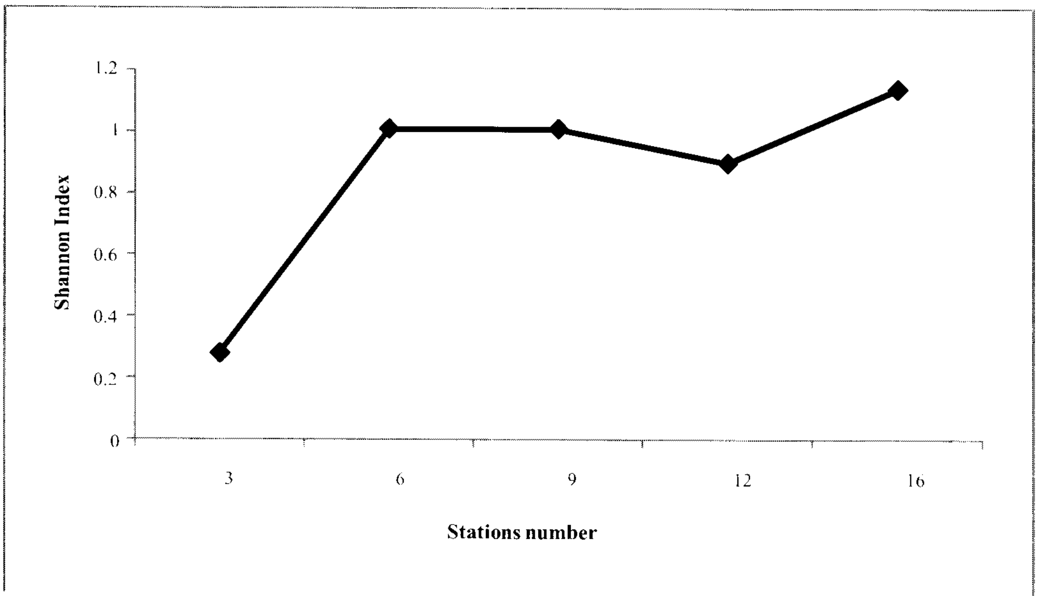

Figure 9: Diversity index (Shannon's) for trawl stations in the depth stratum 401-500 m

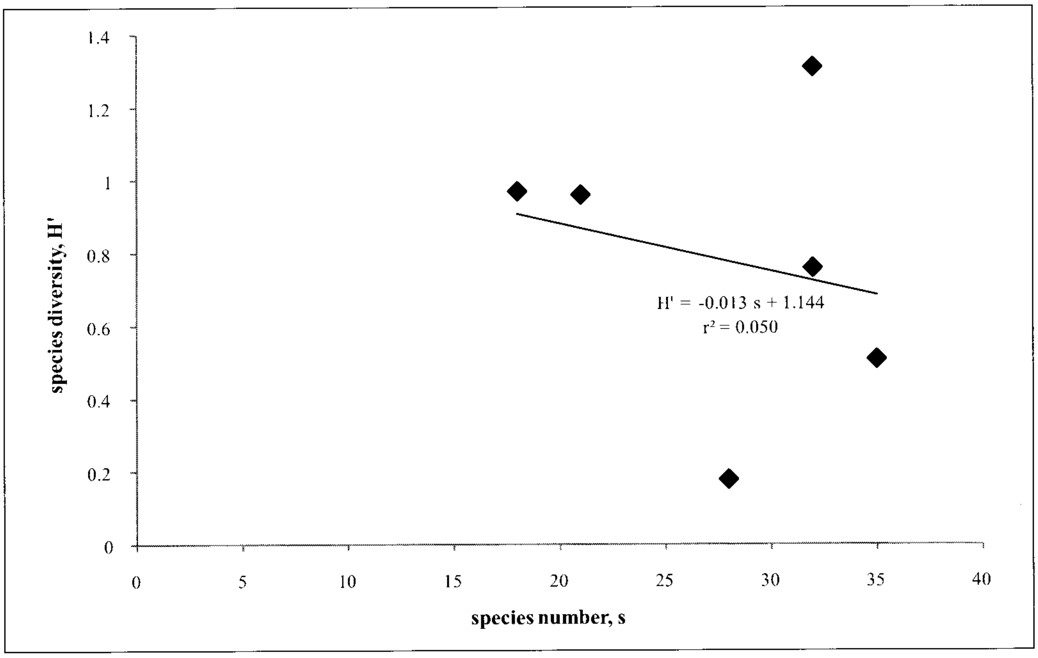

Figure 10: Predictive regression equation for species diversity, H' Versus number of species, s in a trawl haul for stratum 150-300

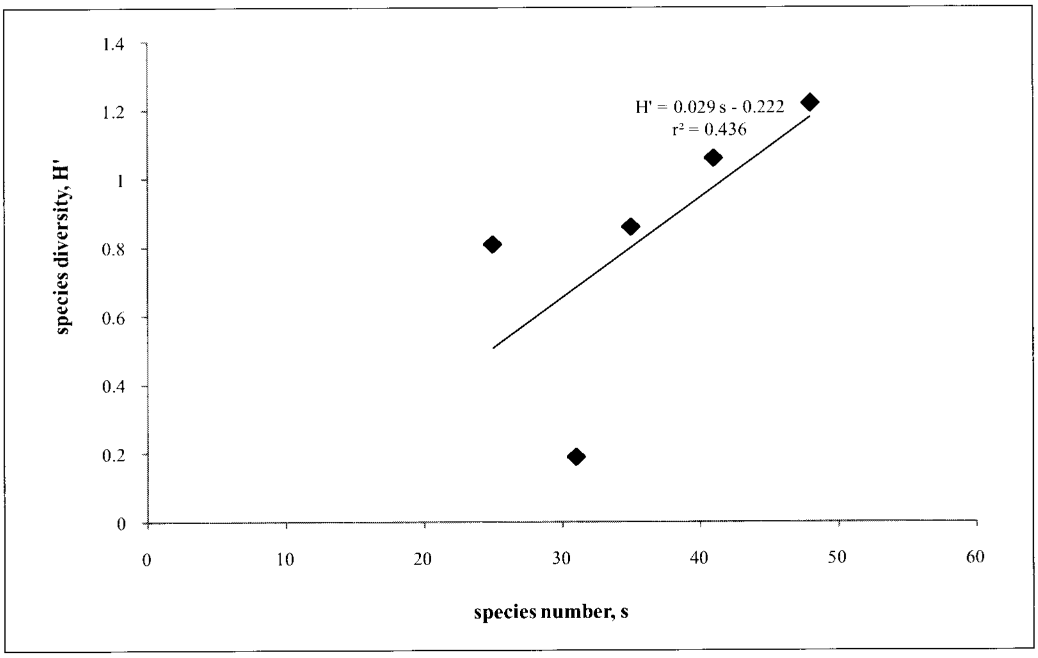

Figure 11: Predictive regression equation for species diversity, H' versus number of species, s in a trawl haul for stratum 301-400 m

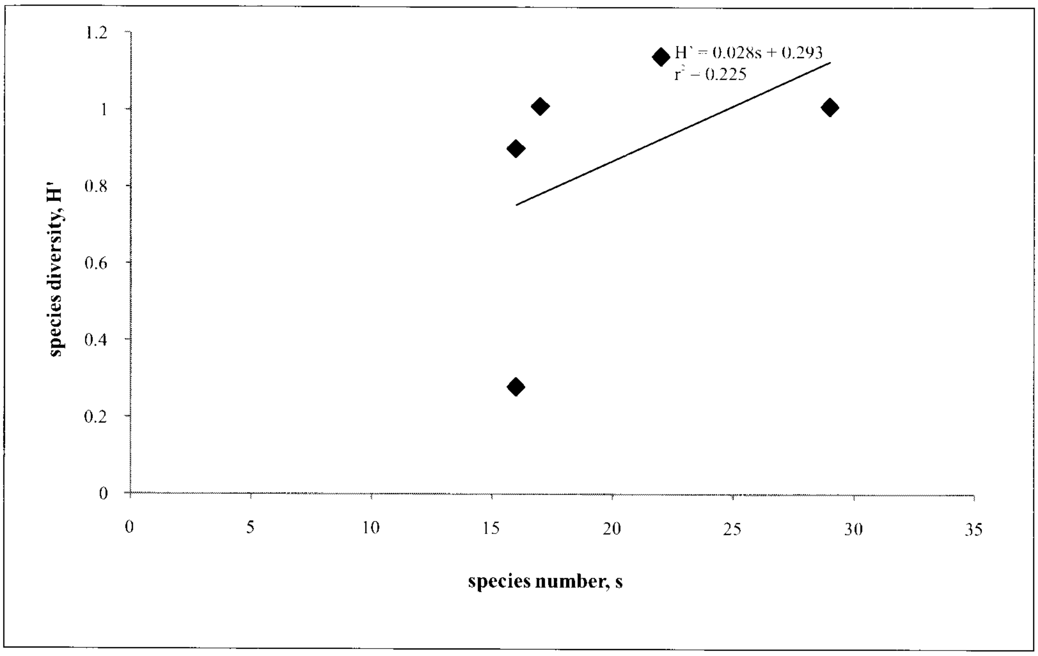

Figure 12: Predictive regression equation for species diversity, H' versus number of species, s in a trawl haul for stratum 401-500 m

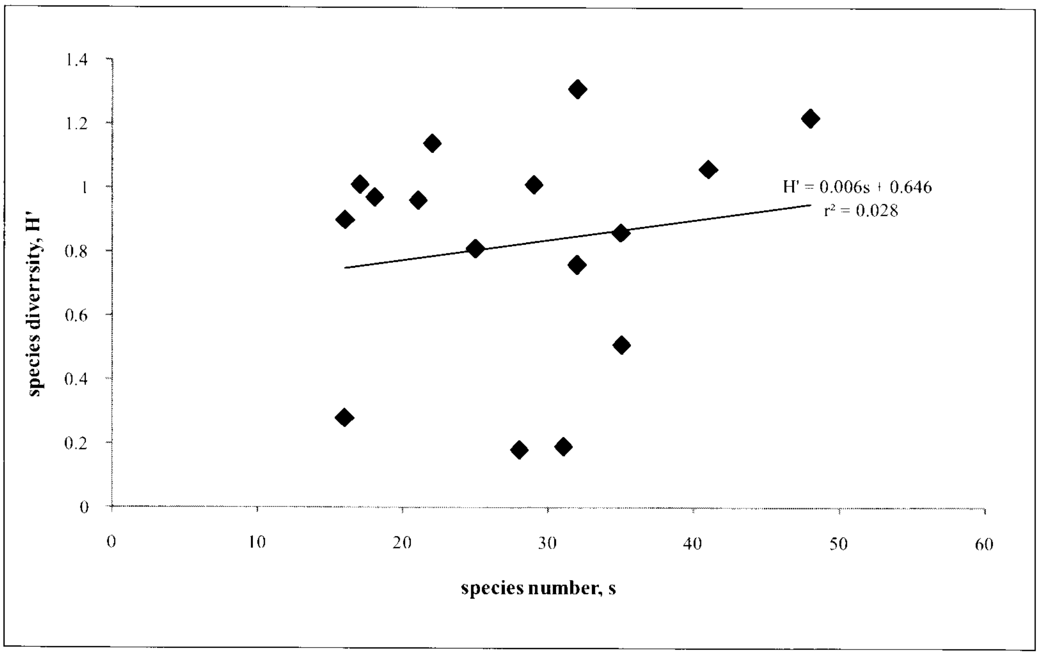

Figure 13: Predictive regression equation for species diversity, H' versus number of species, s in a trawl haul for the whole area surveyed

The correlation coefficients, r^2 were quite low ranging from 0.028 to 0.436 and this caused disproportionate results between observed H' and expected H' as shown in Table 2. This discrepancy in the results is probable due to the catchability inefficiency of the sampling gear in used due to bottom unevenness or unevenly distributed bottom fauna.

Table 2: The expected species diversity, H' calculated using the above predictive equations for the 3 depth strata

Stratum	No. of species	Species diversity, H'	
		Observed	Expected
150-300 m	35	0.51	0.689
$H' = -0.0135s + 1.144$,	28	0.18	0.780
$r^2 = 0.050$	21	0.96	0.871
	32	1.31	0.728
	32	0.76	0.728
	18	0.97	0.910
301-400 m	31	0.19	0.677
$H' = 0.029s - 0.222$,	25	0.81	0.503
$r^2 = 0.436$	48	1.22	1.170
	41	1.06	0.967
	35	0.86	0.793
401-500 m	16	0.28	0.741
$H' = 0.028s + 0.293$,	29	1.01	1.105
$r^2 = 0.225$	17	1.01	0.769
	16	0.9	0.741
	22	1.14	0.909

Comparatively the different between the diversity indices of the catches by beam trawl all through the area explored was not significant. On average the diversity index obtained for catches of each trawl station was 0.83 for all the 3 depth strata. The figure suggested that the water depth from the bottom up to 0.75 m (beam trawl coverage) was less diverse in term of species as compared to the coastal waters of Kuching bay where the diversity indices ranged from 1.24 to 3.31 as reported by Yong (2004) in her comparative study of fish diversity in the area. The reason for the low diversity in the deep water might be due to sea bottoms conditions which are less favorable for habitation which may be a consequence of reduced food availability at this depth or the physiological intolerance of the fishes to greater depths and lower temperatures. Possibly, the other reason was that the sampling gear, beam trawl in used was less efficient in term of coverage since higher diversity values detected can also be attributed to a higher efficiency of the gear in used. It was reported by Yeh *et al.* (2003) that the higher diversity of deep-sea demersal fish was found in <500 m in depth. Using semi-balloon otter trawl it was documented that the faunal diversity in the South China Sea displays a dramatic decline with depth (Yeh *et al.*, 2003). The dramatic decline of diversity in the South China Sea could be due to the shallower nutricline and the two-fold higher concentration of chlorophyll in the surface waters of the South China Sea compared to that of the Western Pacific Ocean (Liu *et al.*, 2002). But, comparatively, it was observed that the diversities of deep-sea demersal fishes in the South China Sea are about two times higher than those in the West Pacific Ocean in the depths less than 500 m (Yeh *et al.*, 2003).

Most of the fishes caught in the area of sampling by beam trawl were predominantly small, in the size of about 2 gm per tail. Bechtel and Copeland (1970) reported that small fishes were able to withstand environmental stress such as high pressure due to differences in metabolic rates. Larger fish have less additional energy available to combat energy-requiring stresses (sapping) because of the greater energy expenditure associated with the maintenance of a large biomass. Large fish are thus absent from the population in area subjected to stress, causing a more even distribution of biomass among the species with smaller individuals predominating (Wohschlag and Cameron, 1967).

Species distribution

The catches by beam trawl in the deep-water bottoms of Malaysian EEZ were quite diverse in term of species distribution (Appendix 3). Fig. 14 shows the 10 dominant species (in term of total weight caught) at different depth stratum. The deep water pink shrimp, *Pandalus* sp. was the most dominant and widespread species in all depth strata: 22.6 kg, 14.0 kg and 5.6 kg landed from stratum 150-300 m, 301-400 m and 401-500 m respectively. But it appeared that the catch of this deep-water caridean shrimps (crustacea: decapoda) seems to decrease as the water gets deeper. The other deep water caridean shrimp caught in substantial amount was *Heterocarpus* sp.: 10.0 kg and 2.4 kg at depth strata 301-400 m and 401-500 m respectively. There was much less of this shrimp in shallower water (Appendix 5). The other invertebrates listed among the dominant species were nephrops (*Metanephrops andamanicus, M. chinensis* and *M. formosanus*), sea cucumbers (holothuroids) and gastropods caught mostly at depth strata 150-300 m and 401-500 m. Nephrops lobster seems to be present at all depth strata but at varying level of dominant; *Metanephrops andamanicus* catch was substantial at stratum 150-300 m but at stratum 401-500 m *M. chinensis* and *M. formosanus* seem to be dominant. It is interesting to point out the presence of these nephropid lobsters which, because of its size, might be considered a potential resource. Sea cucumber, the holothuroids were also present in the whole range of the water depth covered (Appendix 4). Out of the 10 most dominant species, holothuroids appeared to be among the dominant species caught at depth strata 301-400 m and 401-500 m. The present of these high value invertebrates (shrimps, nephrops and sea cucumbers) in the deep water are potential for future commercial exploitation. Among the fish species, *Malakichthys elegans* was the second highest in total catch at depth stratum 150-300 m. Substantial amount of this fish species was also caught at depth stratum 301-400 m. Similar pattern seems to occur for *Setarches guentheri* but substantial amount of this fish was caught at depth strata 301-400 m and 401-500 m. Most of the other fish species (*Lophiomus* sp., *Chlorophthalmus* sp., *Coelorinchus* sp., *Chrionema chlorotaenia, Pterygotrigla hemisticta, Benthodesmus tenuis, Samariscus* sp., *Polymixia* sp., *Cubiceps cf whiteleggii, Chlorophthalmus* sp. *Bembrops caudimacula, Chlorophthalmus nigromarginatus, Neoscopelus* sp. *Ventrifossa* sp. *and Neoscopelus microchir)* appeared to be only dominant at different depth stratum. In deep-sea marine environments, species and communities often change with increasing depth rather than along horizontal gradients (Gage and Tyler, 1991; Cartes *et al.*, 2004, 2007), suggesting the idea of depth bands of high faunal homogeneity separated by boundaries of faunal renewal. For example, macrourids such as *Ventrifossa* sp. are generalist predators feeding on a variety of epifaunal megafauna and small benthopelagic crustaceans. Considering their large size, abundance, and general feeding habits macrourids are important apex predators in the deep-sea environment (Gartner *et al.*, 1997; Jeffrey *et al.*, 2009).

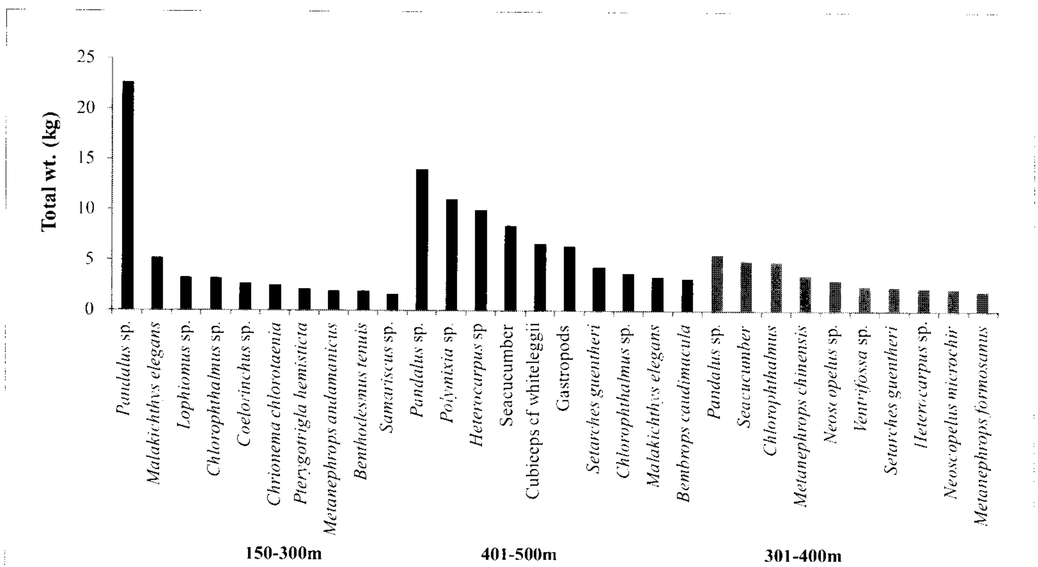

Figure 14: The distribution of species caught by beam trawl in term of total weight (kg) by depth stratum

The distribution of species caught by beam trawl in term of numbers by depth stratum is given by Fig. 15. Synonymous with the distribution in term of total weight caught, the deep sea pink shrimp, *Pandalus* sp. was the most dominant species caught in term of numbers. The number of this shrimp caught were 15,034, 8,689 and 3,862 tails at depth stratum 150-300 m, 301-400 m and 401-500 m respectively. But in Figure 6 the number of *Pandalus* sp. caught was depicted as the multiplication of 50, 8 and 10 times. Similar to the trend observed in term of total weight, the number of this shrimp seem to decrease as the water gets deeper. In the case of abundance, an exponential decrease with depth has been described by several authors (Merrett and Domanski,1985; Gordon, 1986; Merrett *et al.*, 1991), although a stable tendency below a depth of 500m seems to occur in the Mediterranean (Stefanescu *et al.*, 1993; Moranta *et al.*, 1998). In the Mediterranean, beyond 500 m deep, it was reported that abundance values and species richness for deep water fauna declined with increasing depth (Follesa *et al.*, 2011).

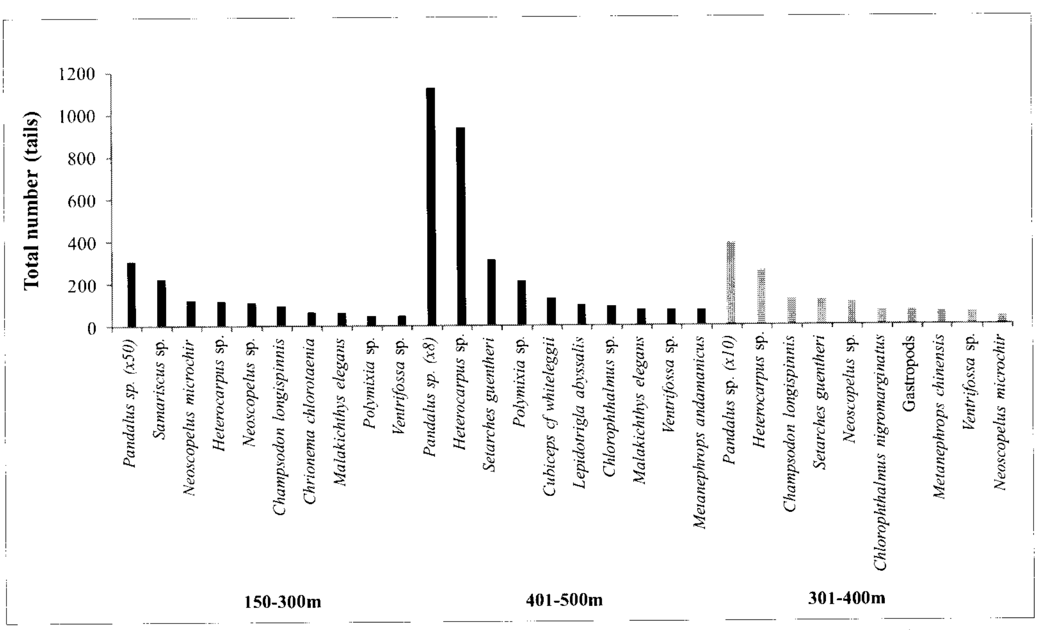

Figure 15: The distribution of species caught by beam trawl in term of numbers by depth stratum

The other shrimp species *Heterocarpus* sp. was also caught in considerable numbers throughout the depth covered: 115, 939 and 258 tails at depth stratum 150-300 m, 301-400 m and 401-500 m respectively. There is no perceptible trend in the dominance of this deep sea shrimp with respect to depth. It was reported that these shrimps, *Pandalus* sp. seems to have a wide range of habitats: in Tosa bay, Japan the shrimp dwells from 130 to 1,280 m (Toriyama and Hayashi, 1982) and in the Atlantic coast the shrimp was found at depths from 102 to 1,150 m (William, 1984). Heterocarpus was reputed to be present at deeper depths; for the Gulf of Mexico this shrimp was found at depths from 150 to 3,740 m (Pequegnat, 1970) and at Tosa bay, Japan, it was reported that this shrimp dwells from 130 to 1,280 m (Toriyama and Hayashi, 1982). Different species of fish seems to be dominant in term of total weight as compare to the dominant species in term of numbers caught (Fig. 3 and 4). This is to show that most of the dominant species (including the shrimps, *Pandalus* sp. and *Heterocarpus* sp.) were of small size, <200 g per tail (Appendix 5). At depth stratum 150-300 m, *Samariscus* sp. was the most dominant species with 221 tails of fish, followed by *Neoscopelus microchir* (120 tails), *Champsodon longispinnis* (94 tails) and others. At depth stratum 300-400 m *Setarches guentheri* was the most dominant species with 312 tails of fish, followed by *Polymixia* sp. (210 tails), *Cubiceps cf whiteleggii* (128 tails) and others. While at depth stratum 400-500 m, *Champsodon longispinnis* was the most dominant species with 124 tails, followed by *Setarches guentheri* (119 tails), *Neoscopelus* sp. (94 tails) and others. There is a logarithmic decline in the number of species of fishes with depth (Priede *et al.*, 2006) due to adverse effects of pressure on cellular processes (Somero 1992; Macdonald, 2001) and problems of increasing remoteness from surface-derived food resources. Neoscopelids, Setarchids and Percophids seem to thrive in the whole range of water depth from 200 m to 500 m. This was possible partly because most of these fishes were carnivores and scavenger that feeds on crustaceans and decay matter (Gartner *et al.*, 1997; Martin and Christiansen, 1997; Drazen *et al.*, 2009). These benthic megafauna are important members of the abyssal communities. Other include the invertebrates such as red shrimps, *heterocarpus* species, crabs and lobsters that live on phyto-detritus and scavenging on carrion were also abundant at ocean depth.

Dominant families

The 20 dominant families caught by beam trawl in term of total weight are shown by Fig. 16. Obviously, Pandalidae with *Pandalus* sp. as the most dominant in term of both total weight and total number was the highest catch overall at 55.5 kg (Appendix 4). With a total catch of 17.3 kg and 15.8 kg, Percophidae and Polymixiidae came in second and third highest. The catches of the other invertebrates, sea cucumber (Holothuroidae) and nephrops (Nephropidae) were quite substantial at 15.8 kg and 14.3 kg respectively. The other 15 more dominant families were all fish except for gastropod having a total catch of 7.7 kg.

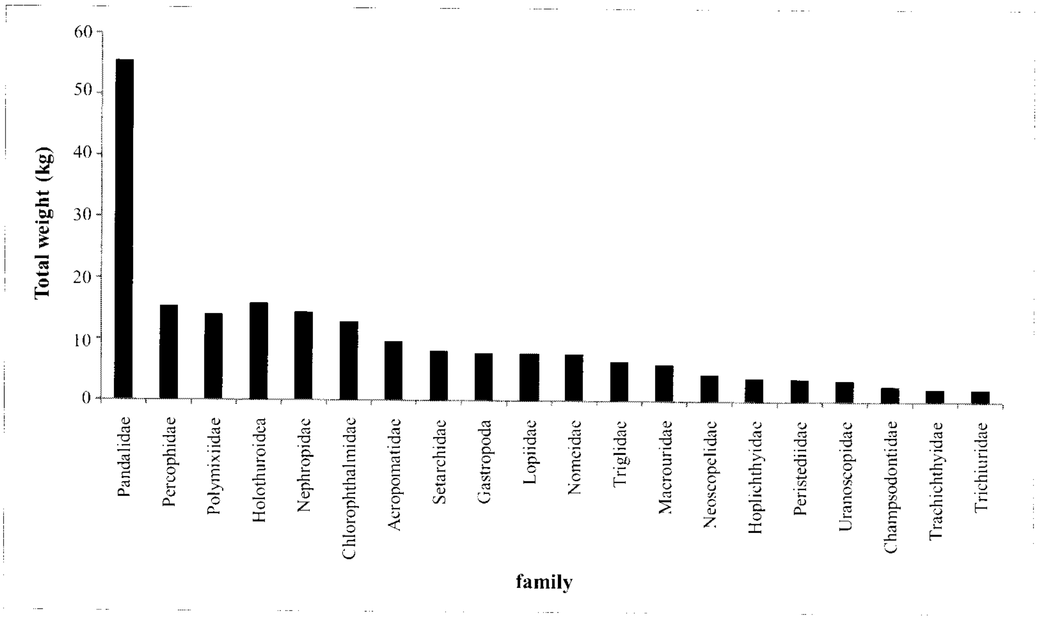

Figure 16: The dominant families caught by beam trawl in term of total weight (kg)

Fig. 17 to 22 and Appendix 4 show that the deep sea shrimp family Pandalidae was the most dominant in term of total weight: 25.6, 24.0, 8.0 kg and in term of catch rate: 5.1, 4.8, 1.6 kg/hr for all the 3 depth strata: 150-300 m, 301-400 m and 401-500 m respectively. But the order of family dominance change after Pandalidae as the depth gets deeper. Next in line in term of total weight (in bracket) and catch rate (kg/hr) were Acropomatidae (5.5 kg), Percophidae (4.7 kg), Triglidae (3.9 kg) and others for stratum 150-300 m (Fig. 15 and 16); Triacanthidae (16.0 kg), Polymixiidae (11.8 kg), Percophidae (10.0 kg) and others at stratum 301-400 m (Fig. 19-20); Nephropidae (5.6 kg), Neoscopelidae (5.3 kg), Holothuroidae (5.0 kg) and others at stratum 401-500 m (Fig. 21-22).

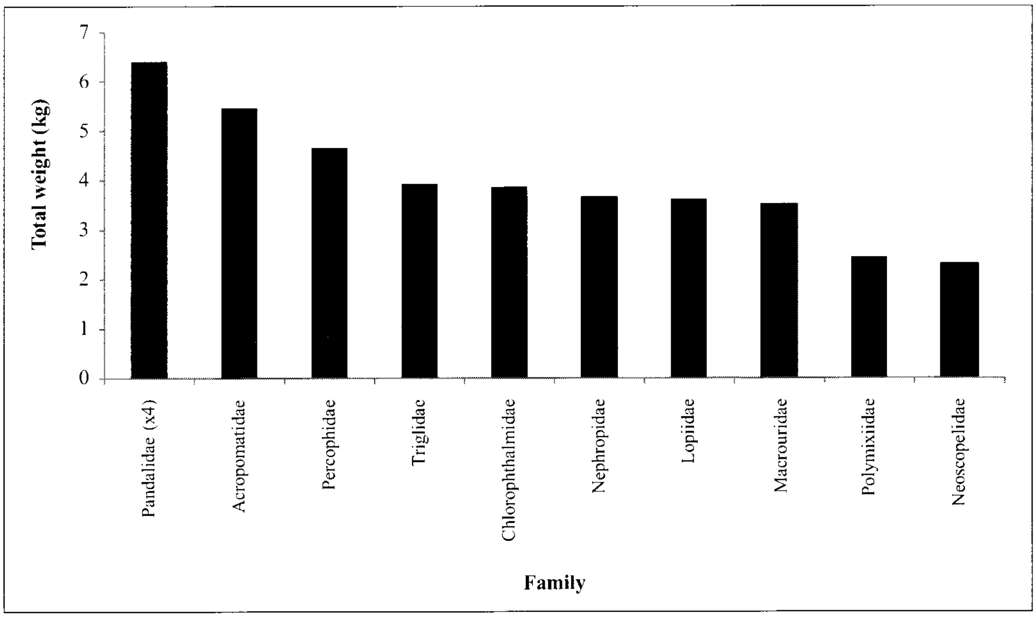

Figure 17: Dominant families in terms of total weight (kg) caught at depth stratum 150-300 m

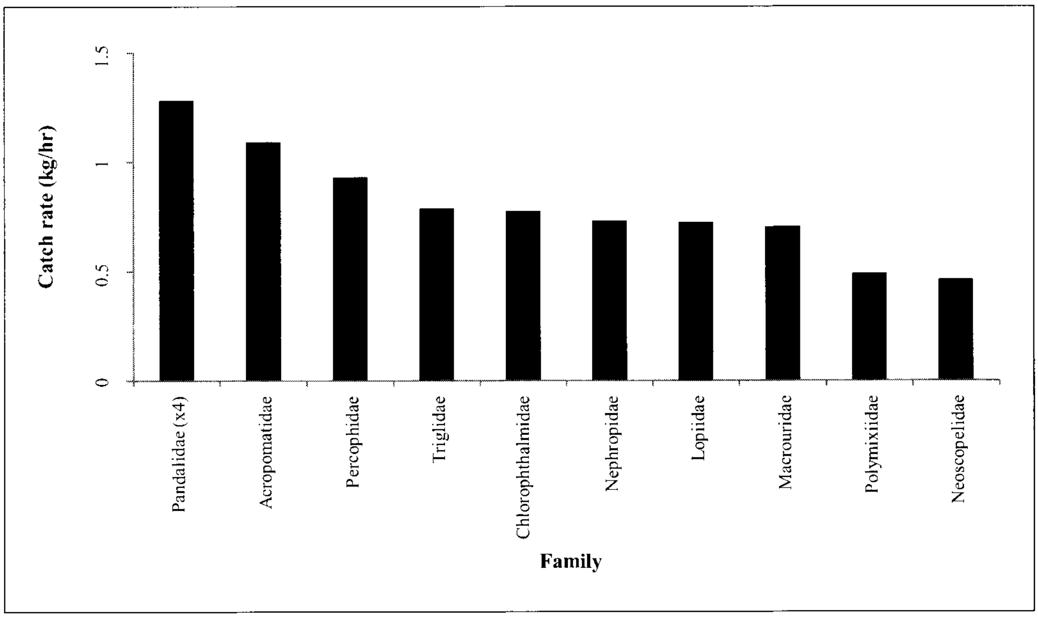

Figure 18: Dominant families in terms of average catch rate (kg/hr) caught at depth stratum 150-300 m

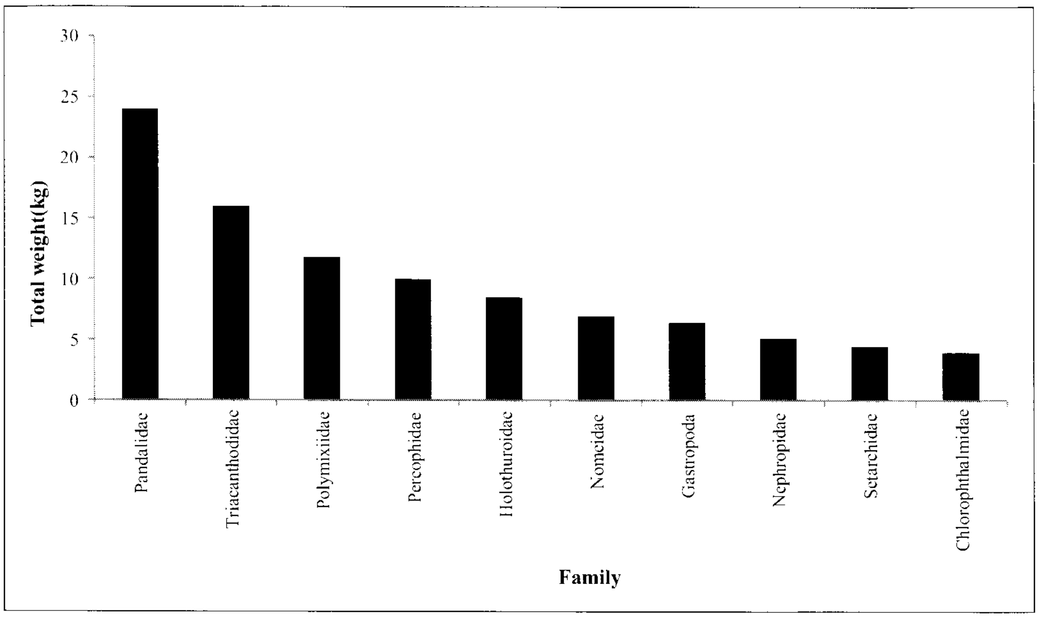

Figure 19: Dominant families in terms of total weight (kg) caught at depth stratum 301-400 m

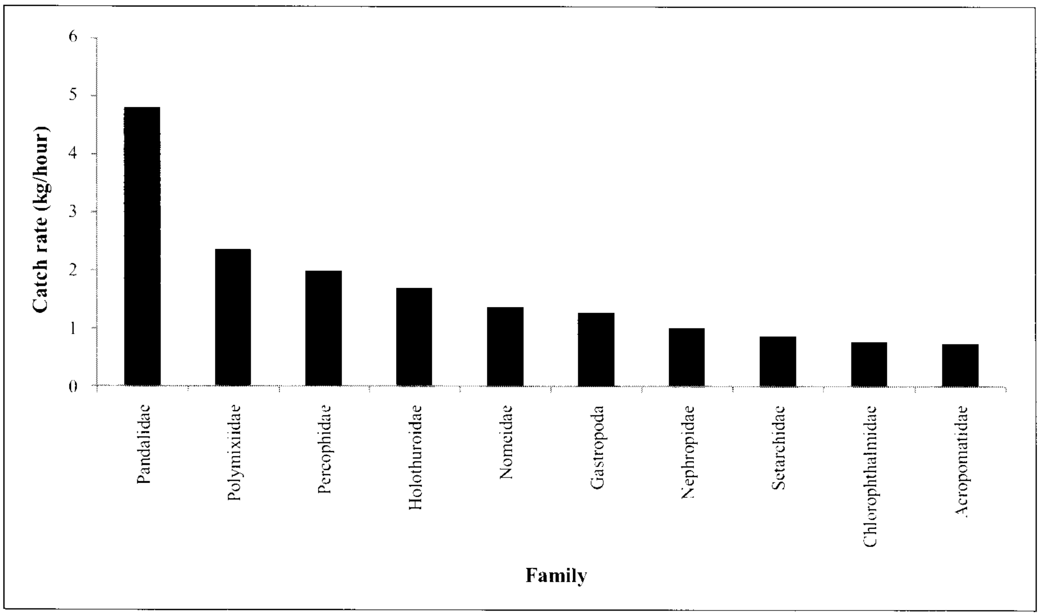

Figure 20: Dominant families in terms of catch rate (kg/hr) caught at depth stratum 301-400 m

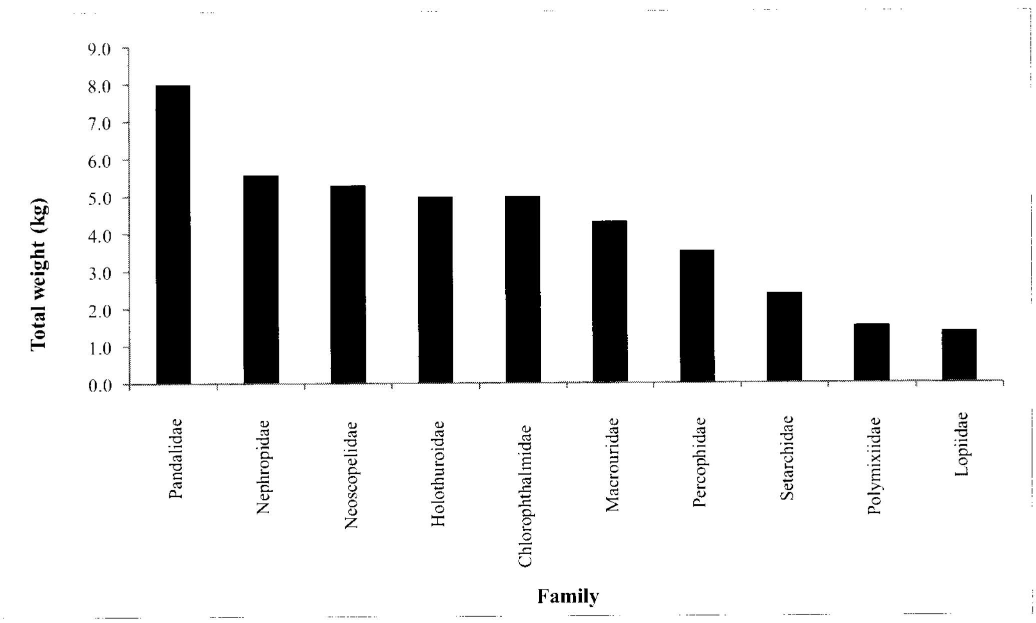

Figure 21: Dominant families in terms of total weight (kg) caught at depth stratum 401-500 m

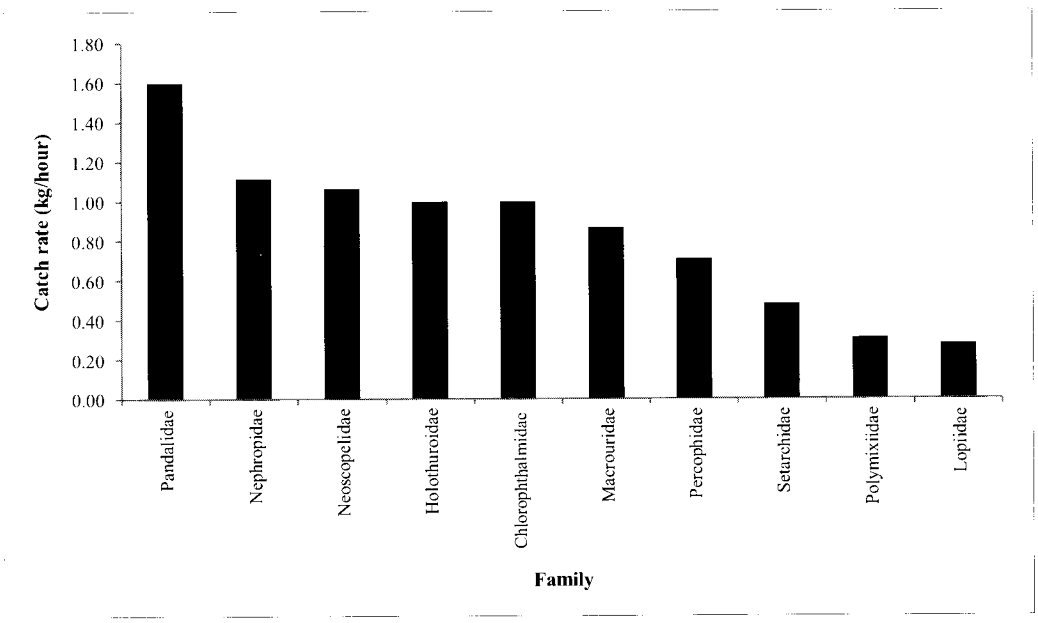

Figure 22: Dominant families in terms of catch rate (kg/hr) caught at depth stratum 401-500 m

Fig. 23 shows the dominant families caught by beam trawl in term of number (tails). The bar for Pandalidae is only one over 50 of the actual number (29,447 tails). Synonymous with the highest catch in term of weight (Fig. 17 to 22), Pandalidae top the dominant families in term of number (Appendix 4) since the size of the shrimp were relatively small at about 2 g per tail. Substantially, the rest of the catch was attributed to 15 fish families starting from Setarchidae (445), Polymixiidae (358), Percophidae (327) until Monacanthidae (73) and the other 4 families were the invertebrates comprised Nephropidae (294), Gastropoda (113), Holothuroidea (91) and shrimp-lobster, Polychelidae (69). Fig. 24 to 29 also show that the small deepsea shrimp Pandalidae leads in term of both total numbers (16,343, 9,939 and 4,120 tails) and catch rate by number of tails (3,269, 1,988 and 826 tails) caught per hour. But the next in line in the order of dominance for family was not comparable to that of total weight or in term of catch rate kg/hr. Here the small size individual influenced the order: for stratum 150-300 m the next in line in term of total numbers (in bracket) and catch rate by number of tails per hour were Samaridae (239), Nescopelidae (231), Percophidae (114) and others (Fig. 24 and 25); Setarchidae (314), Polymixiidae (233), Percophidae (175) and others for stratum 301-400 m (Fig. 26 and 27) and Nescopelidae (146), Champsodontidae (124), Setarchidae (119) and others for stratum 401-500 m (Fig. 28 and 29).

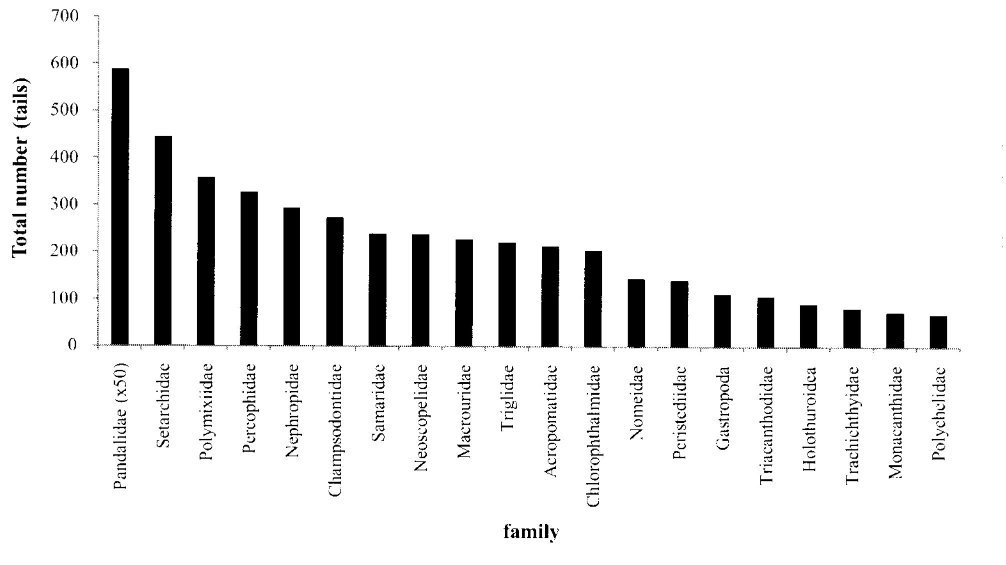

Figure 23: The dominant families caught by beam trawl in term of total number (tails)

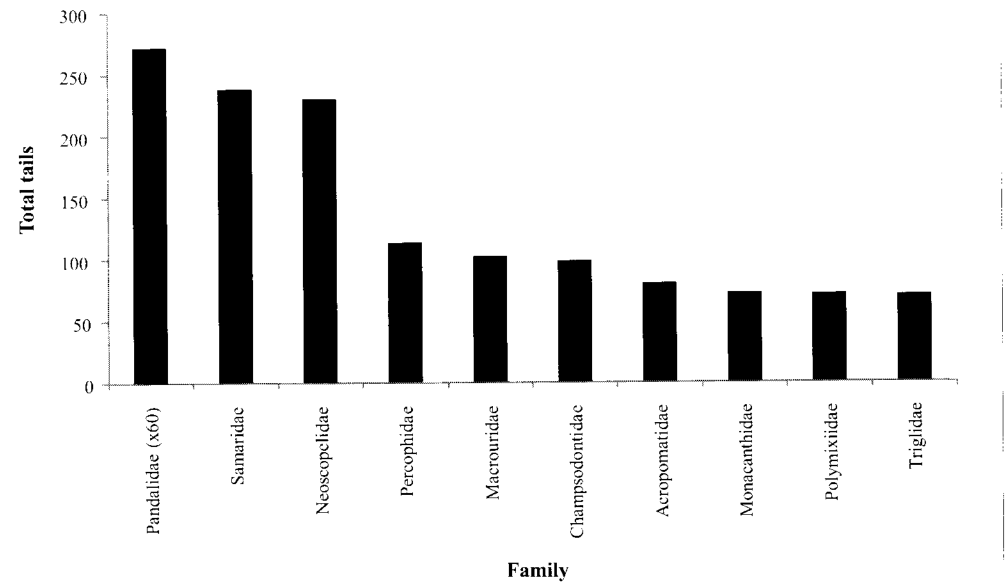

Figure 24: Dominant families in terms of total number of tails caught at depth stratum 150-300 m

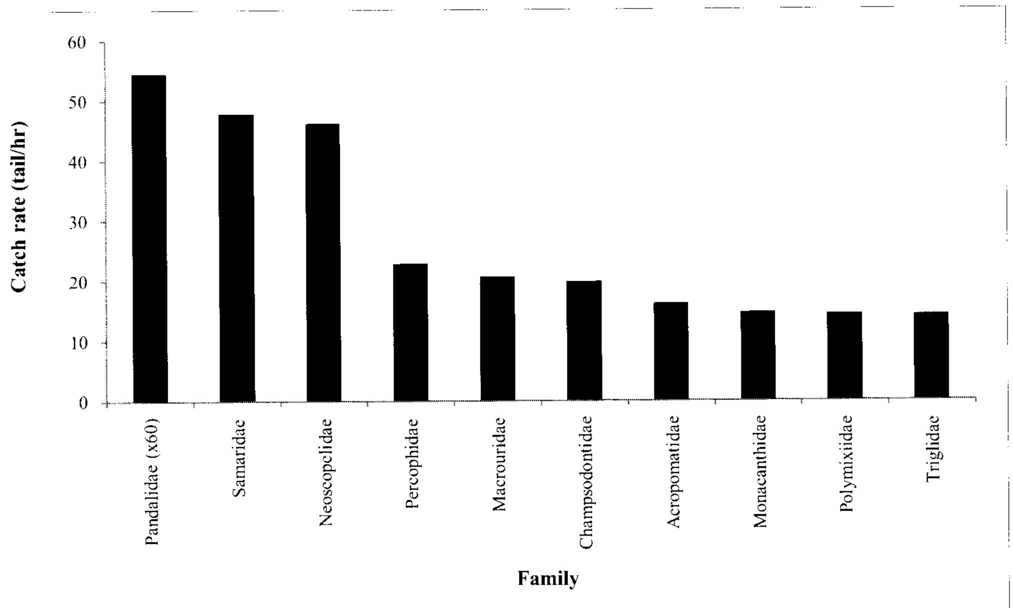

Figure 25: Dominant families in terms of average catch rate (tail/hr) caught at depth stratum 150-300m

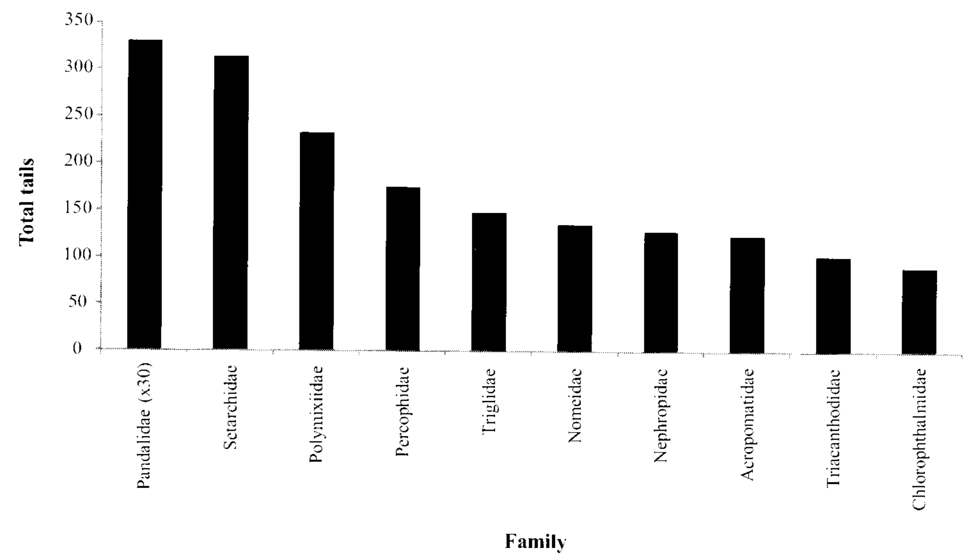

Figure 26: Dominant families in terms of total number of tails caught at depth stratum 301-400 m

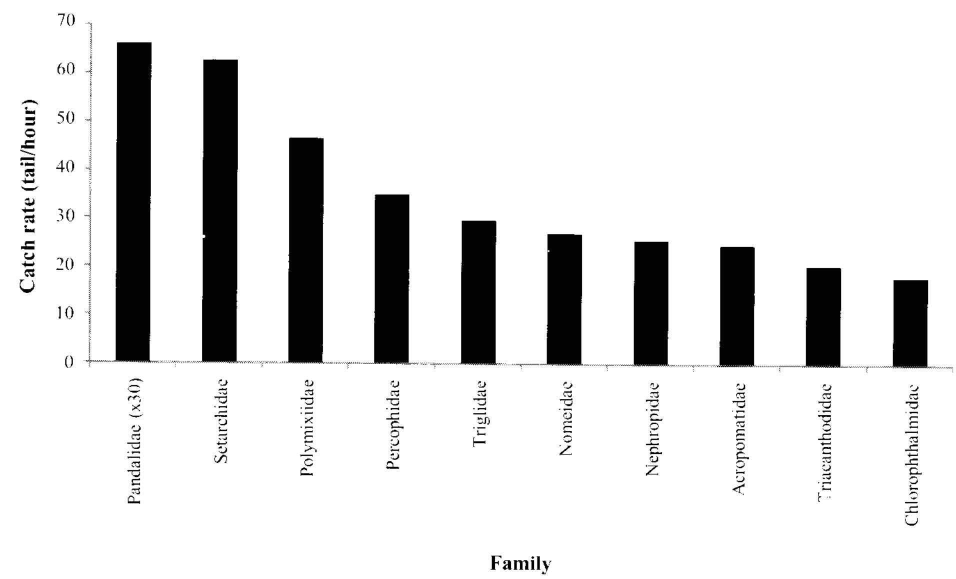

Figure 27: Dominant families in terms of catch rate (tail/hr) caught at depth stratum 301 - 400 m

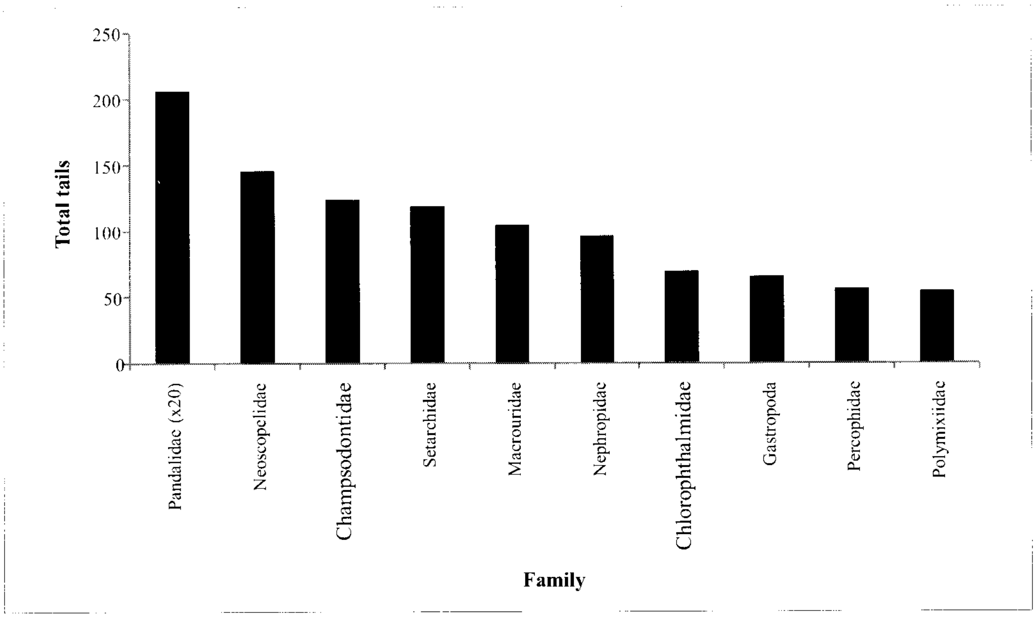

Figure 28: Dominant families in terms of total number of tails caught at depth stratum 401-500 m

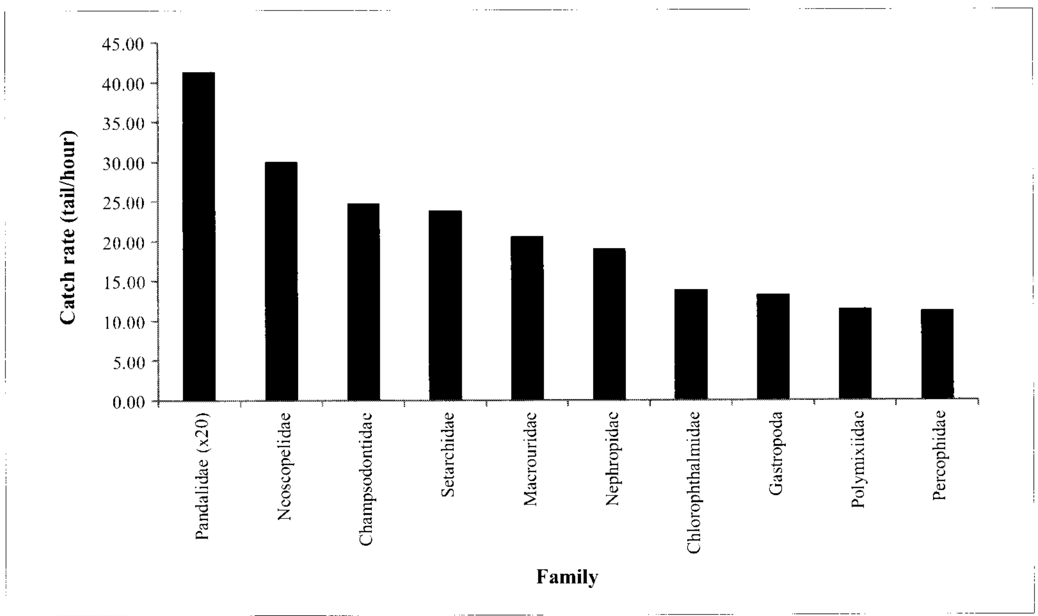

Figure 29: Dominant families in terms of catch rate (tail/hr) caught at depth stratum 401-500 m

Catch rates

The catch rates ranges from 1.07 kg/hr (station 15) to the highest at 52.90 kg/hr for station 5 (Fig. 30 and Appendix 4). In term of number of tails caught, the average catch rate (Tables 3 and 4) for each trawl station was 2,166 tail/hr (267 and 1,899 tail/hr for fish and invertebrate respectively) with the catch rates ranging from 119 tail/hr (station 9) to the largest 16,065 tail/hr at station 5 (Fig. 31). The overall average catch rate of fish was 9.46 kg/hr with the highest average catch obtained from depth stratum 301- 400 m at 13.28 kg/hr (Table 3). Obviously, the size of fish caught was rather small at an average of 36 g per tail. Table 4 shows the pattern of invertebrates' abundance at different depth stratum with the overall average catch rate of 6.60 kg/hr. Similar to the trend observed for fish, the highest average catch rate for invertebrates was obtained at depth stratum 30- 400 m at 9.67 kg/hr. The average size of invertebrates caught at depth between 150 to 500 m was at 4g per tail. These figures suggested that the average size of the fish caught was about 9 times bigger than the individual invertebrate. Overall, the average catch rate of this deep water resource was at 16.06 kg/hr, where fish contributed 9.46 kg/hr (59%) and invertebrate 6.60 kg/hr (41%). The average figure of 38.22 kg/hr by otter trawl using the same vessel in 2005 was slightly higher since sampling was carried out in shallower waters from 134 to 174 m (Samsudin *et al.*, 2006). In this exploratory survey, correspondingly, in term of numbers, the average catch rate was 267 tail/hr for fish (Table 3) and 1,899 tail/hr for invertebrates (Table 4) that is for every tail of fish caught in one hour there would be 7 tails of invertebrates. Fig. 32 shows the catch rates of fish and invertebrates caught according to trawl stations. Obviously, catches of fish was significantly high at stations 5 and 11 whereas invertebrates were caught most at stations 4 and 5. In all the 16 stations sampled (Appendix 4), only at station 4 invertebrates catch rate (18.9kg/hr) was higher than fish (13.4 kg/hr). The fish catch rates ranges from 0.41 kg/hr (station 16) to 27.37 kg/hr (station 5), correspondingly the lowest catch rate for invertebrates was 0.20 kg/hr (station 15) and the highest catch rate was 25.53 kg/hr (station 5). Accordingly, from Tables 3 and 4, the total (fish and invertebrate) catch rate by stratum showed a similar trend having the range from 1.1-52.9 kg/hr (stratum 150-300 m); 5.9-34.7 kg/hr (stratum 301-400 m) and 1.4-23.7 kg/hr (stratum 401-500 m). Survey in 2005 using otter trawl onboard this same research vessel, MV Seafdec2 for depths between 134-174 m gave a range of 18.6 to 71.5 kg/hr (Samsudin *et al.*, 2006) which was slightly higher than the present catches by beam trawl. Thus, in term of total catch, Fig. 32 shows that fish and invertebrates are dominant at depths of 301 to 400 m, followed by a depth of 150-300 m and 401-500 m. In term of productivity distribution, Fig. 33 and Appendix 4 shows that the deeper waters off east coast Sabah were productive having relatively high catch rates between 11.49 to 34.47 kg/hr whereas, for waters off Sarawak the productivity was rather low with catch rate <11.0 kg/hr. This productivity trend was probably associated with upwelling. During the calm months of March until August, there is an occurrence of upwelling due to the divergence and convergence (Snidvongs, 1999) of water currents in the South China Sea especially in the deeper waters off Sabah.

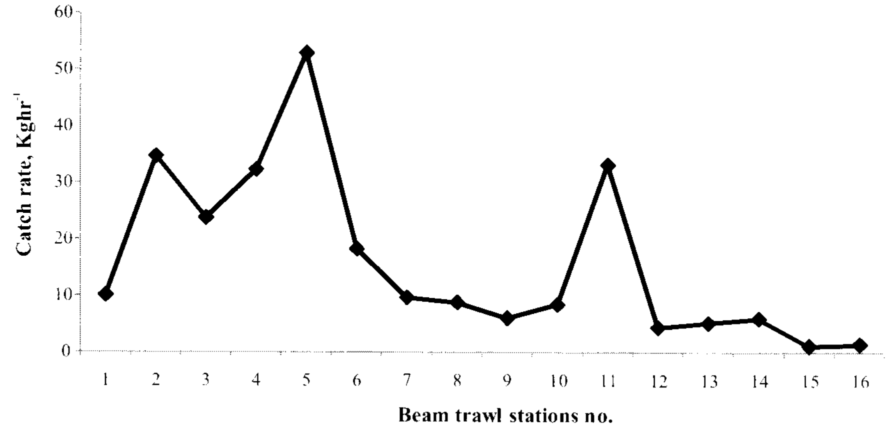

Figure 30: Catch rate (kg/hr) of beam trawl at different station

Table 3: Average catch rate for fish caught by beam trawl according to depth stratum

Depth stratum (m)	No. of station	Total no.	Average Catch Rate (tail/hr)	Total weight	Average Catch Rate (kg/hr)	Stdev	Average/tail (g)
150 - 300	6	1,537	256	51.74	8.62	9.465	34
301 - 400	5	1,866	373	66.40	13.28	8.027	36
401 - 500	5	865	173	32.42	6.48	5.001	37
			267		9.46		

Table 4: Average catch rate for invertebrates caught by beam trawl according to depth stratum

Depth stratum (m)	No. of station	Total no.	Average Catch Rate (tail/hr)	Total weight	Average Catch Rate (kg/hr)	Stdev	Average/tail (g)
150 - 300	6	1,6542	2,757	35.41	5.90	9.731	2
301 - 400	5	1,0328	2,066	48.33	9.67	8.902	5
401 - 500	5	4366	873	21.20	4.24	4.899	5
			1,899		6.60		

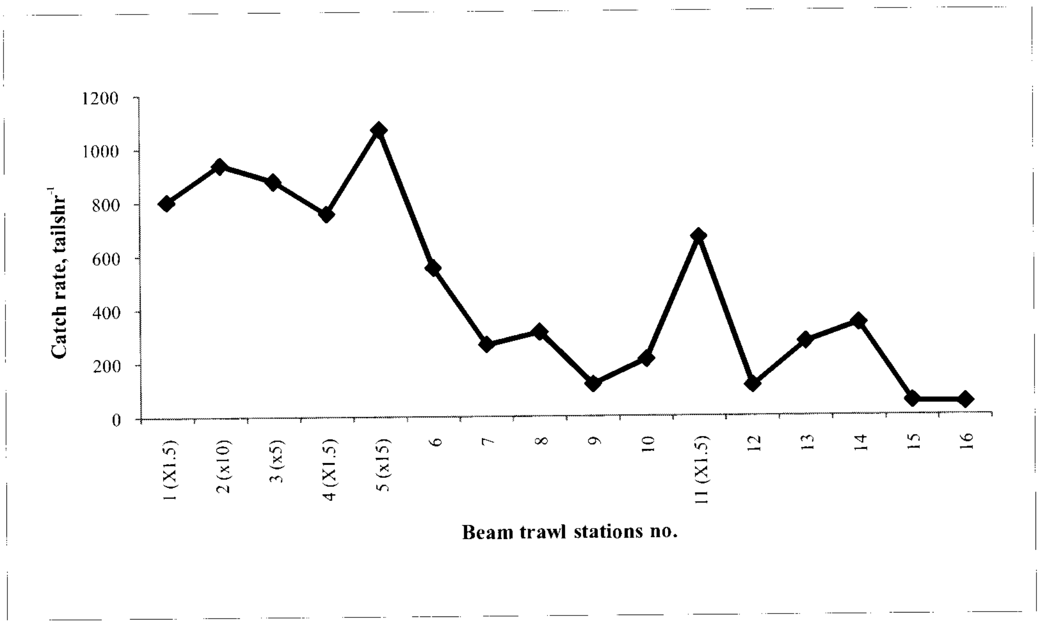

Figure 31: Catch rate (tail/hr) of beam trawl at different station

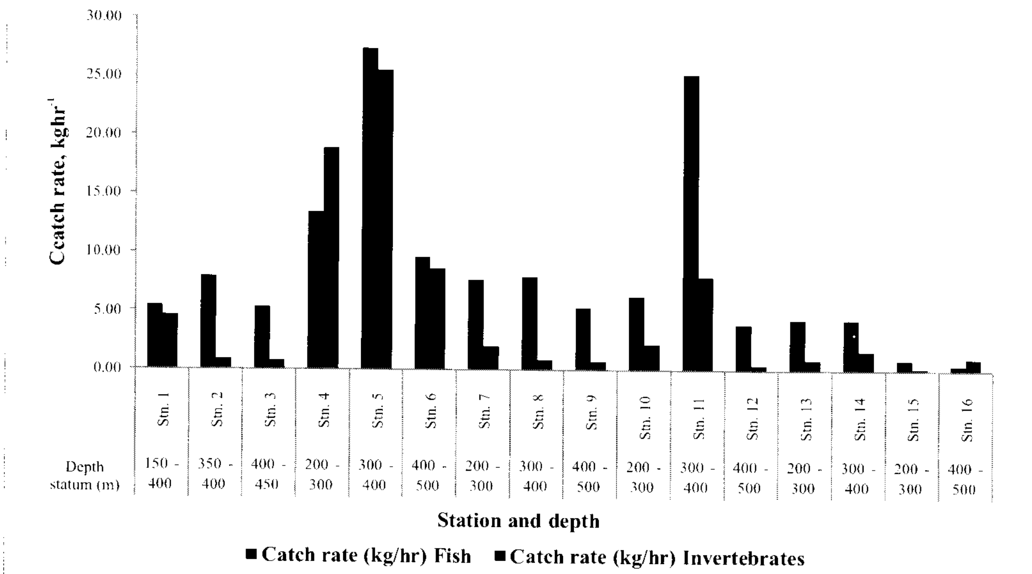

Figure 32: Beam trawl catch rate (kg/hr) by station for fish and invertebrates

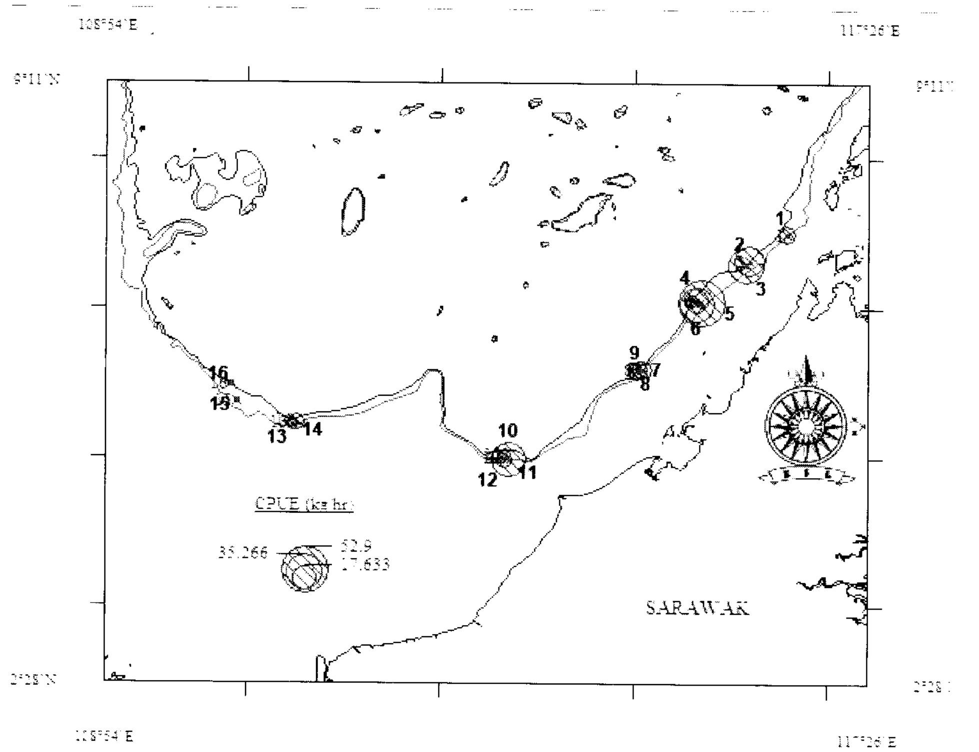

Figure 33: The catch rate (kg/hr) distribution for all beam trawl stations

Density and biomass

Fig. 34 and table 5 show that the density and biomass estimates (at different catchability coefficient, q) of the deep water fish and invertebrate resource off east coast Sabah and Sarawak. For Sabah, the density for fish was the highest (606.57 kg/km^2 at q=1.0) at shallower stratum 150-300 m and decreased toward the deeper stratum. But, the trend in density distribution for the invertebrates seem to suggest that the highest density (581.40 kg/km^2 at q=1.0) appeared at stratum 300-401 m, followed by stratum 150-300 m and 401-500 m. Estimates off the coast of Sarawak showed that the highest density (663.31 kg/km^2 at q=1.0) for fish was obtained from middle stratum 301-400 m, followed by deeper stratum, 401-500 m and shallower stratum, 150-300 m. Similar to the trend observed for fish, the highest density (215.29 kg/km^2 at q=1.0) for invertebrate resource was observed at middle stratum 301-400 m, followed by deeper stratum and shallower stratum. Sampling using otter trawl by MV SEAFDEC 2 in 2005 (Samsudin *et al.*, 2006) estimated the density of fish for depth ranging from 134-174 m to be 0.08 /gm^2± 0.043 /gm^2 equivalent to 80 kg/km^2 ± 43 kg/km^2 and it was indeed lower than the present estimate. This 2005 survey only covers 6 one-hour trawl stations and the area probably was sparsely inhabited by fish. Fig. 35 shows the density distribution of the demersal resources within the depth range of 150-500 m. Waters off Sabah was found to be productive having high density between 0.2 to 1.1 tonnes per square kilometer. The few sampled analyzed showed that the water productivity off Sarawak was less dense. Further survey by increasing the number of sampling stations will be able to confirm these findings.

The biomass (Table 5) for fish was estimated to range from 571 (q=1.0) to 2,774 (q=0.6) tonnes and 860 (q=1.0) to 4,650 (q=0.6) tonnes for Sabah and Sarawak respectively. Correspondingly the biomass estimates for invertebrate ranges from 346 to 2,202 tonnes and 617 to 1,477 tonnes. Table 6 shows the overall estimates of the biomass for the area surveyed; the total resource biomass estimate ranged from 5,460 to 9,099 tonnes and 8,700 to 14,500 tonnes for Sabah and Sarawak respectively. These biomass estimates were not significantly different between the two areas even though the estimated area within the depth range 150-500 m for Sarawak (2,469 km^2) was almost 5 times larger than the area off Sabah east coast (5,488 km^2). Considering that the area been surveyed was rather small, the biomass figures suggest that the resource was quite substantial. Assuming that the resource is still in its virgin state where Maximum Sustainable Yield, MSY=0.5M (natural mortality)*B_v (virgin biomass) (Gulland 1983), Table 6 shows that the sustainable amount of fish that can be harvested will be between 7,080 to 11,799 tonnes taking into consideration that deep sea species are long-lived with low natural mortality (Roberts 2002).

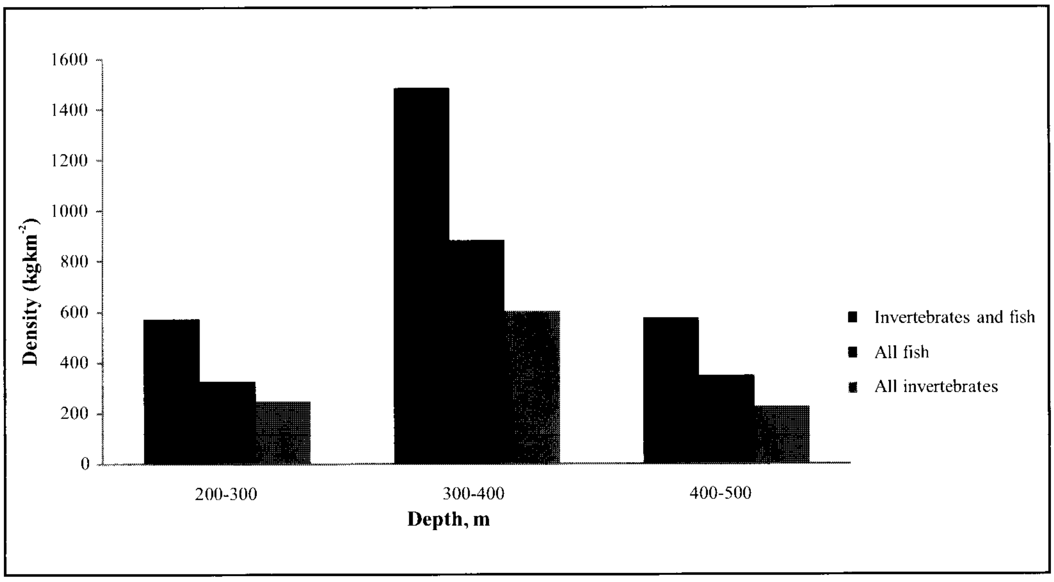

Figure 34: The density of deep sea resources at different depth stratum

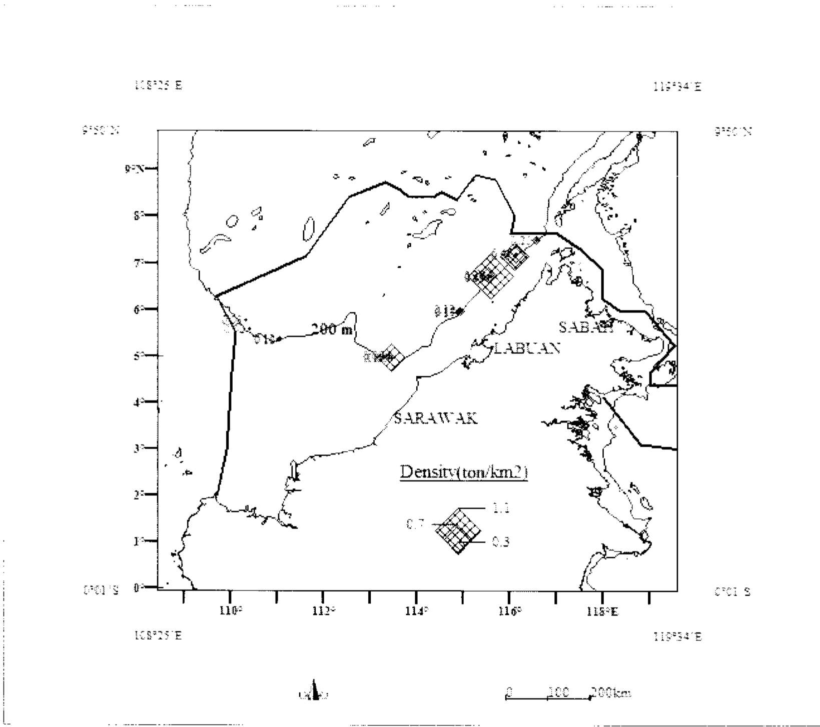

Figure 35: Density (tonnes/km) distribution of the demersal resources at depth range 150-500 m off Sarawak and east coast Sabah sampled by beam trasl July - Agust 2010

Conclusion

These findings using beam trawl were quite phenomenal in that almost all of the species encountered were relatively unknown and this was the first time they were been discovered locally. The commercial value of these fishes is yet to be determined. The concept of temporal stability in the deep-sea is valid for much of the world oceans and over mesoscale terms. However, this presumed stability is only apparent as periodic variability occurs in certain areas more frequently than originally supposed.Thus, seasonal changes in the spatial structure of several deep-sea faunal groups might also happens in the EEZ of Malaysia especially in waters below 500 m (Yeh *et al.* 2003). And this suggests that frequent surveys should be carried out to determine the real potential of this deep sea benthic resources. For sampling purposes under research exploration it was recommended that beam trawl be used since it yield more benthic fauna.

There was an indication to suggest that Malaysian EEZ deep waters are productive but comprehensive evaluation on the methods used to harvest these resources should first be implemented taking into account the vulnerability of the deep water resources to exploitation. The harvest strategy must take into consideration the mesobenthal ecology and the low turnover rates of these deep water fauna adapted to the environment. Detailed studies should be conducted to focus on resources that can be commercialized.

In the context of *r-k* selection theory, some common patterns, such as slow growth, longevity, long life span and delayed maturity, show the deep-sea ichthyofauna to be *k*-strategists. These bio-ecological traits should be considered when establishing management policies for the regulation of any possible expansion of the Malaysian EEZ deepwater fisheries. Such considerations would be relevant in reducing the impact upon the fragile ecosystem of South China Sea by such fisheries.

The management of the deep sea resources is very important. The current knowledge of the biology of deep-water species in the Malaysian EEZ is still new, especially in aspects related to the age composition, growth, reproductive characteristics and fecundity. Improvements in technology should allowed the bathymetric ranges (150-500 m) that have been investigated to be expanded and thus enlarge the understanding of its deep-sea ecosystems and the biology of the most important species. These detailed studies of the resources are prerequisite for a strategic plan of action for commercial deep water fisheries that not only conserve theirs productivity but ensure sustainable development.

Table 5: The density and biomass estimates (at different catchability coefficient, q) of the deep water fish and invertebrate resource off Sarawak and east coast Sabah surveyed by beam trawl in July/August 2010

Depth strata	Fish Avg CR	Stdev	Inv Avg CR	Stdev	Density (kg/km²)				Area		Biomass (kg)			
					Fish		Invertebrate		Nm²	km²	Fish		Invertebrate	
					q=0.6	q=1.0	q=0.6	q=1.0			q=0.6	q=1.0	q=0.6	q=1.0
Sabah														
150-300	13.48	12.079	10.70	12.910	1,010.95	606.57	802.44	481.46	800	2,744	2,773,973	1,664,386	2,201,822	1,321,093
301-400	12.30	4.003	12.92	10.434	922.75	553.65	969.00	581.40	400	1,372	1,265,979	759,588	1,329,427	797,656
401-500	9.25	5.604	5.61	6.923	693.51	416.10	420.34	252.20	400	1,372	951,465	570,879	576,692	346,015
Total									1,600	5,488	4,991,420	2,994,852	4,107,942	2,464,765
Sarawak														
150-300	3.77	2.704	1.10	0.991	282.47	169.48	82.67	49.60	4,800	16,464	4,650,454	279,0273	1,361,014	816,609
301-400	14.74	14.785	4.78	4.451	1,105.52	663.31	358.81	215.29	1,200	4,116	4,550,210	273,0126	1,476,816	886,089
401-500	4.64	4.646	3.33	4.575	348.15	208.89	249.81	149.88	1,200	4,116	1,432,934	859,760	1,028,169	616,901
				Total					7,200	24,696	10,633,598	6,380,159	3,865,999	2,319,599
		Average			727.23		436.34	480.51	288.31					

Table 6: The overall density and biomass estimates (at different catchability coefficient, q) of the deep water fish resource off Sarawak and east coast Sabah surveyed by beam trawl in July/August 2010

Location	Depth(m)	Avg catch rate (kg)	Stdev	Density (kg/km²)		Area (NM²)	Area (KM)	Biomass (kg)	
				q=1.0	q=0.6			q=1.0	q=0.6
Sabah	150 - 300	24.2	24.87	1088.0	1813.4	800	2744	2985479	4,975,798
	301 - 400	25.2	14.32	1135.0	1891.7	400	1372	1557244	2,595,407
	401 - 500	14.9	12.53	668.3	1113.8	400	1372	916894	1,528,157
								5459617	9,099,362
Sarawak	150 - 300	4.9	3.67	219.1	365.1	4800	16464	3606881	6,011,469
	301 - 400	19.5	17.17	878.6	1464.3	1200	4116	3616215	6,027,025
	401 - 500	8.0	2.29	358.8	598.0	1200	4116	1476661	2,461,102
								8699758	14,499,596
		Total				8800	30183	14,159,375	23,598,958

Swept area, a=d*BL, 0.022224 km

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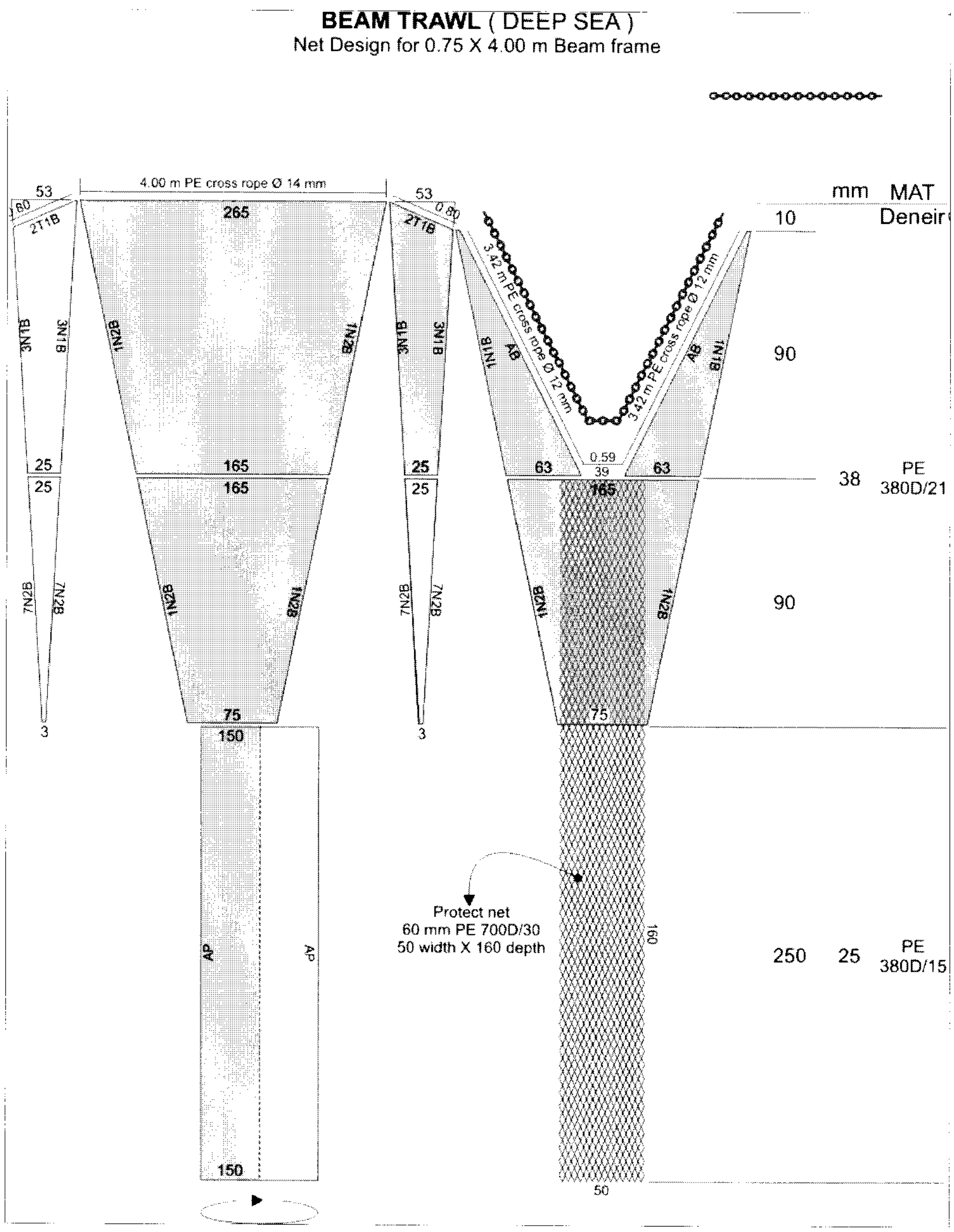
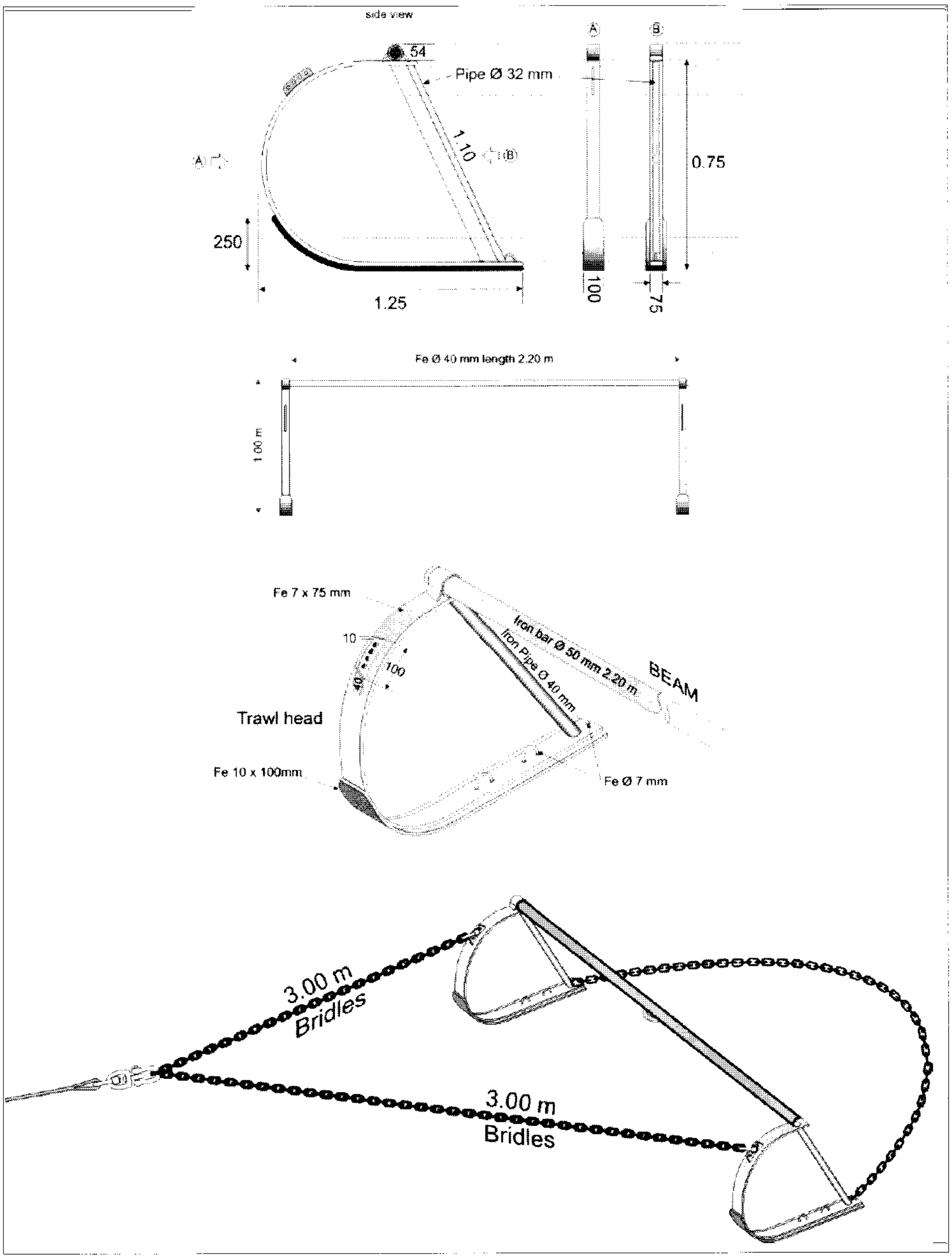
Appendix 1: Monograph for deep sea beam trawl (4m beam)- adopted from Sayan *et al.* 2007)



Appendix 2: Design of the deep sea beam trawl and towing chain arrangements-adopted from Sayan *et al.* 2007 (correction: the iron bar beam should be 4m instead of 2.20 m as shown)



Appendix 3: Beam trawl operation carried out by station from 11th. July until 4th. August 2010

Date	Station	Shooting						Hauling						Fishing Depth (m)
		Time start	Position		Time finish	Position		Time start	Position		Time finish	Position		
			Lat	Long		Lat	Long		Lat	Long		Lat	Long	
11.7.2010	1	0654	07°30.30'N	116°31.3'E	0702	07°29.8'N	116°31.3'E	0758	07°27.8'N	116°30'E	0824	07°27.9'N	116°29.5'E	130-200
12.7.2010	2	0550	07°10.4'N	116°04.40'E	0607	07°11.10'N	116°05'E	0707	07°12.3'N	116°07.2'E	0743	07°13'N	116°06.8'E	348-386
12.7.2010	3	0750	07°13.1'N	116°06.7'E	0805	7°12.8'N	116°05.8'E	0900	07°11.6'N	116°03.5'E	0918	07°11.7'N	116°03'E	390-411
12.7.2010	4	1432	06°44.1'N	115°30.7'E	1508	06°44.3'N	115°31.8'E	1608	06°45.6'N	115°34.1'E	1627	06°45.8'N	115°34.4'E	305-485
12.7.2010	5	1635	06°45.80'N	115°34.80'E	1645	06°45.8'N	115°35.5'E	1745	06°45.8'N	115°37.9'E	1758	06°45.7'N	115°37.9'E	252-296
13.7.2010	6	0604	06°46.70'N	100°30.90'E	0617	06°45.7'N	115°30.9'E	0705	06°43.9'N	115°30.4'E	0735	06°44.2'N	115°29.9'E	405-530
16.7.2010	7	0705	06°0.9'N	114°55.5'E	0718	06°0.5'N	114°54.9'E	0818	05°59'N	114°55.5'E	0840	05°58.9'N	114°52.6'E	225-271
16.7.2010	8	0850	05°58.6'N	114°51.2'E	0900	05°59.2'N	114°51.8'E	1000	06°0.7'N	114°53.6'E	1018	06°0.7'N	114°54'E	310-386
16.7.2010	9	1037	06°01.5'N	114°53.6'E	1047	06°01'N	114°52.9'E	1147	05°59.9'N	114°50.8'E	1205	06°0.1'N	114°50.4'E	475-509
18.7.2010	10	0715	05°0.7'N	113°22.4'E	0725	05°0.3'N	113°22.4'E	0825	05°00'N	113°24.7'E	0837	05°00'N	113°25.2'E	260-306
18.7.2010	11	0855	05°0.3'N	113°25.6'E	0905	05°0.5'N	113°25'E	1005	05°01.3'N	113°22.9'E	1022	05°01.9'N	113°23.1'E	326-336
18.7.2010	12	1144	05°03.3'N	113°23.5'E	1200	05°0.3'N	113°24.3'E	1300	05°02.1'N	113°27'E	1317	05°02.1'N	113°27.2'E	435-506
03.8.2010	13	1305	05°23.8'N	111°00'E	1315	05°23.8'N	111°0.5' E	1415	05°24.5'N	111°02.7 E	1427	05°24.8' N	111°02.9'E	214-231
03.8.2010	14	1435	05°24.8'N	111°02.8'E	1445	05°24.7'N	111°02.3'E	1545	05°23.9'N	110°59.8'E	1555	05°23.6' N	110°59.8'E	233
.8.2010	15	1138	05°38.5'N	110°23.02'E	1152	05°38.3'N	110°22.4'E	1252	05°37.3'N	110°20.1'E	1310	05°36.9' N	110°20.4'E	275-300
04.8.2010	16	0638	05°49.1'N	110°18.6'E	0650	05°49.1'N	110°17.8'E	0744	05°47.8'N	110°16.6'E	0805	05°47.6' N	110°16.3'E	414-513

Appendix 4: The catch rate (kghr[-1]) of all the species caught by MV SEAFDEC 2 vessel using beam trawl in July and August 2010

Station No:				1		2		3		4		5		6		7		8	
Date:				11.7.2010		12.7.2010		12.7.2010		12.7.2010		12.7.2010		13.7.2010		16.7.2010		16.7.2010	
Location-Start Shooting:			Lat:	07°30.30' N		07°10.40'N		07°13.10'N		06°44.10' N		06°45.80' N		06°46.70' N		06°0.9' N		05°58.6' N	
			Long:	116°31.30' E		116°04.40' E		116°06.70' E		115°30.70' E		115°34.80' E		100°30.90' E		114°55.5' E		114°51.2' E	
Depth (m) of Operation:				150-400		350-400		400- 450		300-400		200-300		400-500		200-300		300-400	
Catch Composition																			
No	FAMILY	No	SPECIES	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.
1	Acropomatidae	1	*Malakichthys elegans*							2.31	56	4.82	54	0.36	9	0.43	7		
		2	*Malakichthys griseus*															0.08	1
		3	*Synagrops philippinensis*																
2	Asteroidea	4	**Starfish**													0.08	4		
3	Ateleopodidae	5	*Ateleopus sp.*									0.17	10						
4	Bivalvia	6	**Shellfish**																
5	Bothidae	7	*Chascanopsetta lugubris*	0.19	18														
		8	*Engyprasopan sp.*	0.14	4									0.03	5				
		9	*Jaonoieops dentatus*																
		10	*Kamohoraia megastoma*	0.14	1					0.49	5								
6	Brachyura	11	**Crabs**																
7	Bregmacerotidae	12	*Bregmacerus macciellendii*																
8	Callionymidae	13	*Callionymus sp*																
9	Caproidae	14	*Antigonio copros*	0.17	14	0.05	2									1.1	25	0.05	1
		15	*Antigonia sp.*																
10	Champsodontidae	16	*Champsodon longispinnis*	0.13	4			1.25	104	0.32	50	0.68	94	0.1	20			0	1
		17	*Champsodan sp.*	0.12	1														
11	Chaunacidae	18	*Chaunax fimbriotus*			0.03	2												
		19	*Chaunea abei*	0.53	24	0.33	11							0.14	2				
12	Chiasmodontidae	20	*Oysolotus olcocki*																
13	Chlorophthalmidae	21	*Chlorophthalmus nigromarginatus*					2.79	39					2.11	27			0.13	1
		26	*Clorophthalmus oblongus*																
		22	*Chlorophthalmus sp.*	0.13	1	1.07	36			2.33	50	2.66	27	0.06	2	0.6	1	0.38	3
14	Cirolanidae	23	*Bathynomus daederleinii*																
		24	*Bathynomus sp.*									0.13	2						
15	Citharidae	25	*Citharoides macrolepidatus*	0.34	15														
16	Congridae	28	*Bathycangrus sp.*																
		29	*Conger sp.*													0.45	2	0.02	1
		30	*Conger cinerus*																
		31	*Gnathopsis xenico*																
		32	*Uruconger lepturus*																
17	Crinoidea	33	**Crinoids**																
18	Diretmidae	34	*Diretmichthys parini*																
19		35	*Diretmichthys sp.*																
20	Exocoetidae	36	*Cypselurus naresii*																
21	Galatheidae	37	*Galathea sp*																
22	Gastropoda	38	**Gastropods**			6.4	47	1.3	66										
23	Gempylidae	39	*Gemplus serpens*											0.09	7	0.08	1		
24		40	*Rexea prometheoides*					0.26	11					0.03	1				
25	Goneplacidae	41	*Carcinoplax longimanus*																
26	Gonostomatidae	42	*Diplaphos sp*																
27	Grammicolepididae	43	*Grammicolepis brachiusculus*											0.14	5			0.01	2
28	Histioteuthidae	44	*Histioteuthis sp.*																
29	Holothuroidea	45	**Seacucumber**	0.84	1					6.6	40			5	30	0.09	3		
30	Hoplichthyidae	46	*Haplichthys sp.*			0.89	4									1.2	4		
		47	*Haplichthys longsdorfii*																
31	Lepolidae	48	*Dwstonio pectinifer*															0.01	1
		49	*Owstonio sarmienta*															0.03	5
32	Loliginidae	50	*Loligo sp.*																
		51	*Sepioteuthis lessoniona*	0.79	3														

Station No:				9		10		11		12		13		14		15		16	
Date:				16.7.2010		18.07.2010		18.07.2010		18.07.2010		3.8.2010		3.8.2010		4.8.2010		4.8.2010	
Location-Start Shooting:			Lat:	06°01.5' N		05°0.7' N		05°0.3' N		05°03.3' N		05°23.8' N		05°24.8' N		05°38.5' N		05°49.1' N	
			Long:	114°53.6' E		113°22.4' E		113°25.6' E		113°23.5' E		111°00' E		111°02.8' E		110°23.02' E		110°18.6' E	
Depth (m) of Operation:				400-500		200-300		300-400		400-500		200-300		300-400		200-300		400-500	
Catch Composition																			
No	FAMILY	No	SPECIES	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)	No.
1	Acropomatidae	1	*Malakichthys elegans*					1.11	19										
		2	*Malakichthys griseus*			0.06	1					0.09	3	0.12	26				
		3	*Synagrops philippinensis*									0.06	15	0.11	21	0.01	1		
2	Asteroidea	4	**Starfish**					0.6	13	0.02	1	0.38	12					0.05	2
3	Ateleopodidae	5	*Ateleopus sp.*																
4	Bivalvia	6	**Shellfish**			0.03	3												
5	Bothidae	7	*Chascanopsetta lugubris*									0.01	1	0.18	7				
		8	*Engyprasopan sp.*					0.01	1									0.01	1
		9	*Jaonoieops dentatus*									0.03	1						
		10	*Kamohoraia megastoma*																
6	Brachyura	11	**Crabs**	0.18	18	0.15	10	0.3	9										
7	Bregmacerotidae	12	*Bregmacerus macciellendii*															0	1
8	Callionymidae	13	*Callionymus sp*													0.02	1		
9	Caproidae	14	*Antigonio copros*			0.1	4									0.14	2		
		15	*Antigonia sp.*			0.1	4												
10	Champsodontidae	16	*Champsodon longispinnis*																
		17	*Champsodan sp.*																
11	Chaunacidae	18	*Chaunax fimbriotus*											0.12	1				
		19	*Chaunea abei*									0.03	6	0	2				
12	Chiasmodontidae	20	*Oysolotus olcocki*									0.01	1	0.01	4	0.01	1		
13	Chlorophthalmidae	21	*Chlorophthalmus nigromarginatus*											0.01	1	0.45	3		
		26	*Clorophthalmus oblongus*									0.02	12						
		22	*Chlorophthalmus sp.*							0.03	2								
14	Cirolanidae	23	*Bathynomus daederleinii*									0.1	1						
		24	*Bathynomus sp.*					0.55	23										
15	Citharidae	25	*Citharoides macrolepidatus*																
16	Congridae	28	*Bathycangrus sp.*					0.35	1										
		29	*Conger sp.*															0.13	3
		30	*Conger cinerus*											0.38	3				
		31	*Gnathopsis xenico*									0.2	3						
		32	*Uruconger lepturus*									0.09	1						
17	Crinoidea	33	**Crinoids**													0.11	7		
18	Diretmidae	34	*Diretmichthys parini*	0.21	2					0.05	1								
19		35	*Diretmichthys sp.*							0.03	1								
20	Exocoetidae	36	*Cypselurus naresii*															0.08	1
21	Galatheidae	37	*Galathea sp*													0	1	0.1	12
22	Gastropoda	38	**Gastropods**																
23	Gempylidae	39	*Gemplus serpens*					0.32	1										
24		40	*Rexea prometheoides*																
25	Goneplacidae	41	*Carcinoplax longimanus*							0.2	1								
26	Gonostomatidae	42	*Diplaphos sp*															0.03	1
27	Grammicolepididae	43	*Grammicolepis brachiusculus*																
28	Histioteuthidae	44	*Histioteuthis sp.*															0.67	1
29	Holothuroidea	45	**Seacucumber**			1.35	5	1.6	9					0.29	3				
30	Hoplichthyidae	46	*Haplichthys sp.*			0.4	13	1.2	13										
		47	*Haplichthys longsdorfii*									0	2	0.13	2				
31	Lepolidae	48	*Dwstonio pectinifer*																
		49	*Owstonio sarmienta*																
32	Loliginidae	50	*Loligo sp.*			0.02	2	0.04	1					0.01	1				
		51	*Sepioteuthis lessoniona*					0.04	1										

33	Lopiidae	52	*Lopniamus setigerus*	0.192 8	0.29 9	0.42 6	1.92 5				0.015 2	0.96 2					0.022 2		
		53	*Lopniamus sp.*	0.129 1				3.3 19			0.3 1			0.13 1					
34	Lutjanidae	54	*Pristipomaides sp.*	0.166 4						0.4 1	0.2 1		0.2 1						
35	Macrouridae	55	*Bathygadus sp.*								0.106 3								
		56	*Caeiarindus sp*													0.053 10		0.008 1	
		57	*Coeiarinchus sp.*			0.17 17		2.66 45	0.03 1		0.02 1	1.3 18					0.007 1		
		58	Macrourids																0.008 2
		59	*Gadomus sp*									0.276 10							
		60	*Macrauridae sp*																0.003 1
		61	*Ventrifassa sp.*			2.4 40		0.73 44	0.15 16		0.616 65		0.06 3	0.475 8					
36	Monacanthidae	62	*Thomnaconus hypargyreus*	0.341 65															
		63	*Thamnaconus tesselates*	0.152 8															
37	Myctophidae	64	*Diophus sp.*				0.3 9		0.65 20		0.088 4		0.02 1						
		65	*Myctophidoe*																0.065 1
38	Nemipteridae	66	*Nemipterus bathybius*	0.207 4															
		67	*Parascalapsis tasensis*	0.134 3															
39	Neoscopelidae	68	*Neoscopelus micrachir*				0.07 5	0.62 120			0.11 5	0.64 9		0.57 9	1.6 29				
		69	*Neoscapelus sp.*			2.87 105		1.64 105			2.23 48		0.046 6		0.2 3				
40	Nephropidae	70	*Metanephrops andamanicus*				2.65 59	2 40						0.247 12					
		71	*Metonephrops farmasanus*				0.84 14	1.25 21	1.8 30	0.2 4	0.708 33	0.05 4	0.18 3	0.656 10	0.1 2				0.024 1
		72	*Metanephraps chinensis*			3.6 60												0.029 1	
41	Nomeidae	73	*Cubiceps cf whiteleggii*											6.68 128					
		74	*Cubiceps sp.*					0.68 8	0.07 2		0.038 2			0.177 5					
42	Octopodidae	75	*Octapus sp.*	0.834 2				0.2 3		0.07 2									
43	Ogcocephalidae	76	*Holiautaea sp.*				0.39 5		0.17 8					0.29 1					
		77	*Holieutoeo stellata*						1.14 2		0.123 1								
		78	*Malthapsis annulifera*		0.03 4											0.026 5	0.03 1		
		79	*Malthapsis sp*															0.004 1	
44	Ophichtidae	80	Ophichtids														0.72 19		
45	Ophidiidae	81	*Brotula multibarbata*									0.45 4							
		82	*Hoplobrotula armata*								0.075 1	0.111 1	0.202 2				0.45 4		
		83	*Hoplobratula sp.*		0.09 2						0.021 1								
		84	*Neobythites unimaculatus*														0.116 1		
		85	*Neabythites sp*															0.173 2	
		86	*Ophidiidae*													0.006 1		0.01 2	0.014 2
46	Pandalidae	87	*Plesionika sp.*															0.01 4	
		88	*Heteracarpus sp*	0.896 24			8.6 653		1.804 221	0.8 99	0.01 1	0.48 24	0.02 14	1.374 277	0.05 11		0.028 8	0.014 2	0.029 2
		89	*Pondalus sp.*	1.241 931	12.6 8689	5.6 3862		21.8 15034		0.3 12			0.02 30	0.133 124		0.464 173	1.296 188	0.037 20	0.038 8
47	Parazenidae	90	*Cyttopsis cypha*	0.17 6	0.12 7		0.29 5	0.06 3						0.045 4					
		91	*Cyttopsis rosea*					0.29 14			0.099 5					0.014 3			
		92	*Parazen pacificus*														0.04 1		
48	Penaeidae	93	*Penoeus sp.*															0.003 1	
49	Perciformes	94	*Etelis radiosus*								0.47 1								
50	Percophidae	95	*Acanthaahritis sp.*		1.17 27								0.3 1						
		96	*Acanthophritis azawai*				1.91 27		1.75 27	0.295 6			0.209 5	0.43 4					
		97	*Bembrops caudimacula*		2.42 52	0.09 6	0.67 6		1.62 23	0.676 16	0.13 5		0.186 8			0.01 1			
		98	*Bembraps sp.*					0.44 12			0.024 2			0.456 7					
		99	*Chrionema chlorataenia*		1.11 20		0.41 6	1.99 55			0.012 1	0.087 1				0.5 7	1.232 18	0.045 3	
51	Peristediidae	100	*Gargariscus prionacephalus*								0.245 5	0.25 11		0.039 2					
		101	*Peristedian lianynchus*				0.04 7				0.139 11	0.056 7	0.038 4	0.054 4					
		102	*Peristedion sp.*					0.17 6	0.01 1										
		103	*Satyrichthys langsdarfii*													0.1 2			
		104	*Satyrichthys rieffeli*	0.133 1	0.09 4		0.25 22		0.05 5		0.02 4					0.1 1	0.198 2		0.054 2
		105	*Satyrichthys sp.*	0.126 1	0.9 14					0.45 23				0.018 2	0.012 1				
52	Poecilopsettidae	106	*Paeciiapsetta plinthus*													0.019 2	0.005 1		

53	Polychelidae	107	*Polychelis sp.*				0.2 11	0.15 13			0.12 10			0.774 33					0.022 2
54	Polymixiidae	108	*Polymixia nobilis*			1.37 33	0.14 5	0.67 14			0.207 6		0.323 11	0.381 9					
		109	*Polymixia sp.*		0.09 5					1.15 36	0.78 19		0.3 11	10.2 186	0.15 20				
		110	*Polymixia longispina*														0.019 3		
55	Priacanthidae	111	*Priacanthus macracanthus*	0.203 13	0.13 2														
		112	*Pristigenys niphonia*											0.19 1					
56	Rajidae	113	*Dipturus kwangtungensis*		0.18 2														
		114	*Okamejei caira*	0.308 5															
		115	*Raja (Dipturus) tengu*													1.4 1			
		116	*Raja (Dipturus) kwangtungensis*														0.02 1		
57	Raninidae	117	**Raninidae**																0.004 1
		118	*Ranina ranina*											0.4 1					
58	Samaridae	119	*Samariscus sp.*	0.19 18				1.61 218			0.01 1		0.088 3						
59	Scorpanidae	120	*Ectreposebastes imus*													0.006 1	0.004 8		
		121	*Scarpaena neglecta*													1 1			
60	Scyliorhinidae	122	*Cephaloscyllium fasciatum*			0.6 2													
61	Scyllaridae	123	*Scyllarus sp.*							0.13 12			0.24 10	0.48 12	0.04 6				
62	Serranidae	124	*Chelidoperca hirudinacea*	0.154 5															
		125	*Plectranthias japonicus*	0.175 7	0.14 4						0.065 3					0.029 3			
63	Setarchidae	126	*Setarches guentheri*		3.46 303	0.99 44			0.71 65		0.522 6		1.2 9	0.41 3	0.7 10				
		127	*Liascarpius langiceps*													0.012 3	0.007 2		
64	Soleidae	128	*Brachiurus sp.*	0.136 4	0.045 5														
		129	*Parachirus sp*														0.004 1		
65	Solenoceridae	130	*Solenacera sp.*										0.152 30	0.738 34					
66	Squillidae	131	*Cloridopsis scorpio*													0.002 1	0.016 6		
		132	*Squilloides sp.*							0.3 2									
67	Sternoptychidae	133	*Polyipnus sp.*								0.01 40								
		134	*Polyipnus tridentifer*																0.008 2
68	Syngnathidae	135	*Hippocampus sp*																0.017 1
69	Synodontidae	136	*Saurida undosquamus*	0.167 1															
		137	*Synodus kaianus*	0.129 1															
70	Tetraodontidae	138	*Feroxodon multistriatus*														0.02 1		
		139	*Sphaeroides pachygaster*								0.114 1			0.1 1					
		140	*Tylerius spinosissimus*													0.02 1			
71	Tetrarogidae	141	*Lioranium sp.*											0.52 18					
72	Trachichthyidae	142	*Haplostethus sp.*					0.62 44	0.06 7		0.064 3	0.173 1		0.47 5	1.1 25				
73	Triacanthodidae	143	*Halimachirurgus alcocki*								0.011 1						0.006 2		
		144	*Halimochirurgus centriscoides*				0.28 23		0.02 4						0.023 1				
		145	*Macrorhamphosodes platycheilus*				1 23												
		146	*Triacanthodes ethiops*		0.02 2		0.19 36												
		147	*Triacanthodes anomolus*														0.003 1		
		148	*Tydemania navigatoris*				0.09 14												
74	Triakidae	149	*Triakis sp.*														0.003 1		
75	Trichiuridae	150	*Benthodesmus tenuis*					1.99 14	0.08 12										
76	Triglidae	151	*Lepidotrigla abyssalis*		0.78 95						0.148 2								
		152	*Lepidotrigla spilaptera*	0.14 3	0.23 2			0.75 26					0.5 3						
		153	*Pterygotrigla hemisticta*	0.187 4				0.82 20	0.015 1	0.8 8	0.165 1	0.774 7	0.512 3						
		154	*Pterygotrigla leptacanthus*		0.3 38				0.03 2				0.01 1						
		155	*Pterygotrigla multiacellata*													0.01 1			
		156	*Pterygotrigla sp.*								0.02 2		0.2 2	0.57 8					
77	Uranoscopidae	157	*Uranoscopus archionema*													0.35 1	0.311 2		
		158	*Uronoscopus kaianus*		1.61 9								1.18 9						
78	Vitreledonellidae	159	*Vitreledonella richardi*																0.043 1
79	Zeidae	160	*Zenopsis nebulosus*		0.07 2														