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ASSESSMENT OF DEMERSAL FISHERY RESOURCES OF THE SOUTHEAST AND SOUTHWEST WATERS OF VIETNAM, BASED ON BOTTOM TRAWL SURVEYS IN 2000-2005

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ABSTRACT

This study is a preliminary analysis on abundance indices, fish assemblages and assessments of the biodiversity of the demersal fish resources of the Southeast and Southwest waters, Vietnam, based on bottom trawl surveys conducted during the years 2000 - 2005. The survey program was implemented under the project of "Assessment of the Living Marine Resources of Vietnam - ALMRV" which was supported by DANIDA (Danish International Development Agency) and Vietnamese government. A commercial fishing boat equipped with 500 HP engine was used. The sampling gear used was a bottom trawl with an opening width of 11.6 m and the stretched mesh size of the cod-end of 35 mm. The surveys were designed based on a "fixed station system", stationary grid with an average distance of 30 nautical miles between hauls. All tows were conducted during the daytime. The average towing speed was 3.5 and towing duration of 1.0 hour. CPUA (catch per unit area) is used to standardize the abundance index. Catchability (q) is assumed to be constant for all fish species. Kriging technique is applied to map the distribution of the demersal fish stock of the Southern water of Vietnam. The evenness, richness and biodiversity of the demersal fish communities distributed in these areas are evaluated by estimating the values of various indices including Shannon-Weinner index (H') and Pielou's index. Ward Hierarchical Cluster analysis is applied to analyze the biological assemblage of the fish stocks. The study shows a considerable decrease in fish abundance of the area during the period from 2000 to 2005 and a high variance in the relative abundance as well as the structure of fish community by seasonal monsoons. Different patterns of fish assemblages of the demersal fish in the Southeast and the Southwest waters were observed.

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1 INTRODUCTION

Marine capture fisheries play an important role in Vietnam's socio-economic standard.. Since the 1990s, the Vietnamese government has considered the fishing industry as a "key" sector for developing its economy. Offshore fishing fleets have been subsidized aiming to move toward offshore fishing grounds which have been neglected because of the lack of capable fishing boats. Even though, stock assessment has not been paid much attention to by the government, the "fisheries independent" data source is still inadequate and is relatively poor. In the middle of the 1970s, some investigation on fish behaviours, mainly on shoaling and diel variations were conducted in Vietnamese waters under the cooperative research program between Research Institute for Marine Fisheries (RIMF) and the Institute of Marine Research (IMR), Bergen, Norway. These studies were based on acoustic surveys using a paper based scientific Echo-sounder. After 1980, no study on fish behaviour in the large fishing grounds of Vietnam has been carried out. Most surveys performed have focused on specific objectives; mainly to estimate fish abundance including CPUA, biomass and individual fish biology etc. Additionally, surveys have not been planned as a long term survey strategy or as routine tasks. The yield from the fish stocks have been decreasing as a result of high fishing pressure and weak monitoring, control and surveillance system (Christensen, 1998; Christensen *et al.*, 2003). A number of papers have reported that fish resources of most of the fishing grounds of Vietnam have been overfished and many resource and economic indicators have shown negative signs (Nguyen, 2001; Chu *et al.*, 2006; Nguyen and Nguyen, 2008).

Due to the multiple species and small scale fisheries, the management of the sector might be not suitably implemented in the way of single species fisheries in which a QUOTA system normally works. Management on a small scale in Vietnam (Raakjær *et al.*, 2007) and the Asian region (SEAFDEC, 2003; Wilson *et al.*, 2006) have introduced the adaptive approach with the basin on a number of indicators. Therefore, a set of indicators is set dependent on each nation, however, the main indicators belong to fishing effort (BAC – Boat Active Days), fisheries economic indicators, fisheries resource indicators (CPUE, mean fish length caught, proportion of the economically important species in annual catches, mean maturity length of fish…) and ecological indicators (mean trophic levels, biodiversity indices, fish assemblages, and fisheries socio-economic indicators (average income of fishermen …) (FAO, 1999; MOFI *et al.*, 2001). Owing to the tropical characteristics, most fish species have a high growth rate and can be quickly replaced by the others species when suddenly natural environmental changes happened and/or selective impacts made by human beings. Assessment of the fisheries resources and evaluation of the marine capture fisheries is normally implemented under the evaluation of a set of indicators. Consequently, policy management decisions are based on scientific assessments of the indicators concerned.

The present study used data collected by seven bottom trawl surveys which were conducted during the period from 2000 to 2005 under a cooperative research programme between Vietnam and Denmark. The major objective of the project was to assess the marine living resources of Vietnamese sea water. A commercial bottom trawler with a 11.6 opening width was used to collect fisheries resource samples. Four surveys were performed during the Southwest monsoon and three surveys were conducted during the Northeast monsoon. A fixed stations system was used for taking sampling hauls during each survey. Some indicators were representative for the relative abundance of the demersal fisheries resources and some ecological indicators (biodiversity indices, structure of fish community) were the focus of the evaluation in the present work. The main objectives of the present research are to assess the relative abundance indicators of the demersal fisheries resources of the Southeast and the Southwest waters of Vietnam. The groups of highly economically important species and ecologically sensitive species were evaluated using the variation in abundance over time series. Biodiversity indices including Shannon – Weinner index (H'), Magaleft index (D) and Pielou's index (J') are monitored for these demersal fish resources. Preliminary studies on fish assemblage structure of the demersal fish resources by seasonal variation are implemented for both the Southeast and the Southwest waters of Vietnam during 2000 – 2005. The general purpose of the present study is to evaluate the demersal fisheries resources of the Southern water in Vietnam based on some indicators mentioned above.

- **Scope and goals**

This study is limited tothe bottom trawl surveys conducted during 2000 – 2005 in the Southeast and the Southwest waters of Vietnam. The survey area covered the strata from 20 m depth to 200 m depth. The "trawlable" areas of the Southeast water and Southwest water are considered as survey areas. The "trawlable" area means that the area is not too deep and has a relatively flat seabed. Data used is retrieved from the surveys conducted under the Assessment of the Living Marine Resources of Vietnam (ALMRV) project during 2000 - 2005.

The main goal of this project is to analyse abundance indices and fish assemblages in the southern waters of Vietnam. In addition, the ecological aspects of the demersal fisheries resources are assessed e.g. biodiversity indices including species evenness and species richness. Moreover, possible seasonal changes in abundances, species composition and biodiversity indices by strata depth are analysed.

- **Objectives**

✓ to estimate the overall fish abundance indices of the Southeast and Southwest areas over the survey time of 2000 – 2005;

✓ to analyse if there is a trend in abundance of three groups of fish species including ecologically sensitive species, highly economically important species and low commercially valuable species;

✓ to assess the level of diversity of the demesal fish communities and the variation pattern of these indices over time;

✓ to analyse the fish assemblage structure in the Southern waters of Vietnam with respect to seasonal variation;

✓ to support technical advice on strategy on survey design including the number of stations allocated by strata depth and sampling time;

2 LITERATURE REVIEW

- **Natural conditions in Vietnam**

With more than 1 million square kilometres of EEZ, and width stretching from the South (about 6^{o}00'N) to the North (about 22^{o}00'N), the marine waters of Vietnam have relatively variable characteristics in terms of oceanography and ecosystems. Additionally, the Gulf of Tonkin in the northern area and the Gulf of Thailand in the Southwest area have fairly different regimes both in biotic and abiotic factors compared to the waters off the coast of Vietnam. For administrative management purposes, the Southeast and Southwest areas are separated into management units at the longitude of 105^{o}00'E. The two main monsoon seasons, Southwest monsoon which lasts from May to September and Northeast monsoon which lastsfrom November to the following March characterize the hydrograph of these management areas. The climate and water currents are different during these two monsoon seasons (Figure 1).

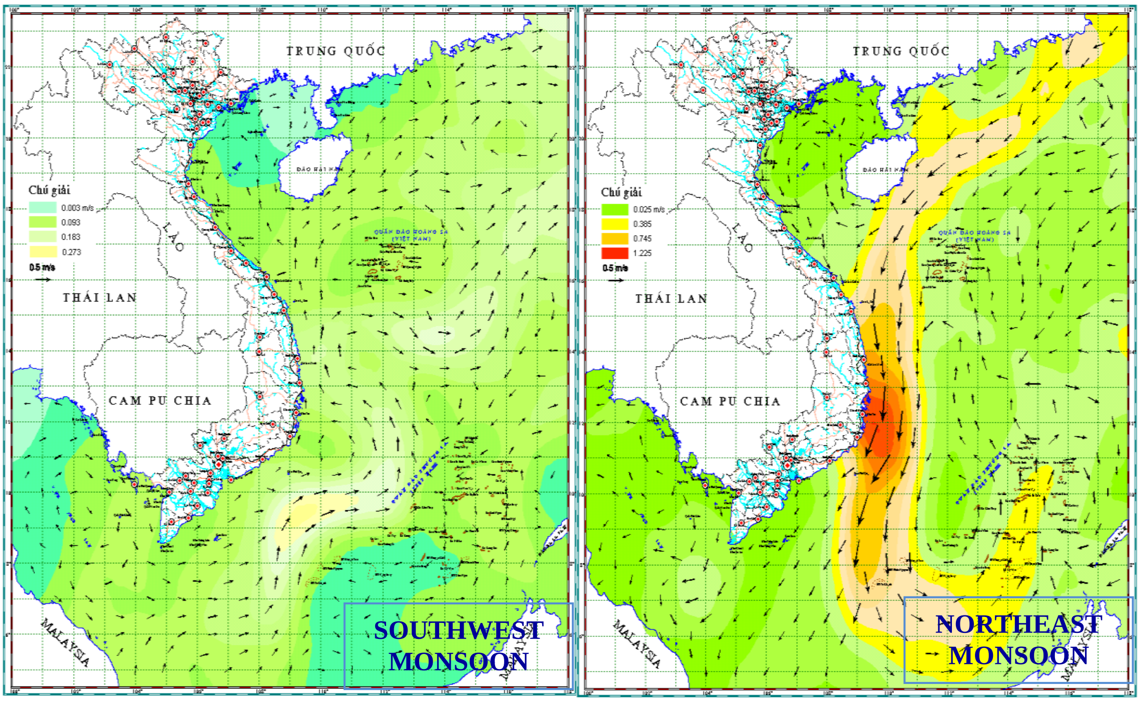

Figure 1: Water current flows of Vietnam sea water during the Southwest monsoon and the Northeast monsoon. *Source: RIMF, 2007.*

- **Fishing grounds**

Vietnam has five main fishing grounds namely the Gulf of Tonkin (I); the Central (II); the Southeast (III); the Southwest (IV) and the Spratly Archipelago (V). Of the five, three have trawlable fishing grounds: the Gulf of Tonkin, the Southeast and the Southwest areas (Figure 2). The trawler fleet is very diverse in size, the engine power and the gears used as well as the targeted species. Trawl fisheries is one of the main fishing industries in Vietnam. In 2001, trawl fisheries accounted for 30% of the total number of fishing boats in the gulf of Tonkin (Nguyen, 2001). The areas III and V are major fishing grounds for tunas (skipjack tuna, yellowfin tuna, bigeye tuna) which are the main targeted species of the gillnet and longline fleets.

Figure 2: Map of the five main fishing grounds (I, II, III, IV, V) of Vietnam.

- **Fishing efforts**

Accordingly, in the year 2008, the total number of the fishing boats of the Southwest area accounted for 12.3% of fishing boats of the whole nation. The number of fishing boats of all provinces situated in the Southeast area accounted for about 23.4% of the total number of fishing boats of the country. The main fishing gears are otter trawlers, gillnetters, purse seiners, longliners and handline for squids. Multiple gears are frequently operated in most fishing boats. The average engine power of the offshore fishing boat of Southeast and Southwest areas is 200 HP (DECAFIREP, 2009).

Trawlers are the most important for fisheries in both areas. Trawlers accounted for approximately 35.7% of the total number of fishing boats in the Southeast area and about 36.6% in the Southwest area (Figure 3). The second most important fleet are gillnetters which account for 23.4% total number of fishing boats (Southeast) and 31.9% of the number of fishing boats in the Southwest area. Boats operating with hooks and lines are approximately estimated to be 16% of the total number of fishing boats in both areas. The rest including various different gears used are about 20.4% and 12.0% of the total number of fishing boats in Southeast and Southwest areas respectively.

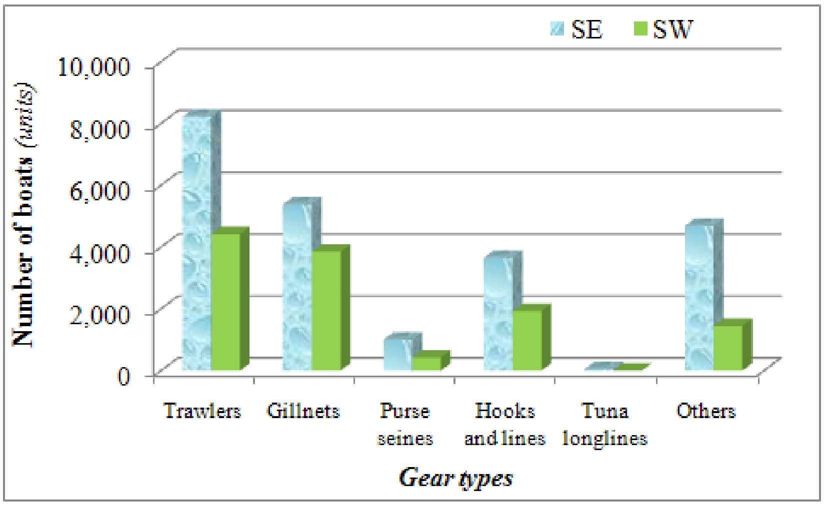

Figure 3: Number of fishing boats by main fishing gears used in the Southeast and the Southwest areas, Vietnam, in 2007.

- **Landing and catch rate**

Marine capture fisheries in Vietnam have grown considerably in landing as well as in fishing pressure in recent years. The estimated total annual landing in Vietnam is presently about 2,000,000 metric tonnes (MT); corresponding to 95,000 boats with total of 5,800,000 HP (GSO, 2008). The overall catch rate – CPUE (Catch per Unit Effort) of Vietnam marine capture fisheries shows a notable decrease in the recent decades. The mean CPUE (ton/HP/year) was estimated to be 1.0 (in the 1980s) and dramatically declined to about 0.3 in 2006 (Nguyen and Nguyen, 2008). The overall trend in fishing effort (HP), landing (MT) and CPUE of Vietnam marine capture fishery (all fishing gears) is shown in Figure 4.

According to GSO (2008), the total landing for the Southern part of Vietnam has almost doubled, from about 800,000 MT (1995) to approximately 1,300,000 MT (2007) (Figure 5). In 1995, total offshore fishing boats of the Southeast and the Southwest areas was 4,367 boats while it was 10,560 boats in 2007. The catch rate (CPUE) of the marine capture fishery in this area showed a dramatic decline as observed for overall fisheries. In 2001, the CPUE (MT/HP/year) was estimated to be 1.12 then it dramatically dropped to 0.57 MT/HP/year in 2007.

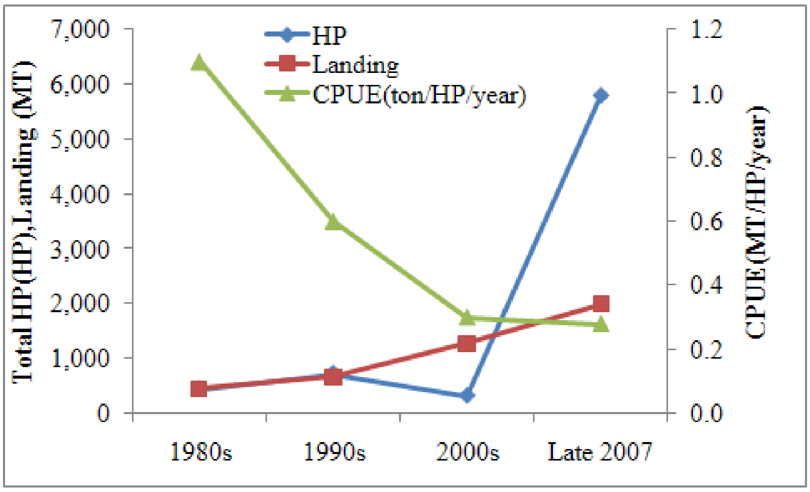

Figure 4: Overall trend in fishing effort (1000 HP), landing (1000 MT) and catch rate-CPUE(MT/HP/year) of Vietnam fishing industry during the last two decades.

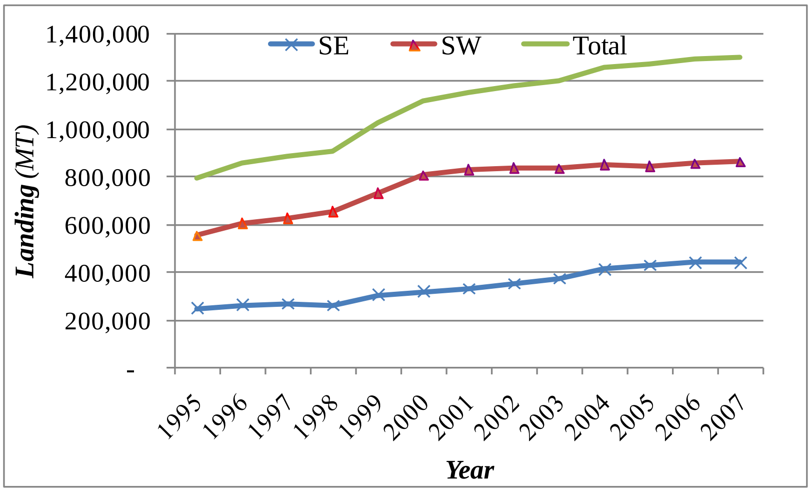

Figure 5: Landings of the Southeast and the Southwest areas during 1995 – 2007.

- **Fishery resources**

Located in a tropical area, the marine aquatic resource of Vietnam has a great number of species and high productivity. About 2,080 fish species have been identified, of which 130 fish species are considered as economically important species. Additionally, previous researches have reported that there are approximately 2,500 species of mollusc; about 1,600 species of crustaceans of which about 300 species are crabs; 77 species of shrimps and 8 species of lobsters. There are 18 species of cuttlefish and squid; 653 species of algae and 289 species of corals etc (Pham *et al.*, 2000; Bui *et al.*, 2001; Dao and Pham, 2003).

Most fish species have short life span, high growth rate and high natural mortality (Pham and Nguyen, 1997; Bui, 1999; Nguyen, 2005; Dang and Nguyen, 2007; Nguyen, 2008). The increased fishing efforts seem to have a seriously damaged the fish resources as well as their habitats in recent decades. Signs of overfishing have been noticed in number of papers such as a decline in catch rate of some important fishing fleets (Nguyen, 2005; Nguyen and Nguyen, 2005a; Chu *et al.*, 2006; Nguyen and

Nguyen, 2008). The high fishing pressure has affected the ability of the recovery of fish stocks (Rodwell and Roberts, 2004).

- **Survey history**

Research surveys on fisheries resources in Vietnamese waters have been carried out since the 1970s. Owing to the vast area and lack of research facilities including manpower, research capacity and budget, these surveys are neither consistent nor similar in specific objectives and research areas. Understanding in fish behaviours, schooling, migration and diet variation of fish stocks in Vietnam waters are really poor.

Assessments of fisheries potential in the Association of Southeast Asian Nations (ASEAN) countries mainly depend on bottom trawl surveys. The results of these surveys have mostly been used as reference points for managing the marine capture fisheries in many countries in the region (Gayanino *et al.*, 1997). For purpose of studying the long term dynamics of the fish stocks there is a need for collaboration among historians, fisheries biologists, ecologists, oceanographers and climatologists (Kenzie *et al.*, 2002). In the ASEAN region, study on fish stocks based on an ecosystem approach has been carried out e.g. in Thailand, using the model Ecosim with Ecopath (EwE) in order to evaluate different fisheries management objectives including maximizing economics, maximizing landed value (catch) or maximizing "ecosystem structure" (Christensen, 1998; Christensen and Walter, 2004).

Owing to the high diversity in species richness, managing the fisheries in Asian countries cannot be done with a "single species" framework. Moreover, fisheries managers need to understand the importance of taking into account fish assemblage structure in management decisions (Garces *et al.*, 2006). Researches on biological structures of the aquatic communities including phytoplankton, zooplankton (Gong and Xie, 2001; El-Otify, 2002; Berasategui *et al.*, 2006; Jyothibabua *et al.*, 2008), cephalopods (Bowerl *et al.*, 1999), fish and fish larvae (Rogers and Pikitch, 1992; Borges *et al.*, 2007; Isari *et al.*, 2008) and benthos (Vittor, 1997) have a relatively long history. Fish assemblages are normally studied in connection with biodiversity and their interactions with environmental variables (Cao *et al.*, 1999; Munne' *et al.*, 2003; Acar *et al.*, 2004; Mellina *et al.*, 2006; Selleslagh and Amara, 2008). A software package called: Two ways Indicator Species Analysis (TWINSPAN) has been widely applied in investigating the classification and ordination of fish communities in many waters (Acar *et al.*, 2004; Rawlinson *et al.*, 2005; Aguilar-Perera and Appeldoorn, 2008). Basically, the study on fish assemblages follows the cluster analysis principles with the main method of ward hierarchal cluster analysis. In the Asian area, some demersal fish communities of a number of countries have been analysed based on the data of bottom trawl surveys and applying TWINSPAN for analyses, such as Bangladesh, Philippines, Thailand, Malaysia (Garces *et al.*, 2006).

Several studies on fish communities of marine waters have been reported in Vietnam. However, most studies are on a small scale and in a very limited area. Some studies have focused on communities of coral reef-associated fish (Do *et al.*, 2008) and fish communities in some mangrove forests areas (Nguyen *et al.*, 2008). In the middle 1970s, under the collaboration with IMR , several acoustic surveys were implemented in the whole waters of Vietnam. Data on schooling behaviour of several fish stocks were collected and scrutinized based on echoes received from an Echo-sounder. Since that time, no study on fish assemblages in the larger areas of Vietnam has been implemented.

- **Fisheries management**

Presently, managing fisheries is a great challenge for the Vietnamese government. Marine capture fisheries is a small scale industry with a great number of small fishing boats, multiple gears used, discrete distribution of fishermen and a large number of poor fishermen. Pressure on livelihoods is one of the biggest difficulties the government has while applying the MCS (Monitoring Control and Surveillance) regime in the sector. A large number of fishing boats, particularly small fishing boats, are not registered, 65% in the Southeast area and 55% in the Southwest area (DECAFIREP, 2009). The statistical system of the fishing industry has not been working as a routine task, therefore time series data of fishing efforts, landings, fisheries economics etc. are not available. Additionally, the characteristics of multispecies and and a short life span and a high variability in fisheries resource also pose more challenges for driving the sector toward sustainability. Regulations on "input control" such as gear types and mesh size allowed, destructive fishing methods, and closed areas have been introduced to the sector. However, monitoring, control and surveillance as well as compliance are relatively weak.

3 MATERIALS AND METHODS

3.1 Data collection

Survey area

Seven bottom trawler surveys were carried out in the Southeast and Southwest waters in the period from 2000 to 2005. Four surveys were implemented during the Southwest monsoon season which occurs annually from May to September. The other three surveys were implemented during the Northeast monsoon that occurs from November to March. Due to the smaller area, the number of stations sampled in the Southwest water is relatively low, 16 stations, compared to 55 stations of the Southeast area (Figure 6).

In the southwest water, three depth strata make up totally an area of 77,830 km^2. The shallow water (20 - 30 m) is estimated at 18,400 km^2, the largest area is stratum in the depth zone 30-50 m which accounts for 31,350 km^2 and the rest is the offshore area, stratum of 50-100 m, estimated to be 28,080 km^2. The Southeast area is twice as large as the Southwest, about 172.620 km^2. The areas of the four depth strata of the Southeast area namely 20 - 30 m, 30 - 50 m, 50 - 100 m and 100 - 200 m are respectively 24,640 km^2; 68,120 km^2; 51,950 km^2 and 27,910 km^2. The number of sampled stations by strata and surveys is shown in Table 1.

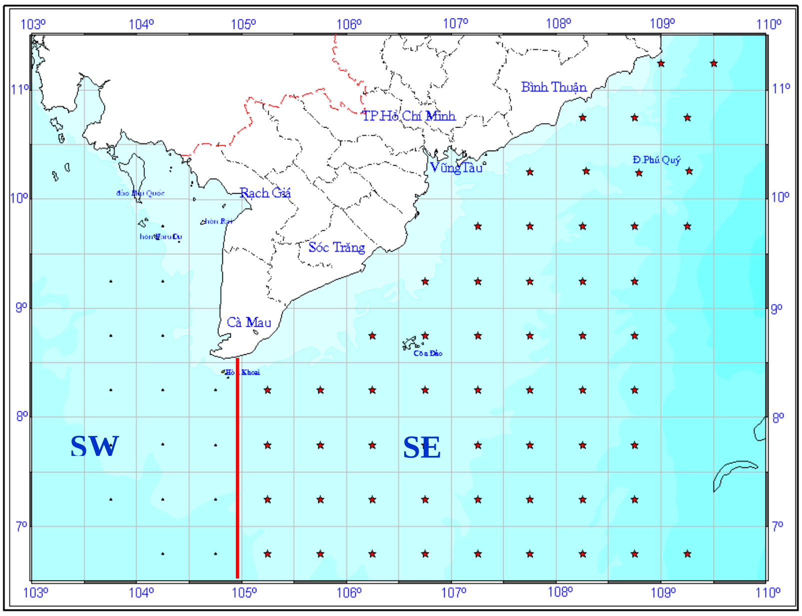

Figure 6: The fixed stations system used for the four bottom trawl surveys performed in the Southeast water (SE) and the Southwest water (SW) in Vietnam, during 2000 - 2005.

Table 1: Number of stations by strata and surveys conducted during the Southwest monsoon (SW) and the Northeast monsoon (NE) in the Southeast and the Southwest areas of Vietnam during 2000 - 2005.

Area	*Monsoon season*	*Survey year*	*Depth strata(m)*				*Total*
			20 - 30	30 - 50	50 - 100	100 - 200	
Southeast (SE)	***SW***	*2000*	2	25	20	9	56
		2002	3	24	19	9	55
		2004	6	22	20	8	56
		2005	5	20	18	10	53
	NE	*2000*	3	23	21	7	54
		2002	4	24	19	11	58
		2003	1	22	18	7	48
Southwest (SW)	***SW***	*2000*	5	6	5		16
		2002	5	7	4		16
		2004	7	6	3		16
		2005	6	7	3		16
	NE	*2000*	5	6	5		16
		2002	5	7	3		15
		2003	5	7	4		16

- ***Sampling vessel and gear used***

A commercial bottom trawler of 26 m in body length, and equipped with 500 Horse Power (HP) engine, Dongnam 05, was used to conduct all the surveys. Samples were collected with a commercial bottom trawl with the estimated horizontal opening of 11.6 m, 29.0 m length of head rope and 35 mm stretched mesh size of the cod-end. The detailed information of the technical diagram of the trawl used is presented in Figure 7. The average towing speeds used was 3.4 ± 0.02 knots. Normally, towing duration was one hour. The mean ratio between warp length (m) and the water depth (m) was approximately 4.3 ± 0.04: 1.

- ***Catch and biological data***

The total catch of each haul was sorted into commercial groups and species. For the high catch hauls, all large individual fish were firstly sorted out then weighted, counted and the length measured. For the rest of catch, sub-samples were collected afterwards and raising factors were used to calculate the total haul catches. Number and weight of each fish species caught were recorded in the survey forms. Biological data including sex ratio, maturation, stomach fullness and length frequency of the high commercially valuable species were given priority to analyse. Basically, samples were taken according to conventional sampling techniques for tropical fisheries (Sparre *et al.*, 1989).

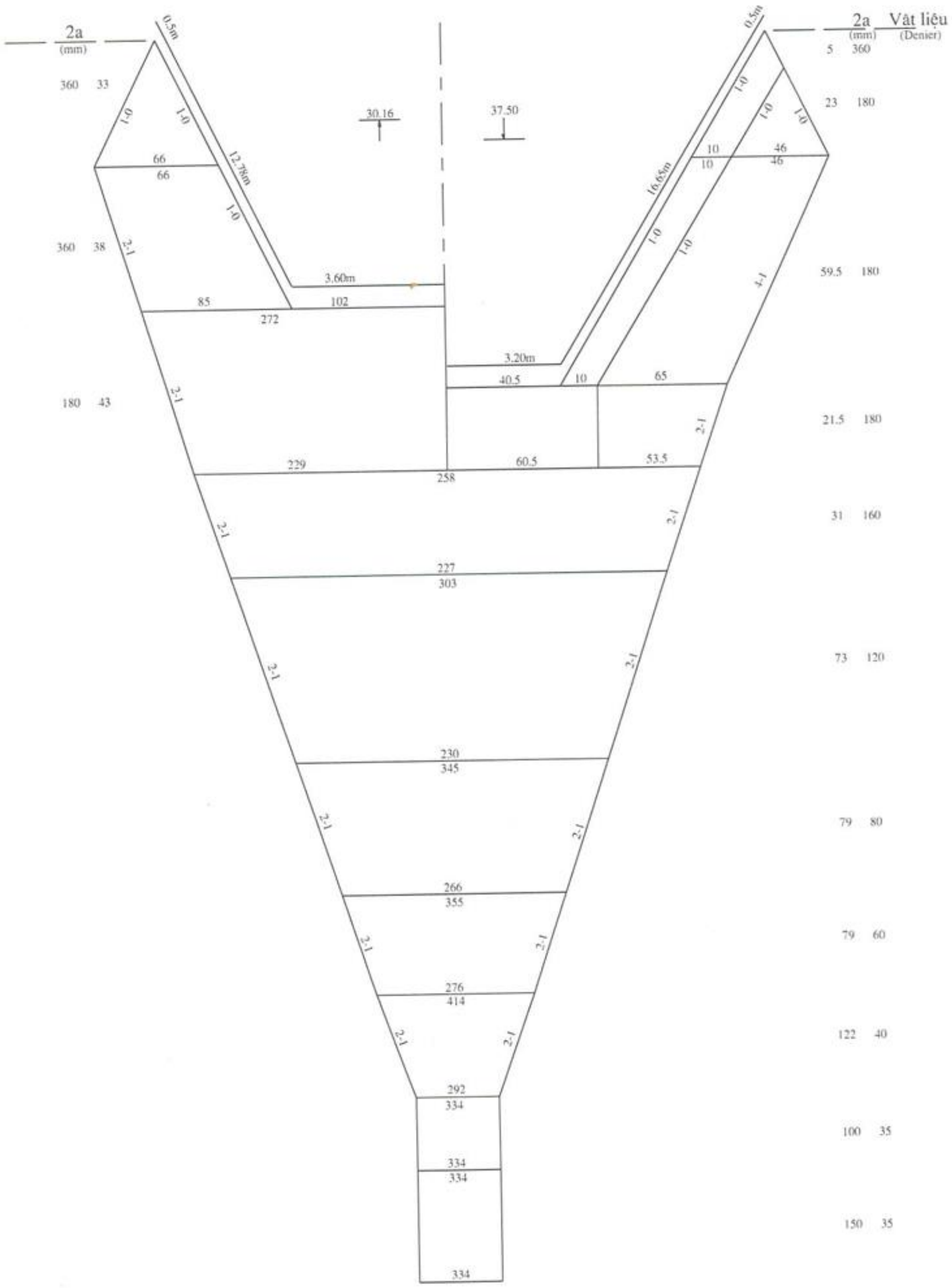

Figure 7: The technical draw of the sampling gear used for surveys performed in the Southeast and the Southwest waters during 2000 - 2005.

3.2 Methods and preliminary data analysis

3.2.1 Fisheries resource spatial distribution

Simple bubble maps are used to present the spatial distribution of the demersal fish resource based on the relative abundance index of each sampling haul and its corresponding coordinates. The contour maps of CPUA are made based on bivariate interpolation method (Akima, 1978; Akima, 2008). The base maps are plotted using the combination of packages "mapdata" (Becker *et al.*, 2009a) and "maps" (Becker *et al.*, 2009b) which are installed in R statistical packages. A mapping package, so-called "geo" that has been developed by Hoskuldur Bjornsson (2008) at the MRI in Iceland, was applied for generating bubble maps and density kriging maps.

In R, the setting of parameters for plotting density maps of fish abundance was as follows: variogram comprises of three components with values of sill =1, nugget = 0.02 and range = 50. The maximum number of neighbourhood points used to estimate for each kriging point was 12 or 12 stations. Number of data points was 45 knot. Thus all data points located in the range of 50 knots are taken into account for estimating the kriging values. The interval grid of survey station was 30 knots between stations along the same latitude, therefore, the maximum distance among the two closet stations was estimated around 45 knots. The initial levels of CPUAs set for kriging are < 200; 200 – 500; 500 – 1,000; 1,000 – 5,000; 5,000 – 10,000; 10,000 – 15,000 and > 15,000 kg/km^2. Corresponding to the levelscolour scheme was set. The fish abundance was graphically plotted and presented in a spectrum of colours.

3.2.2 Catch composition

Sampling catch is usually sorted then weighted and counted by species level. In analysing data, fish species were grouped and/or isolated based on given criterion. In this study, three main groups of fish in catches of the concern surveys are used including groups of economically important species (high and low economically important groups) and groups of ecologically sensitive species. These groups are here regarded as indicators which might be useful to apply for the adaptive fisheries management in tropical areas.

3.2.2.1 Definition of the economically important species

Normally, based on the fish size and commercial value, fish species are categorized into highly commercial species and low economically valuable ones. Vietnamese fishermen use a simple definition of their landings as an exported fish group,a mixed fish group and "trash fish". Here fish species are classified as commercial fish based on the market prices and fish size captured. Then sampled fish species are sorted and grouped by these two categories in each station catch. The estimates of the mean values of these groups are basically following the stratified method shown in 3.2.4.

3.2.2.2 Definition of the ecologically sensitive species

In this study, ecologically sensitive species are sorted on the basis of references from previous researches and regional publishes, especially information reported by FISHBASE. All fish species that have high trophic level, long life span, slow growth rate and low fecundity are considered "ecologically sensitive species". In the tropical area, particularly in Vietnamese waters, ray, stingray, bamboo-shark, carpet shark, pale-edged stingray etc are considered ecologically sensitive. (Dang and Nguyen, 2007; Nguyen, 2008).

3.2.3 Diel variation

The fish diel migration behaviour is analysed using the relative catch rate of sampling hauls. In this study, all samples were taken during the day time, i.e. from 6am to 6pm. Samples were categorized as "morning hauls" and "afternoon hauls". Samples taken during 6 am to 12 o'clock were considered morning hauls. The hauls towed during 1 pm to 6 pm as afternoon hauls. Mean value of overall catch rates were analysed with respect to sampling time whether there was a difference between morning and afternoon catch rates. The two-way ANOVA is applied to evaluate the influence of time and depth zone (spatial factor) on the relative abundance index of the fish stocks.

3.2.4 The relative abundance index (CPUA)

3.2.4.1 Calculation of CPUA

Catch per Unit Area - CPUA is used as a measurement of the relative abundance index in this study as a catch (kg) per one square kilometre (km^2) swept area of the sampling trawl. Normally, the haul duration is one hour in most surveys. During sampling operation some hauls were towed longer or shorter than usual duration. The towing speed is also not always stable because of certain circumstances including water current, topography condition, wind and wave condition etc. Therefore, the calculated CPUA was standardized in the following way:

$$CPUA_i = \frac{Catch_i}{Ai} \qquad \text{(eq.1)}$$

$$A_i = 1.852 * v_i * t_i * 11.6 * 10^{-3} \qquad \text{(eq.2)}$$

<u>*Where*</u>: $CPUA_i$ (kg/km^2) is the catch per area of stations i;
$Catch_i$ is total catch (kg) of the station i;
A_i is the corresponding swept area (km^2) of that station
v_i is the towing speed (knot) of the station i;
t_i is the towing duration (hour) of haul i.

Swept area of station i is depended on the towing speed v_i (knots) and towing duration t_i (hour) and the opening width of the gear. The opening width of the trawl is estimated equal to 11.6 m or 11.6 $*10^{-3}$ km. In order to estimate the swept area in square kilometres (km^2), a conversion ratio in the measurement system of length units between nautical miles and kilometres is applied as one knot equals to 1.852 km.

Estimates of CPUAs mainly follow the descriptive statistics; "box plot" is applied to describe the distribution of observed values and mean values based on suggestion of Tukey (Tukey, 1977). Due to minimize the noisy (Gimona and Fernandes, 2003) and/or effect of the extremely high values of sampling hauls (Pauly, 1983; Pape *et al.*, 2007) and to satisfy the assumption of ANOVA (Myers and Pepin, 1990; Prenal *et al.*, 1999), logarithm function is applied for transforming data. Two-way ANOVA is used for comparing mean values of the relative abundance index between surveys and strata to see if there is a statistically significant difference.

3.2.4.2 Stratified estimates

Mean values of the relative abundance index and biodiversity indices are calculated as stratified. A given index of the whole area is estimated by using weighting factors based on the area of each stratum in proportion to the total area. Each index of the total area is calculated as follows:

$$Index_i = \sum_{j=1}^{k} p_{j} \cdot \overline{Index_j} \quad \text{(eq.3)}$$

And $$p_j = \frac{A_j}{A} \quad \text{(eq.4)}$$

Where $Index_i$ is the total index (CPUA, H', D or J') for the whole area; j = 1, 2…, k, is the number of strata of the survey area. p_j is proportion of the area of that stratum to total area. And $\overline{Index_j}$ is mean value of the index estimated for the stratum j. A_j is the area of stratum j, A is the total area of the survey.

3.2.4.3 Box plots

A box plot technique is applied to present the variation of the relative abundance index of the demersal fish resources as described by Tukey (1977). Normally, median value is presented in dendrogram of box plots, however, mean value can be presented optionally or not (Tukey, 1977). The box is limited by the first quartile and the third quartile values. Then, the inner fences are defined by the first quartile minus 1.5 times interquartile range (IQR) or so-called lower inner fence and the third quartile plus 1.5 * IQR (upper inner fence). Similarly, the outer fences of a box plot are also comprised of lower outer fence (1^{st} quartile – 3*IQR) and upper outer fence (3^{rd} quartile + 3 *TQR). The moderate outliers are values in range between inner fences and outer fences while extreme values are located outside outer fences. The detailed description of values and definitions are described graphically in Figure 8.

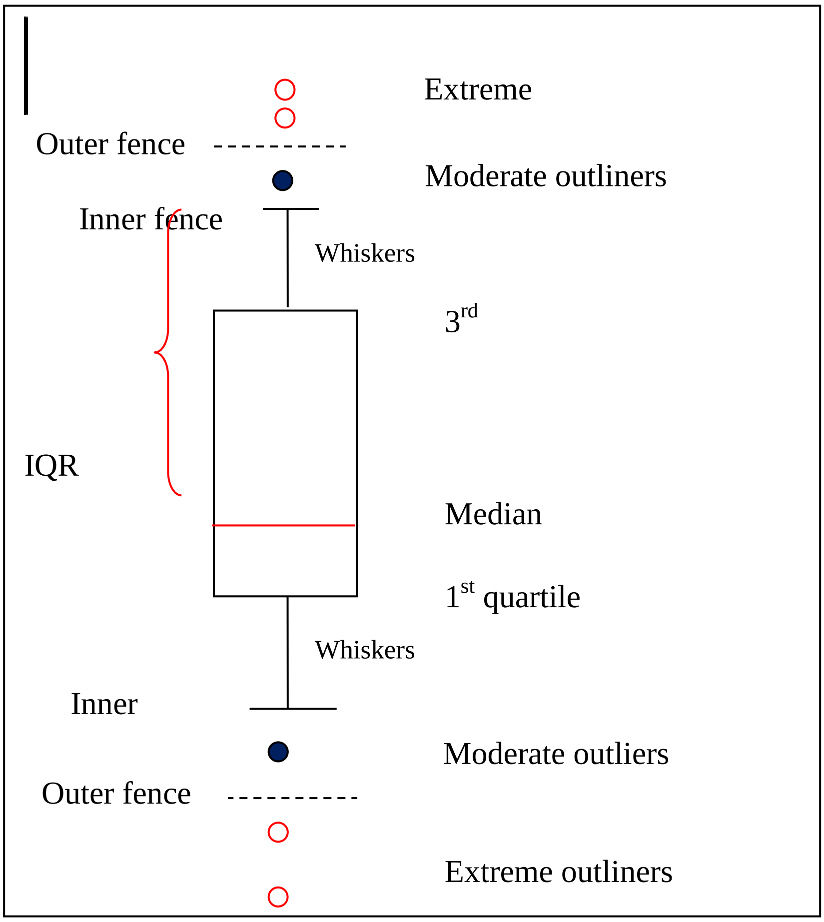

Figure 8. Description of diagram of boxplot with main attributes and parameters.

3.2.5 Biodiversity indices

A number of studies using bottom trawl survey data to assess the biodiversity and to analyse spatial structure and temporal changes in fish assemblages has been done (Allen and Herbinson, 1989; Cryer *et al.*, 2002; Goza'lez and Sa'nchez, 2002; Madurell *et al.*, 2004; Saitoh *et al.*, 2008). In this study, data sources of seven bottom trawl surveys conducted during different monsoon seasons are used to analyse the biodiversity of the demersal fish stocks in two important fishing grounds of Vietnam, namely the Southeast and Southwest waters.

Estimates of biodiversity indices are so-called α-diversity; integrating or individual species level which have context-free syntactic information and have unclear ecological meaning. This differs from, β-diversity or compositional diversity which is normally in space such as heterogeneity in the widest sense; spatial dependence, spatial autocorrelation and configurationally diversity. This approach takes into account the differences in ecological factors, e.g. biotic and abiotic elements. Measures of diversity are frequently seen as indicators of the wellbeing of ecological systems.

In this paper, some basic biodiversity indices are estimated as indicators of the demersal fish communities distributed in the Southeast and Southwest waters of Vietnam. No interaction between abiotic environmental factors and fish community are studied. Thus the emphasis is to evaluate single indicators rather than to investigate the possible linkages existing in the ecosystem.

- **Shannon - Wiener index**

The biodiversity index was estimated based on the method named Shannon – Weiner (1949) and it was estimated as the follows:

$$H' = -\sum_{i=1}^{s} p_i * log_2 p_i \qquad \text{(eq.5)}$$

Where: H' is the value of Shannon – Weiner index of diversity
pi is the proportion of species i in total catch, biomass or number.
ln is natural logarithmic function
s is the number of species encountered in the community
∑ is mathematical function meaning "the sum of"

Shannon and Weiner index (H') is based on randomly sampling individuals from an independently large population. Additionally, it also assumes that all the species are represented in the sample. Logarithm base 2 is normally used to estimate the index H', nevertheless, any log base can be used. Shannon-Weiner index is a very widely used index for comparing diversity between various habitats (Clarke and Warwick, 2001). The higher the value of H' the more diversity of the habitat and the higher H' value also indicates the increased sustainability of the community or implying a more sustainable ecosystem.

- **Species richness (Margalef index)**

Margalef developed and suggested using an index to measure the species richness of a community in 1957 (D.A. Crossley *et al.*, 1973; Ekpenyong, 2000; Jyothibabua *et al.*, 2008). It is calculated from the total number of species present and the abundance or total number of individuals. In general, the higher the index value the greater the diversity. However, this index is very sensitive to sample size.

$$D = \frac{S-1}{\ln(N)} \qquad \text{(eq.6)}$$

Where: D is the value of Margalef index of species richness,
S is the number of species encountered;
N is the number of individuals

- **Pielou's evenness index (J')**

There are number of indices to assess the evenness of a community, for instances, some suggestions issued by Sheldon (Sheldon, 1969) and Hill (Hill, 1973). However, the most commonly used evenness index is Pielou's index (Heip, 1974). This index was proposed by the Pielou (Pielou, 1966) and the index is estimated using the following formula:

$$J' = \frac{H'}{ln(S)} \qquad \text{(eq.7)}$$

Where: ln(S)= H'max, therefore, this equation (eq.7) can be re-written as below

$$J' = \frac{H'}{H'_{max}} \qquad \text{(eq.8)}$$

The value of J' is in range from 0 to 1. The community is at perfect evenness when it equals to 1 and the maximized value indicates that all the species have the same number of individuals.

3.2.6 Cluster analysis

Cluster analysis is a multivariate method which aims to classify a sample of subjects (or objects) on the basis of a set of measured variables into a number of different groups. Generally, cluster analysis can be divided into two main methods as hierarchical methods and non-hierarchical methods. Hierarchical methods involve constructing a tree of clusters in which the root is a single cluster containing all the elements and the leaves each contain only one element (Pollard and Laan, 2005). Hierarchical methods include two groups of methods as follows:
-Agglomerative methods: Subjects start in their own separate cluster. The two "closest" or the most similar clusters are then combined and this is done repeatedly until all subjects are in one cluster. Finally, the optimum number of cluster is chosen out of all cluster solutions.
-Divisible methods: All subjects start in the same cluster and the above strategy is applied in reverse until every subject is in a separate cluster. Agglomerative methods are used more often than divisive methods, so this report will concentrate on the former rather than the latter.
Hierarchical cluster analysis consists of a number of different methods such as nearest neighbour method (single linkage method), furthest neighbour method (complete linkage method), average (between groups) linkage method, centroid method and Ward's method. Some more detailed description of these methods are presented as follows:
-Nearest neighbour method: the distance between clusters is defined to be the distance between the two closet members or neighbours. This method is preferred in cases where the natural clusters are not spherical or elliptical in shape.
-Furthest neighbour method: in this case the distance between two clusters is defined to be the maximum distance between members, i.e. the distance between the two subjects that are furthest apart.
-Average (between groups) linkage method (sometimes referred to as UPGMA-Unweighted Pair Group Method with Arithmetic Mean): the distance between two clusters is calculated as the average distance between all pairs of subjects in the two clusters. This is considered to be a fairly robust method.
-Centroid method: here the centroid (mean value for each variable) of each cluster is calculated and the distance between centroids is used. Clusters whose centroids are closest together are merged. This method is also fairly robust.
-Ward's method: in this method all possible pairs of clusters are combined and the sum of the squared distances within each cluster is calculated. This is then summed up over all clusters. The combination that gives the lowest sum of squares is chosen. This

method tends to produce clusters of approximately equal size, which is not always desirable. It is also quite sensitive to outliers. Despite these shortcomings, it is one of the most popular methods, along with the average linkage method.

Cluster analysis has been applied in fish community research. A number of papers have been published that mention it as useful tool in study on fish assemblages e.g. (Ungaro *et al.*, 1998; Madurell *et al.*, 2004; Berasategui *et al.*, 2006; Garces *et al.*, 2006; Borges *et al.*, 2007; Unsworth *et al.*, 2007; Jyothibabua *et al.*, 2008). The cluster analysis consists of different methods such as cluster rows, cluster columns and additive trees (Wilkinson et al., 2004). The differences in fish assemblages are assumed to differ from fish habitats and their behaviours including shoaling, schooling and diel variation.

Normally, the hierarchical cluster method is applied to investigate the fish assemblages (Guti, 2006). In this study, hierarchical cluster analysis following Ward's method is applied aiming to classify the structure of the demersal fish stock of the Southeast and Southwest waters during different monsoon seasons. Accordingly, this is a fairly popular method used in many fields (Dolnicar, 2003). For data that shows modal relationships such as ecological data, the Sørenson (Bray-Curtis) distance is a better descriptor of similarity (Holland, 2006). Average fish abundance (CPUA(kg/km^2) of the four Southwest surveys and three Northeast surveys are used as input data for analysis.

Due to the huge number of fish species, the data of fish abundance in each survey is sorted by family. Families have occurrence frequency of more than 5% and/or account for over 1% of total abundance estimates included in the cluster analysis. In order to have attributes contribute more equally to the similarities among objects, data need to be transformed (Romesburg, 1984). The data of number of individuals of each fish family encountered by stations was the fourth root transformed to minimize the tail distribution or skewness. Examples for distribution of data before and after transforming and scaling to mean zero and variance unit are presented in Figure 8. Assume that we have a data matrix X(i,j) with n attributes that are subscripted i = 1, 2…., n; and t objects subscripted t = 1, 2…, t. Therefore, in the data matrix, the corresponding value in standardized data matrix of X_{ij} is denoted Z_{ij}. The standardizing function used is presented below:

$$Z_{ij} = \frac{X_{ij} - \overline{X_i}}{S_i} \qquad \text{(eq.9)}$$

where

$$\overline{X_i} = \frac{\sum_{j=1}^{t} X_{ij}}{t} \qquad \text{(eq.10)}$$

and

$$S_i = \left(\frac{\sum_{j=1}^{t} \left([\![X_{ij} - \overline{X_i} \right)]\!]^2}{t-1} \right)^{\frac{1}{2}} \qquad \text{(eq.11)}$$

The distance measurements following the “correlation” and “Bray-Curtis” methods are used to estimate the distances among clusters. The packages “cluster”(Maechler, 2009) and “vegan” (Oksanen *et al.*, 2008) is applied in R software to do these analyses. Additionally, the package “pvclust” developed by Suzuki (2006) is used for providing p-values for hierarchical clustering based on multiscale bootstrap resampling. The approximately unbiased (au) p-values and bootstrap probability (bp) value are computed. The high p-values indicate the significance of the two clusters analyzed (Suzuki and Shimodaira, 2006).

The histograms of CPUAs of the four most abundance families sampled in the four Southwest monsoon surveys are presented in Figure 9. They are transformed using the fourth root square and untransformed (raw values) data are graphically described. Obviously, the transformed data show a better fit for relative “normal distribution” compared to the original data. High variations are observed in most fish families sampled in the Southwest monsoon surveys, especially leather jacket (Monacanthidae), squid (Loliginidae) and lizard fish (Synodontidae).

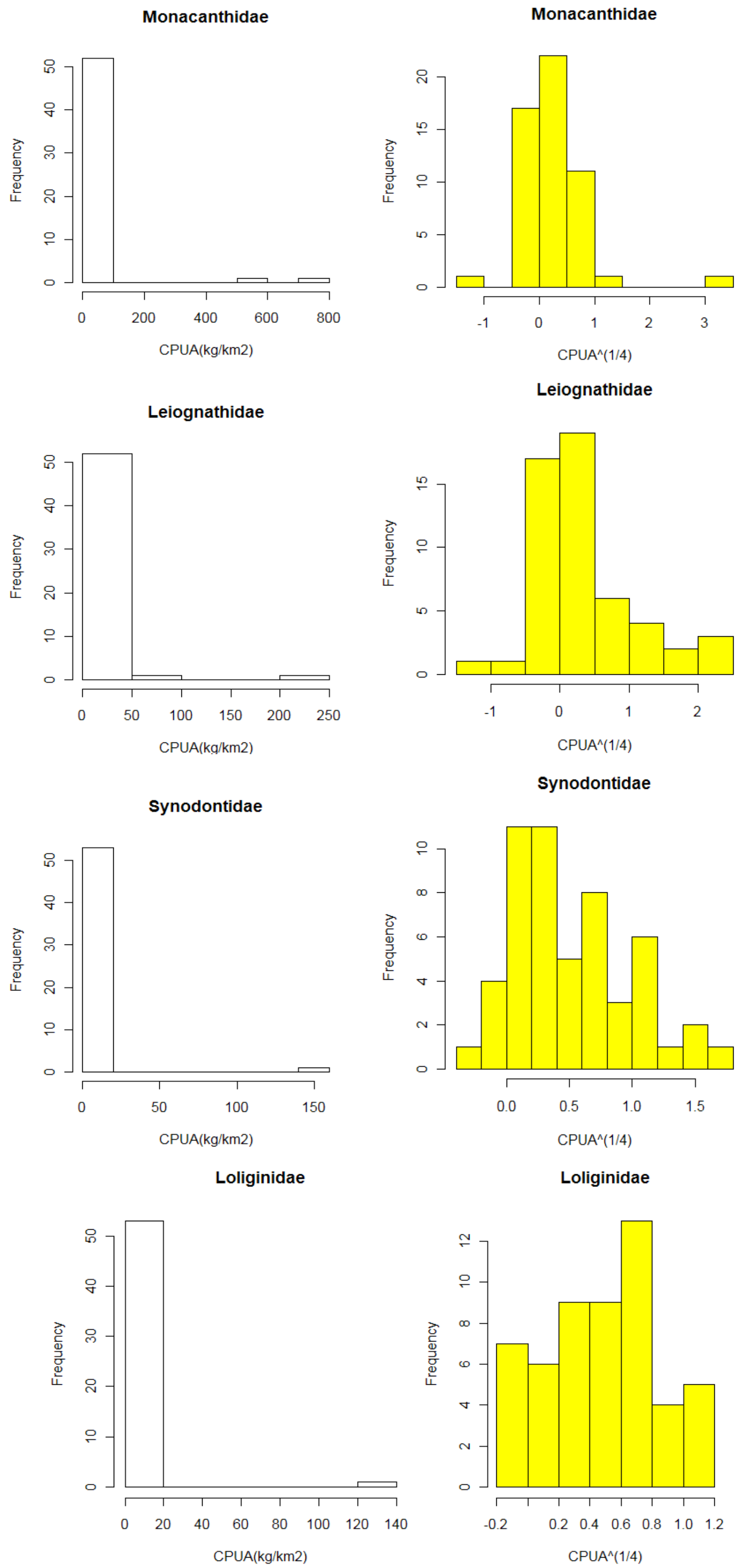

Figure 9: Distribution of the Catch per uniet area (CPUA(kg/km^2) before and after transforming to fourth root square and standardized to mean 0 and variance 1.

4 RESULTS

4.1 Spatial distribution of the demersal fishery resource

- **Southwest monsoon**

Bubble plots of the CPUA of the four surveys conducted in the Southeast and the Southwest waters of Vietnam are presented in Figure 10. A relatively high variation in catches of sampled hauls was observed in the first survey in the year 2000. Generally, a relatively low variation in CPUA in the shallow waters (less than 50 m depth) was observed in most surveys except for a few stations with fairly high catch rates. The general pattern of the CPUA in the Southeast and the Southwest waters is a relatively low mean catch rate in the shallow water and high catch rates in offshore water (more than 50 m depth), especially in the stratum of 100 – 200 m depth. No high variability in CPUA distribution over time was observed during the Southwest monsoon surveys in the survey period.

- **Northeast monsoon**

In the cold season, the Northeast monsoon during 2000 - 2003, a somewhat higher variation in catch rates was observed in the shallow water compared to the Southwest monsoon surveys (Figure 11, 12). Similar to the Southwest monsoon surveys, higher catch rates were observed offshore to the east and in the stratum of 100 – 200 m depth in the Southeast water. However, high catch rates were also observed in the Southern and offshore in the Southwest water. In general, the high CPUAs were observed southward of the Southeast water and also in offshore water in the Southwest water while no high catch rate were observed in the Southwest water during the Southwest monsoon.

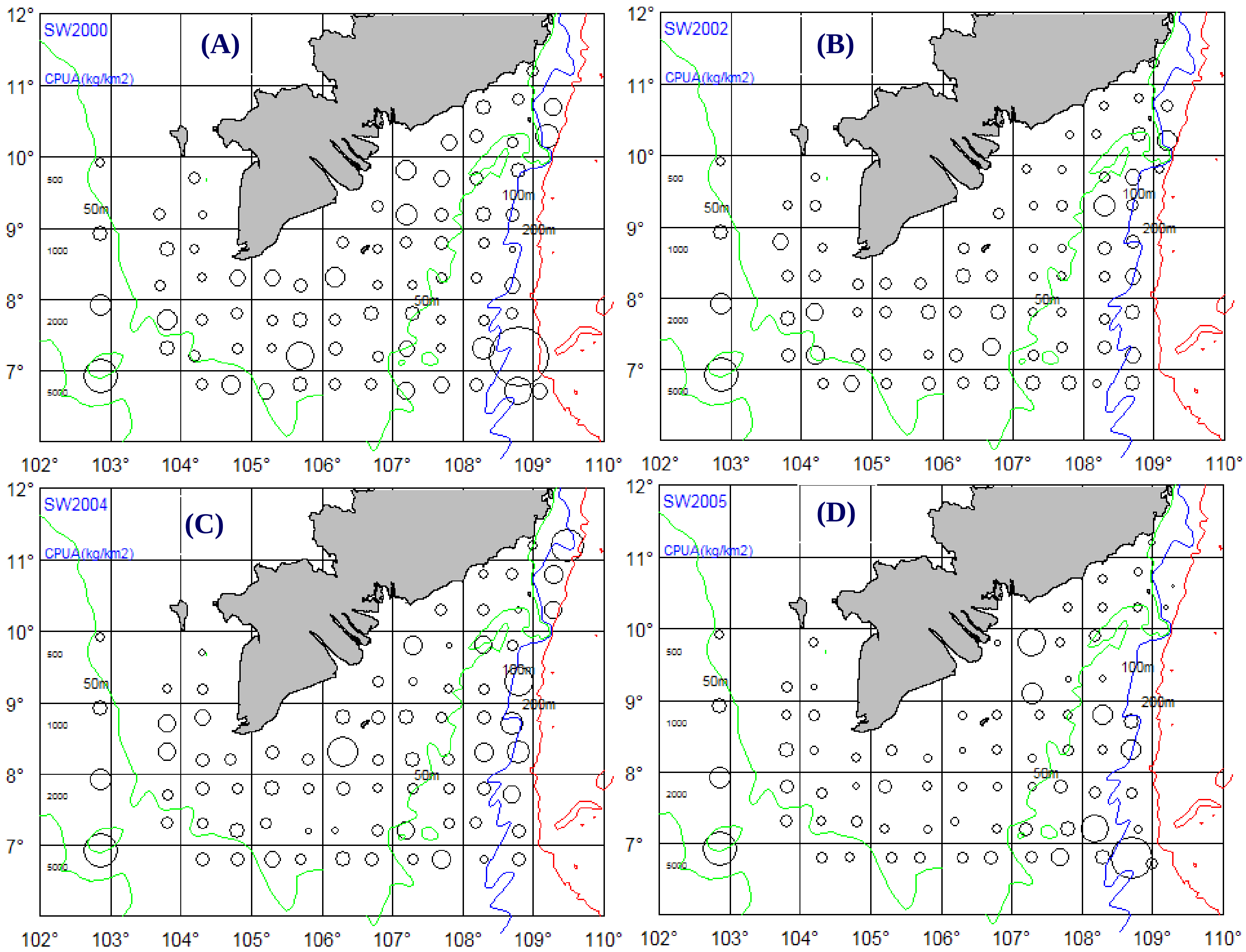

Figure 10: Spatial distribution of the demersal fish resource of the Southeast and the Southwest areas, Vietnam, based on the relative abundance index (CPUA(kg/km^2)), monitored by bottom trawl surveys performed in the Southwest monsoon during 2000 – 2005.

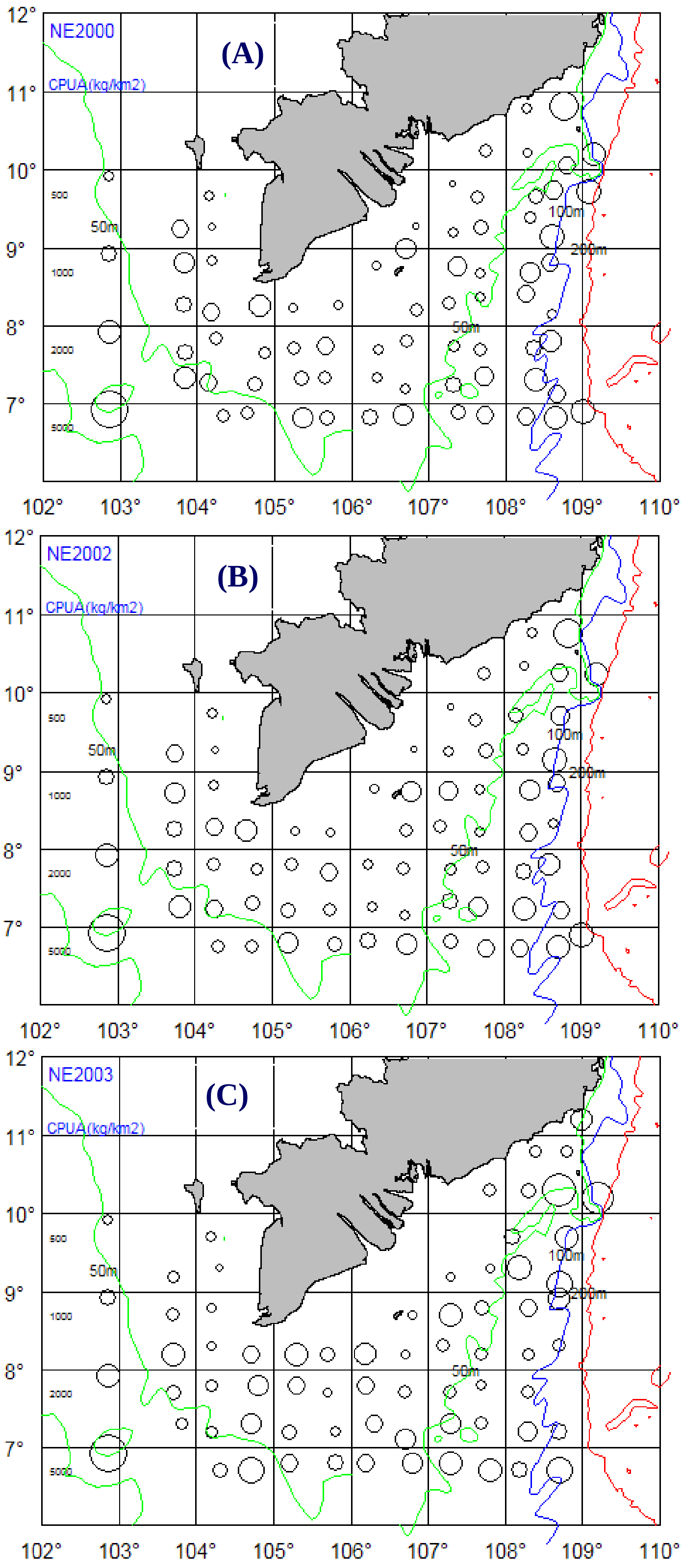

Figure 11: Spatial distribution of the demersal fish resource of the Southeast and the Southwest areas, Vietnam, based on the relative abundance index (CPUA(kg/km^2)), monitored by bottom trawl surveys performed in the Northeast monsoon during 2000 – 2003.

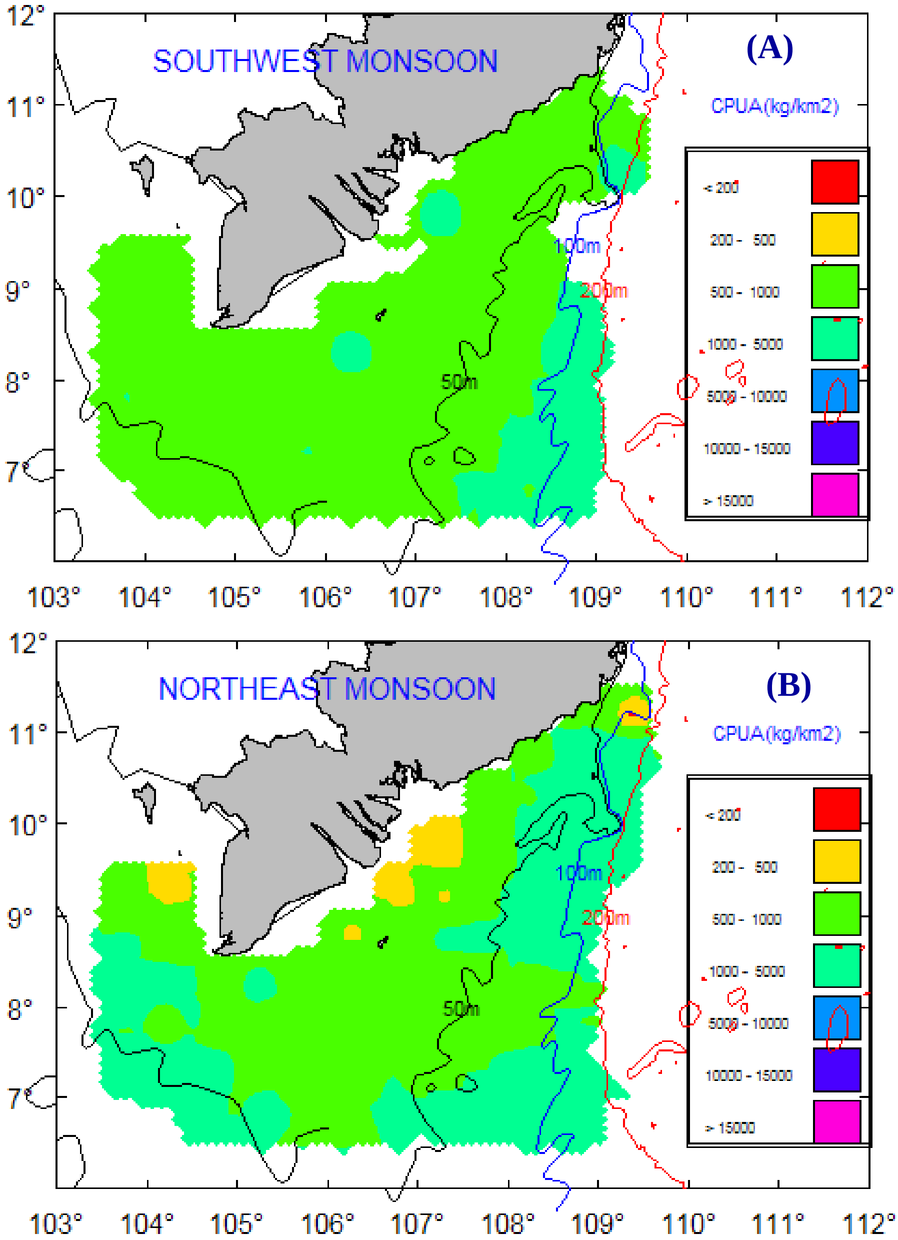

Figure 12: Spatial distribution of the relative abundance index (CPUA(kg/km^2)) of the demersal fish stock of the Southeast and the Southwest areas, Vietnam, based on kriging technique, monitored by bottom trawl surveys performed in the southwest (A) and the northeast (B) monsoons, 2000 – 2005.

- **Contour maps**

Contour maps of the overall demersal fish abundance of the Southeast and the Southwest areas showed the same pattern in spatial distribution of the fisheries resources in the surveyed waters. The higher fish density area makes the higher value of the contour of the fish relative abundance index, CPUA (kg/km^2). The survey has more stratified values of CPUAs giving a different number of contours. Contour maps of the demersal fish stock distributed in the Southern water of Vietnam measured by surveys are presented in Annex 2. The number of contours and their corresponding values of CPUAs are graphically described in the maps.

4.2 4.2. Catch composition

- **Number of fish species**

The number of fish families and species identified in the surveys in the Southeast and the Southwest waters of Vietnam is shown in Table 2. The number of fish families in the Southeast area fluctuated from 99 to 112 while the number of species varied from 225 to 295. The Southwest water has a relatively smaller area compared to the Southeast water, so the numbers of fish species and families are lower. In total, 130 – 160 fish species belonging to 64 -72 families were identified in the Southwest water (Table 2). No significant seasonal difference in the number of fish families in both the Southeast and the Southwest waters was observed.

Table 2 : Number of family and species identified by surveys and monsoon seasons in the Southeast and the Southwest waters of Vietnam based on the bottom trawl surveys implemented during 2000 – 2005.

Monsoon seasons	***Year***	***The Southeast water***		***The Southwest water***	
		Family	Species	Family	Species
The Southwest	2000	108	279	64	137
	2002	112	263	70	152
	2004	110	295	67	152
	2005	99	237	72	162
The Northeast	2000	107	243	70	151
	2002	110	255	70	139
	2003	94	225	68	157

- **The Southeast water**

The most abundant fish species grouped by family in catches of the seven surveys in the Southeast water showed opposite trends in catch composition (%) (Table 3). The less economically valuable species were becoming more dominant during the survey period while important economic species were decreasing. This is pronounced,especiallyfor Ponyfish, Crested flounders (Samaridae) and Soles (Soleidae) which are normally considered as less economically important fishes and are sorted as "trash fish" in most trawl fisheries of Vietnam. The survey results showed that these species have increased as part of the catch proportion. Ponyfish and Soles accounted for almost 9% and 7% respectively of total catch of the last survey conducted in the year 2005 compared to 0.2% and <<0.1% in the year 2000 respectively.

The most important commercial species showed a decline in their catch proportion (%) in these four surveys. Some fish families showed a rapid reduction of their abundance in survey catches including Goatfish (Mullidae), Ray (Dasyatidae) and Snapper (Lutjanidae) etc… (Table 3).

Table 3: Catch composition (%) of the most abundance fish families monitored by bottom trawl surveys implemented in the Southeast area of Vietnam, the southwest monsoon, 2000 – 2005.

Importance	***Family name***	***2000***	***2002***	***2004***	***2005***	***Note***
Low Economically Important Species	Apogonidae	0.1	0.5	0.5	0.6	*
	Cynoglossidae	0.1	0.2	0.1	0.3	*
	Leiognathidae	0.2	1.5	7.4	8.9	**
	Samaridae	0.2	0.9	0.4	4.3	**
	Rajidae	0.5	1.5	0.5	0.5	*
	Soleidae	0.0	0.2	0.0	7.1	**
	Scorpaenidae	0.2	0.8	0.8	0.4	*
	Tetraodontidae	0.9	1.2	1.7	1.7	**
High commercially Important Species	Carangidae	4.7	4.6	5.1	5.2	*
	Dasyatidae	1.1	0.9	1.8	0.3	##
	Lethrinidae	0.1	0.4	0.9	0.2	#
	Loliginidae	5.4	10.9	9.0	9.2	#
	Lutjanidae	0.4	0.9	1.4	0.5	#
	Nemipteridae	4.5	5.2	4.0	3.2	#
	Portunidae	2.6	3.4	3.0	2.1	#
	Priacanthidae	2.9	10.8	4.3	19.9	**
	Sciaenidae	0.1	0.1	0.1	0.0	#
	Serranidae	0.2	0.4	0.4	0.1	#
	Synodontidae	10.3	13.1	11.3	9.1	#
	Trichiuridae	0.2	0.3	0.4	0.0	#
	Mullidae	4.0	6.9	7.2	1.9	##
Total		***38.7***	***64.7***	***60.3***	***75.5***	

*Note: * denotes the increasing, ** significant increasing, # decreasing and ## denotes the considerable decreasing.*

Similarly, the Northeast monsoon surveys conducted in this area showed the same pattern in terms of changing in catch composition of economically important species. Ponyfish, (Apogonidae) and Pufferfish (Tetraodontidae) became more abundant while Carangids (Carangidae), Snapper (Lutjanidae), Lizardfish (Synodontidae) and Largehead hairtail dropped in proportion in the catches (Table 4). The economic important group includes Cephalopods e.g. squid (Loliginidae) and Cuttelfish (Sepiidae) particularly.Squid are a fast growing species and their life span is normally less than 1.5 years. Therefore, this resource can be recovered relatively quickly from high fishing pressure.

Table 4: Catch composition (%) of the most abundance fish families monitored by bottom trawl surveys implemented in the Southeast area of Vietnam, the northeast monsoon, 2000 – 2003.

Importance	***Family name***	***2000***	***2002***	***2003***	***Note***
Low	Apogonidae	0.9	0.4	2.7	**
Commercially	Leiognathidae	1.3	3.9	2.6	**
Important	Monacanthidae	4.8	1.5	1.6	##
Species	Samaridae	0.4	0.3	0.8	*
	Tetraodontidae	1.1	1.0	2.1	**
High	Carangidae	7.5	11.2	3.2	##
Commercially	Dasyatidae	0.3	4.4	2.4	-
Important	Loliginidae	5.6	5.5	8.2	*
Species	Lutjanidae	2.2	0.6	0.7	##
	Mullidae	9.9	11.2	8.5	#
	Nemipteridae	7.4	4.4	6.7	#
	Portunidae	1.8	3.6	2.1	#
	Priacanthidae	7.7	8.8	8.2	-
	Sepiidae	9.0	5.8	6.9	#
	Synodontidae	17.0	12.4	14.4	##
	Trichiuridae	1.8	0.6	0.7	##
Total		***78.7***	***75.6***	***71.9***	

*Note: * denotes the increasing, ** significant increasing, # decreasing and ## denotes the considerable decreasing.*

- **The Southwest water**

In the Southwest water, Ponyfish and Pufferfish showed a relatively high abundance in catches most of the surveys conducted during both monsoon seasons. In the Southwest monsoon surveys, Ponyfish ranged from 5 to 12% of the total catch sampled and Pufferfish accounted for 4 to 14% (Table 5). Pufferfish are not allowed to fish, to transport and or to sell commercially in Vietnam as they are poisonous. As observed in the Southeast area economically important species tended to decrease in catches of the seven surveys. For instances, the numbers of fish species belonging to the following families: Carangids, Squid, Cuttelfish, Nemipterids, Croacker (Sciaenidae) and Lizardfish had been substantially dropped in their catch composition in the period from 2000 to 2005 (Table 5). Squid, Cuttelfish and Nemipterids showed a considerable decline in their catch compositions during the Northeast monsoon surveys implemented in the period from 2000 to 2003 (Table 6). Additionally, the dominances in catches of Ponyfish, Pufferfish and Apogon in the Southwest area are also shown in Table 6.

The summary results of the changes in abundance of the two groups, highly commercially important species and low commercially important species are graphically presented in Table 7. The green colour indicates the increase in fish abundance while the red colour describes the decline in CPUA of these groups during the survey period.

Table 5: Catch composition (%) of the most abundance fish families monitored by bottom trawl surveys in the Southwest area, the southwest monsoon, 2000 – 2005.

Importance	Family name	*2000*	*2002*	*2004*	*2005*	*Note*
Low commercially important species	Apogonidae	2.3	2.9	1.1	1.9	#
	Tetraodontidae	3.7	4.9	13.9	9.2	**
	Leiognathidae	6.7	5.4	12.5	6.2	**
	Mullidae	1.0	5.3	1.9	2.2	*
High commercially important species	Carangidae	11.7	8.0	3.9	4.5	##
	Clupeidae	2.5	0.2	0.2	0.0	##
	Dasyatidae	1.1	4.1	1.4	2.3	#
	Loliginidae	14.1	11.4	10.9	13.7	#
	Lutjanidae	0.4	0.7	1.2	0.5	*
	Nemipteridae	6.5	7.3	4.2	4.6	#
	Portunidae	0.8	4.7	1.9	0.8	#
	Priacanthidae	3.2	4.7	1.8	4.0	#
	Sciaenidae	8.2	2.9	9.6	9.8	*
	Scombridae	3.8	1.8	1.6	3.0	#
	Sepiidae	5.7	8.4	4.3	6.7	#
	Serranidae	0.8	0.5	0.7	0.8	-
	Synodontidae	5.5	3.5	4.5	2.7	##
	Trichiuridae	3.9	2.4	3.9	3.8	#

Table 6: Catch composition (%) of the most abundance fish families monitored by bottom trawl surveys in the Southwest area, the northeast monsoon, 2000 – 2003.

Importance	Family name	*2000*	*2002*	*2003*	*Note*
Low commercially important species	Apogonidae	2.2	4.7	2.9	**
	Tetraodontidae	2.8	7.0	3.7	**
	Leiognathidae	17.5	23.1	13.3	#
	Mullidae	2.9	0.9	1.4	#
High commercially important species	Carangidae	7.8	3.2	8.2	*
	Clupeidae	0.9	0.6	0.6	#
	Dasyatidae	3.1	2.4	3.4	#
	Loliginidae	9.4	8.9	6.4	##
	Lutjanidae	1.0	1.2	2.5	*
	Nemipteridae	8.0	3.1	3.1	##
	Portunidae	2.8	3.7	4.0	*
	Priacanthidae	2.0	1.4	6.7	**
	Sciaenidae	4.4	9.1	5.8	*
	Scombridae	2.0	1.6	2.4	*
	Sepiidae	7.2	3.6	3.9	##
	Serranidae	0.9	0.6	0.7	#
	Synodontidae	5.1	4.5	6.9	*
	Trichiuridae	4.5	3.1	4.2	#

*Note: * denotes the increasing, ** significant increasing, # decreasing and ## denotes the considerable decreasing.*

Table 7. Summary results of the catch proportion (%) of the high economically important species and low economically important species in the Southeast and Southwest waters of Vietnam in the two monsoon seasons during the survey period.

Areas	***Monsoon seasons***	***High economically important species***	***Low economically important species***
Southeast	*Southwest*		
	Northeast		
Southwest	*Southwest*		
	Northeast		

4.3 Diel variation

The numbers of hauls towed and the mean values of estimated CPUAs by surveys of the demersal fish stock of the Southeast water are presented in Table 8. No statistically significant difference in catch rates of sampling hauls by sampling time was observed, with $\alpha = 0.05$, $P = 0.48$. In addition, no interaction between survey and sampling time in fish abundance index is observed in the Southeast water with $\alpha = 0.05$, $P = 0.27$. In conclusion, there is no statistically significant difference in samples taken by bottom trawl during the daytime. Therefore, it is not necessary to concentrate on the sampling time for further analysis. The number of sampling stations allocated is relatively small in the Southwest water. Therefore, the comparison in catch rates of sampling hauls taken by sampling time in the Southwest area was not performed because of the limitation of the sample sizes collected.

Table 8: Sample size (number of stations) and CPUA (kg/km^2) of the demersal fish resource estimated based on the bottom trawl samples taken in the morning and afternoon in the Southeast area of Vietnam, 2000 – 2005.

Index	***Sampling time***	***The Southwest monsoon surveys***				***The Northeast monsoon surveys***		
		2000	2002	2004	2005	2000	2002	2003
No stations	Morning	35	43	37	32	36	37	35
	Afternoon	21	12	19	23	18	21	14
CPUA	Morning	981	681	1,024	970	1,019	978	1,304
	Afternoon	1,806	925	998	611	1,054	1,278	1,127

4.4 The relative abundance index

4.4.1 Overall catch rate

In the period from 2000 to 2005, the overall catch rate of demersal fish stock in the Southeast water of Vietnam monitored during the Southwest monsoon bottom trawl surveys showed a considerable decrease (Figure 13 A). There was a significant difference in the relative abundance index (CPUA) between surveys, decreasing by year, the highest in CPUA was observed in the year 2000, and the lowest in2005. (α = 0.05, $P << 0.05$). There was an increasing trend toward offshore ward, although no statistical significance was observed between three first strata namely I (20 - 30 m), II (30 - 50 m) and III (50 -100 m), and the stratum IV with $\alpha = 0.05$, $P = 0.001$. No interaction between survey (year) and depth strata was found with $\alpha = 0.05$, $P = 0.26$.

During the Southwest monsoon surveys, values of mean relative abundance index of the demersal fish stock of the Southwest water (SW) were fairly stable in the period of 2000 – 2004 and then dramatically dropped in 2005 (Figure 14 A). Statistically, the overall catch rate in this area had decreased significantly during 2000 – 2005 ($\alpha = 0.05$; $P = 0.03$). A significantly increasing trend in fish abundance towards offshore water was observed ($\alpha = 0.05$; $P = 0.01$).

Conversely, in the Northeast monsoon surveys showed are relatively stable catch rate in both the Southeast and the Southwest areas during the survey period (Figure 13 C, Figure 14 C). No statistical difference in fish abundance in the survey period were observed in the Southeast water during Northeast monsoon in this period ($\alpha = 0.05$, $P = 0.07$), however strong variation and considerable increase in fish density from inshore water toward offshore was observed ($\alpha = 0.05$, $P << 0.05$). While a slight decrease in CPUA in the Southwest water was observed, the fish density seemed to increase toward offshore water. However, the Two-way ANOVA shows no statistically significant changes in fish abundance of the Southwest water over time ($\alpha = 0.05$; $P=0.58$) nor depth strata ($\alpha = 0.05$; $P=0.18$) in Northeast monsoon surveys

The general pattern of fish distribution in both areas in the two monsoon seasons is the increase in fish density of offshore ward (Figure 13 B, D & Figure 14 B, D). In some years, especially in the Southwest monsoon, high variation (extreme outliers) were observed as is graphically presented in Figure 13 & Figure 14.

In order to analyse the effect of the extremely high outlier values on the results of the analyses was redone excluding the outliers. Generally, excluding the outliers gave very similar results.

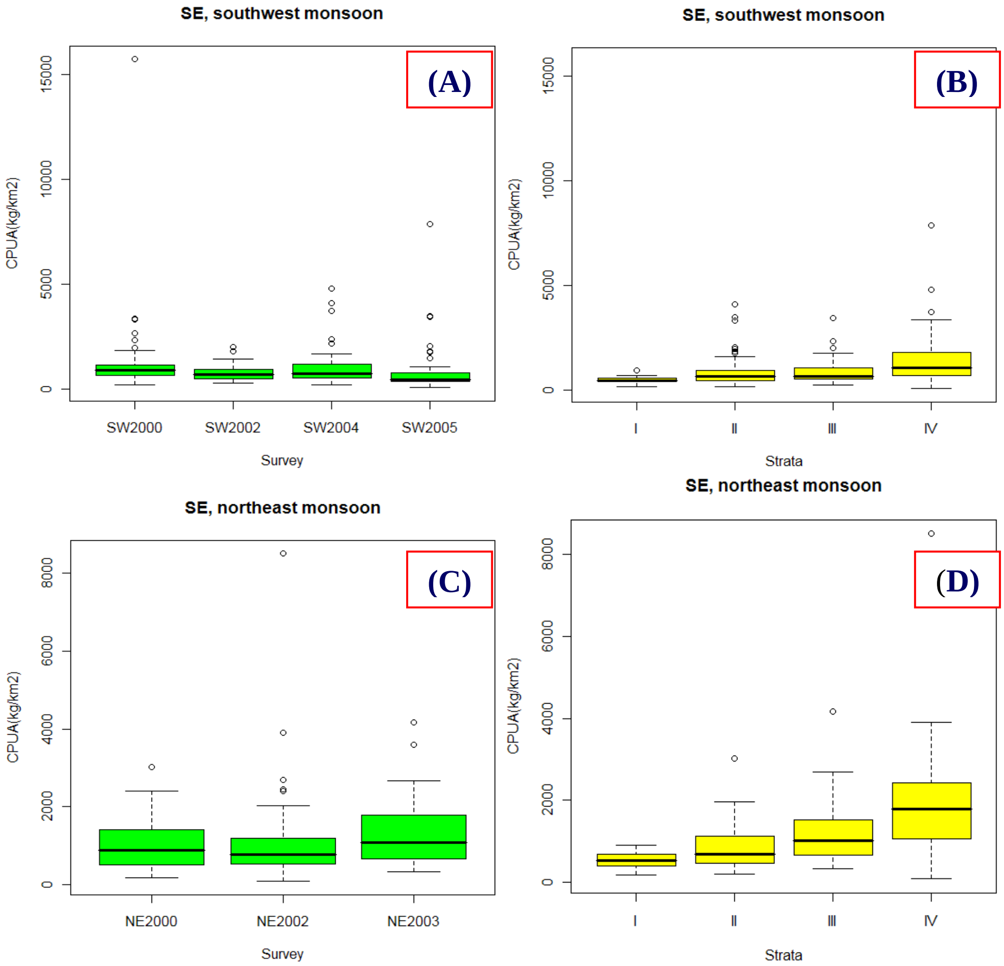

Figure 13: Changes in in abundance (CPUA (kg/km^2)) of demersal fish stock of the Southeast (SE) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne)monsoons, 2000-2005.

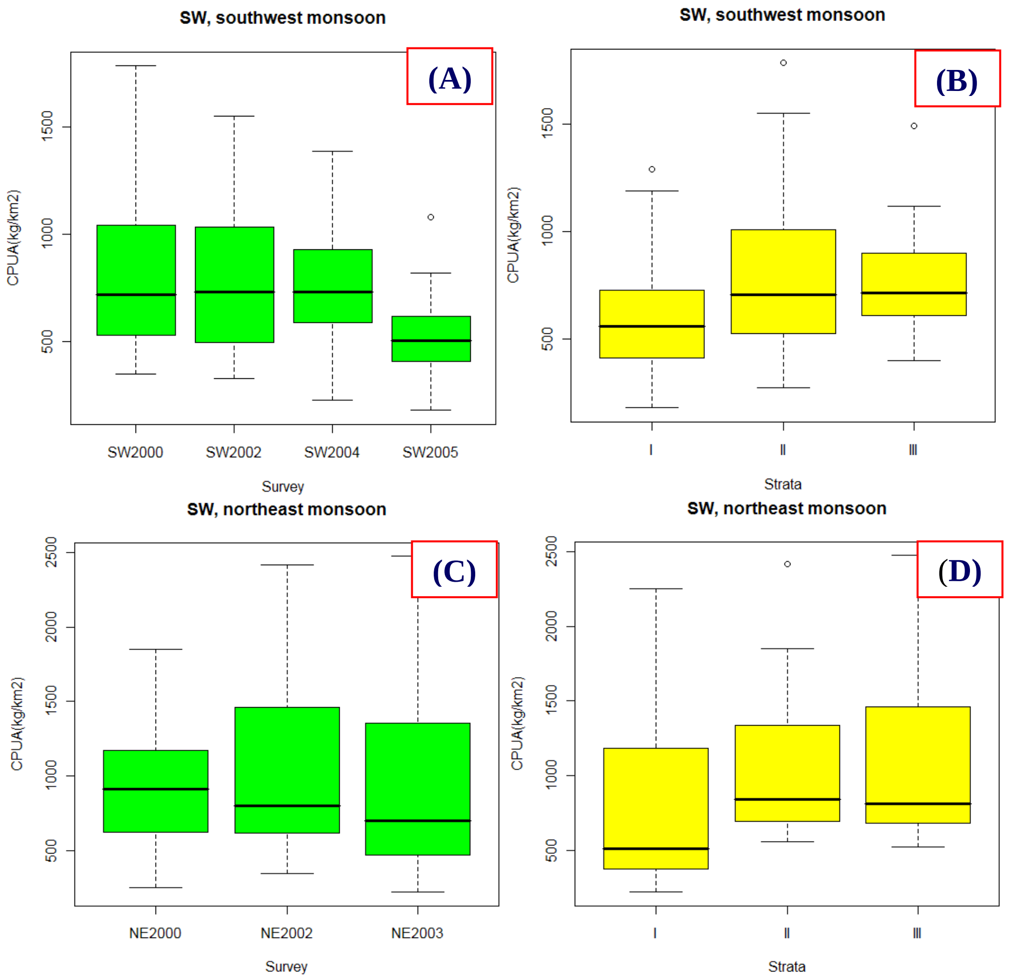

Figure 14: Changes in abundance (CPUA(kg/km^2)) of demersal fish stock of the Southwest (SW) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000 - 2005.

4.4.2 High economically important species

The relative abundance index of highly economically important species has decreased during the Southwest monsoon in the period of 2000 – 2005 in both areas (Figure 15 A, Figure 16 A). A sharp decrease was observed in the areas of less than 50 m depth which is considered the main fishing ground for most trawlers. In the Southeast water, the Two-way ANOVA indicated a statistically significant differences in fish stock abundance over time ($\alpha = 0.05$; $P \ll 0.05$) and depth strata ($\alpha = 0.05$; $P = 0.04$). In the Southwest water, a significantly lower abundance was observed in the last survey (SW2005), $\alpha = 0.05$; $P = 0.003$. The decreasing in fish stock of the Southwest water during this period was considerable. High variation in fish abundance of the economically important fish was seen obviously in the Southeast area (Figure 15), particularly the last Southwest monsoon survey and stratum of 100 – 200 m - Stratum IV, Figure 15 B. The fluctuation in commercially important fish species of the Southwest area was not high compared to the Southeast water. Nevertheless, some moderately high outliers are still observed (Figure 16).

The surveys conducted during the Northeast monsoon indicated a relatively stable state of fisheries resources there in both areas. No statistically significant CPUA in the Southeast water was observed ($\alpha = 0.05$; $P = 0.07$). However, the differences in fish density of offshore water and inshore waters was statistically significant with $\alpha = 0.05$ and $P \ll 0.05$. The statistical results also showed no significant in CPUA in the Southwest water during the same time period.

In general, the abundance of highly economically important species in the Southeast water has slightly declined over the survey period and the density tends to increase their relative abundance in the offshore ward. Excluding extreme outliers from the analysis gives the same overall results.

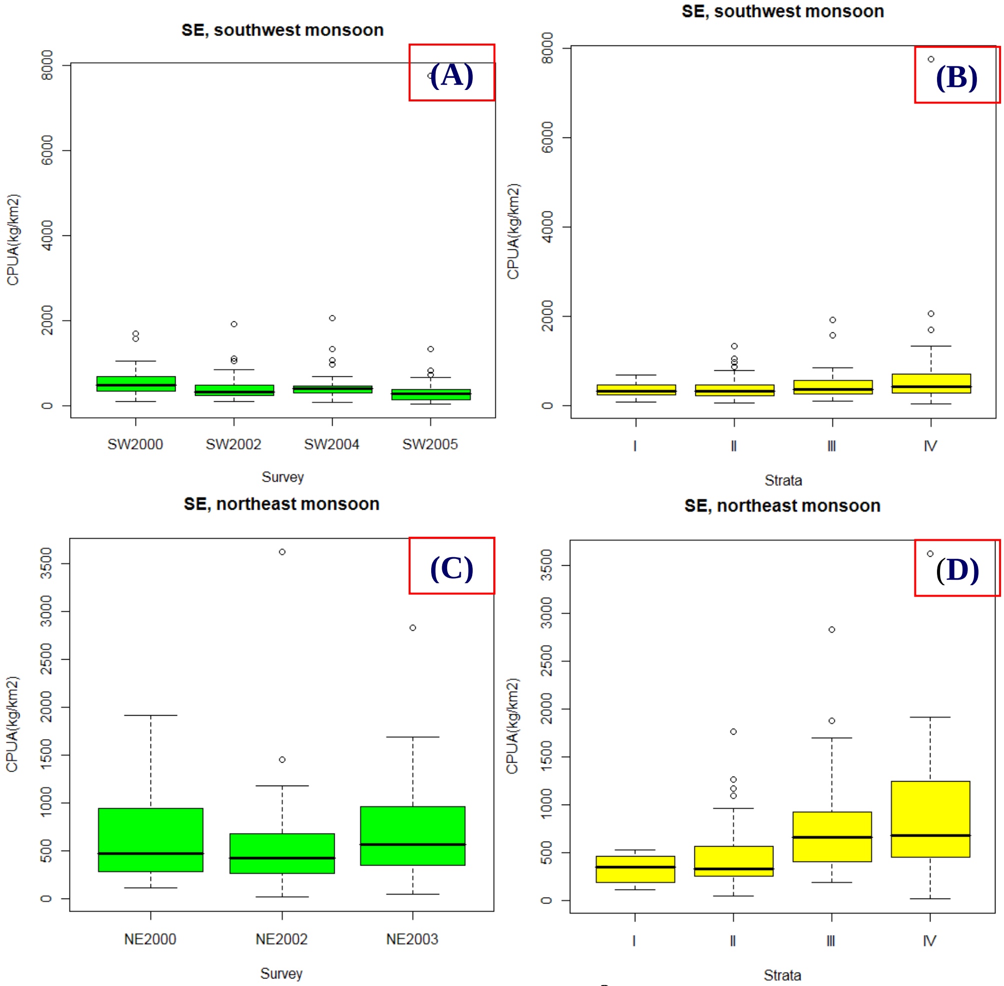

Figure 15: Changes in abundance (CPUA(kg/km^2) of high economically important species of the Southeast (SE) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

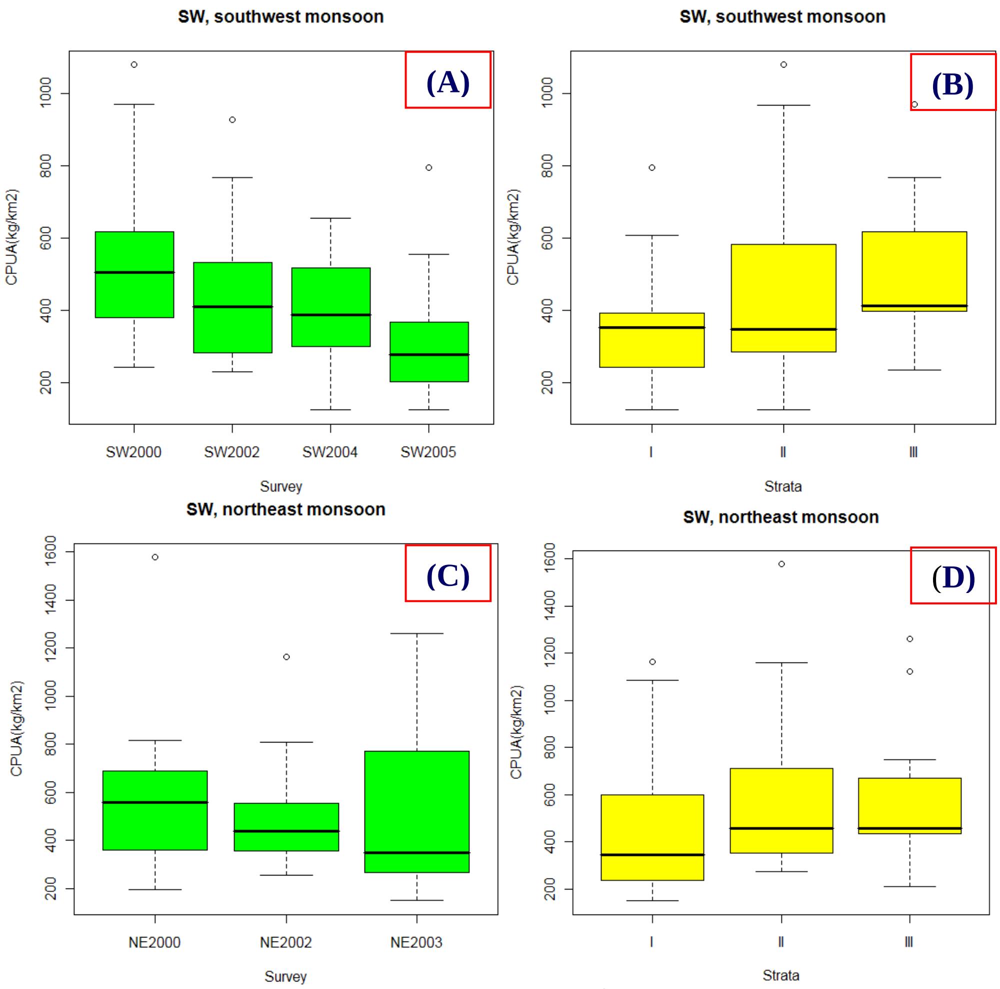

Figure 16: Changes in abundance (CPUA(kg/km^2) of high economically important species of the Southwest (SW) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

4.4.3 Low commercially important species

A fairly high variation in fish abundance of the low commercially important species was observed in four surveys carried out in the Southeast and the Southwest waters of Vietnam (Figure 17 A, B; Figure 18 B, D). High catch rates in the same hauls were reflected in high variance of the average CPUA in the three northeast monsoon surveys. In the southwest monsoon surveys, an abundance of low economically important species showed an increase in the Southeast water (Figure 18 A), while it was relatively stable in the Southwest area (Figure 17 A). No difference in this index was observed among strata during the four surveys of the Southeast water (Figure 17 B). But in the Southwest water, in the inshore zone, a considerable lower value of abundance index was observed than in the offshore water (Figure 18 B, D) with $\alpha = 0.05$; $P = 0.03$.

Conversely, in the three Northeast monsoon surveys, there was no statistical difference in the abundance of the low economically valuable species between three surveys in both areas. However, the survey data reflected a clear difference in the relative abundance in the inshore water and offshore waters during the three Northeast monsoon surveys, $\alpha = 0.05$, $P << 0.05$ in the Southeast water.

Generally, the mean CPUA of the whole area increased from 190 kg/km^2 (in 2000) to 340 kg/km^2 (in 2002) and dropped again to 170 kg/km^2 (in 2003). Additionally, no time trend in the CPUA of low valuable fish species was found here . Similar distribution patterns as by the highly economically important species are observed with increasing density of the offshore ward.

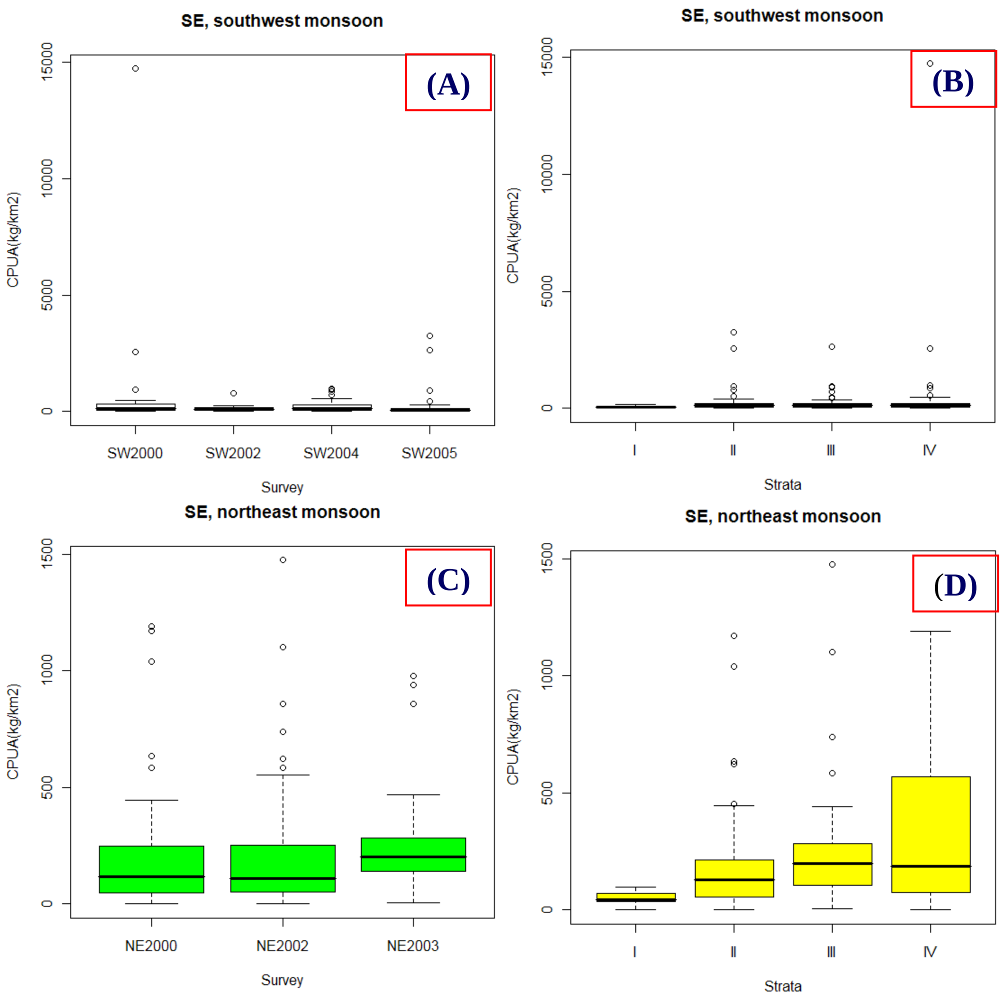

Figure 17: Changes in abundance (CPUA(kg/km^2) of high economically important species of the Southeast (SE) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

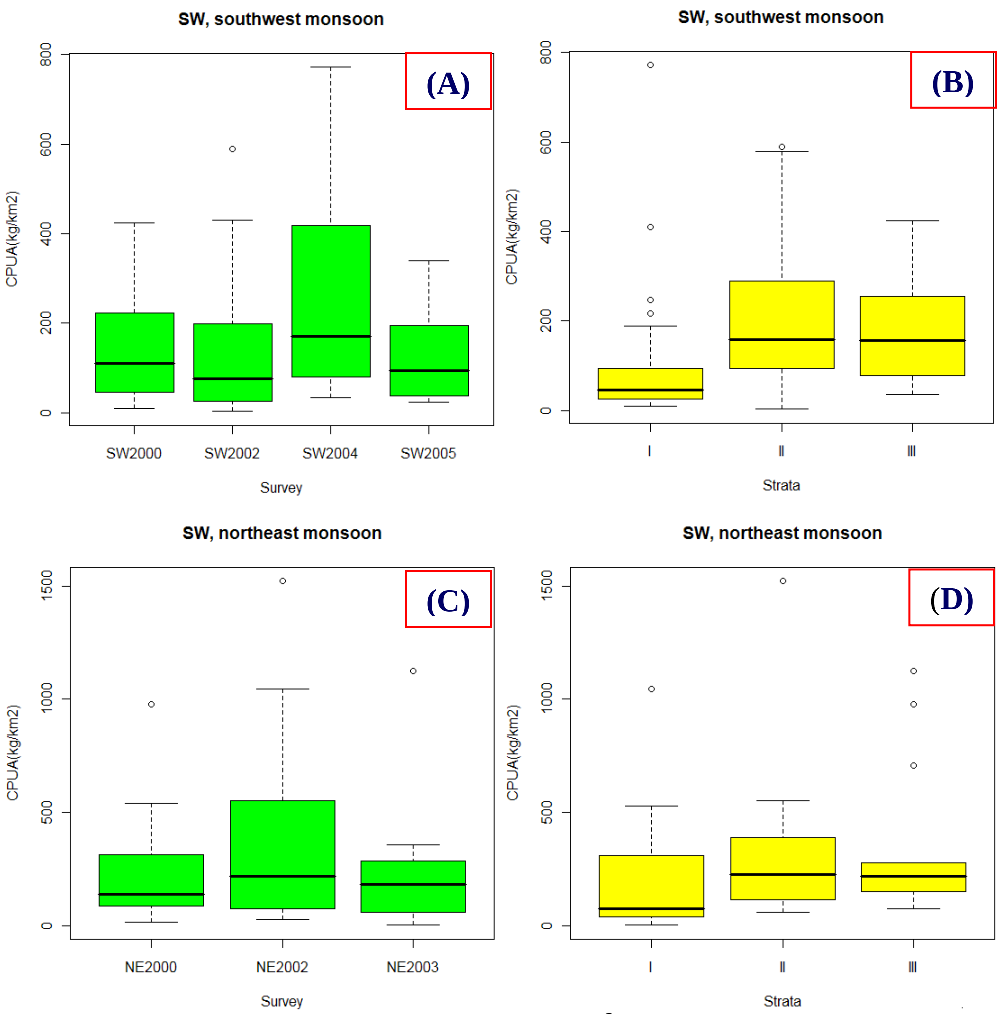

Figure 18: Changes in abundance (CPUA(kg/km^2) of low economically important species of the Southwest (SW) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

4.4.4 Ecologically sensitive species

The stratified mean CPUA values of the sensitive species in the Southeast area from the four Southwest monsoon surveys showed a substantial decrease. The observed difference by depth and time are statistically significant. The two first surveys have higher abundance compared to the two last ones (α=0.05, P = 0.01). And the depth zone of 20 - 50 m has lower CPUA than 50 – 100 m and 100 - 200 m (α=0.05, P << 0.05).

In the Southwest water, the CPUA of the sensitive species showed a high variability. Survey results showed a higher fish density in shallow water (< 50 m) compared to offshore water (50 – 100 m). Even though a decreasing trend in abundance was observed over time the trend was not statistically significant (α= 0.05, P = 0.24). No significant change in abundance by depth strata was observed (α= 0.05, P = 0.32).

In the three northeast monsoon surveys, in the Southeast area, a high variability was observed in the CPUA of the ecologically sensitive species, especially in the area of less than 100 m. The abundance of this group in deep water (>100 m) is significantly higher than the CPUA of the shallow waters. No statistical difference change in the ecologically sensitive fish species was observed (α = 0.05, P = 0.07). At the same survey time, in the Southwest water, the sensitive fish species tended to be more abundant in the shallow water rather than in the deep water (Figure 20 D). No signal of decrease of this group was detected in these three surveys (α= 0.05, P = 0.92). The CPUA of ecologically sensitive fish group was fairly stable in the period from 2000 to 2003 during the Northeast monsoon, no statistical significance in abundance was found between depth zone (α= 0.05, P = 0.55).

The summary of changes in the relative abundance index of the overall demersal fish resource, the low economically important species, the high economically important species and the ecologically sensitive species are graphically present in Table 9. The red colour indicates the decrease in fish abundance while the green colour indicates the stable status of the resource.

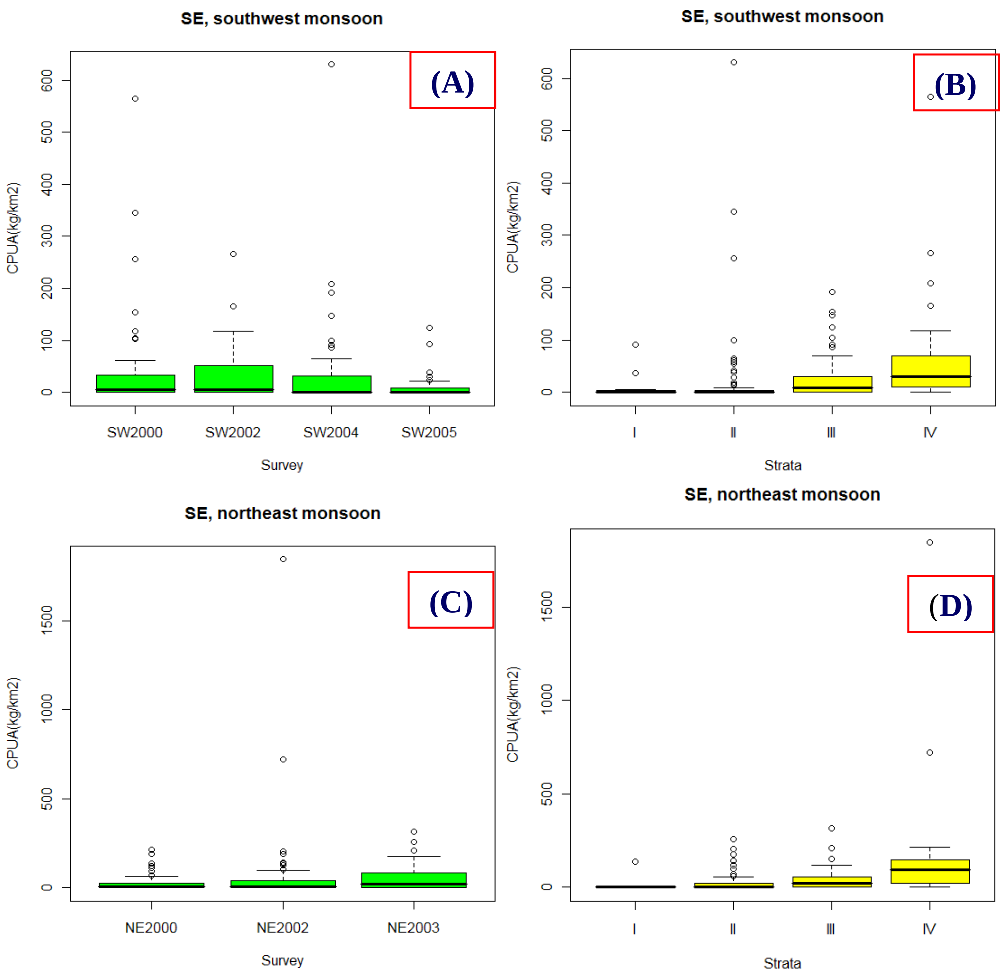

Figure 19: Changes in abundance (CPUA(kg/km^2) of ecologically sensitive species of the Southeast (SE) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

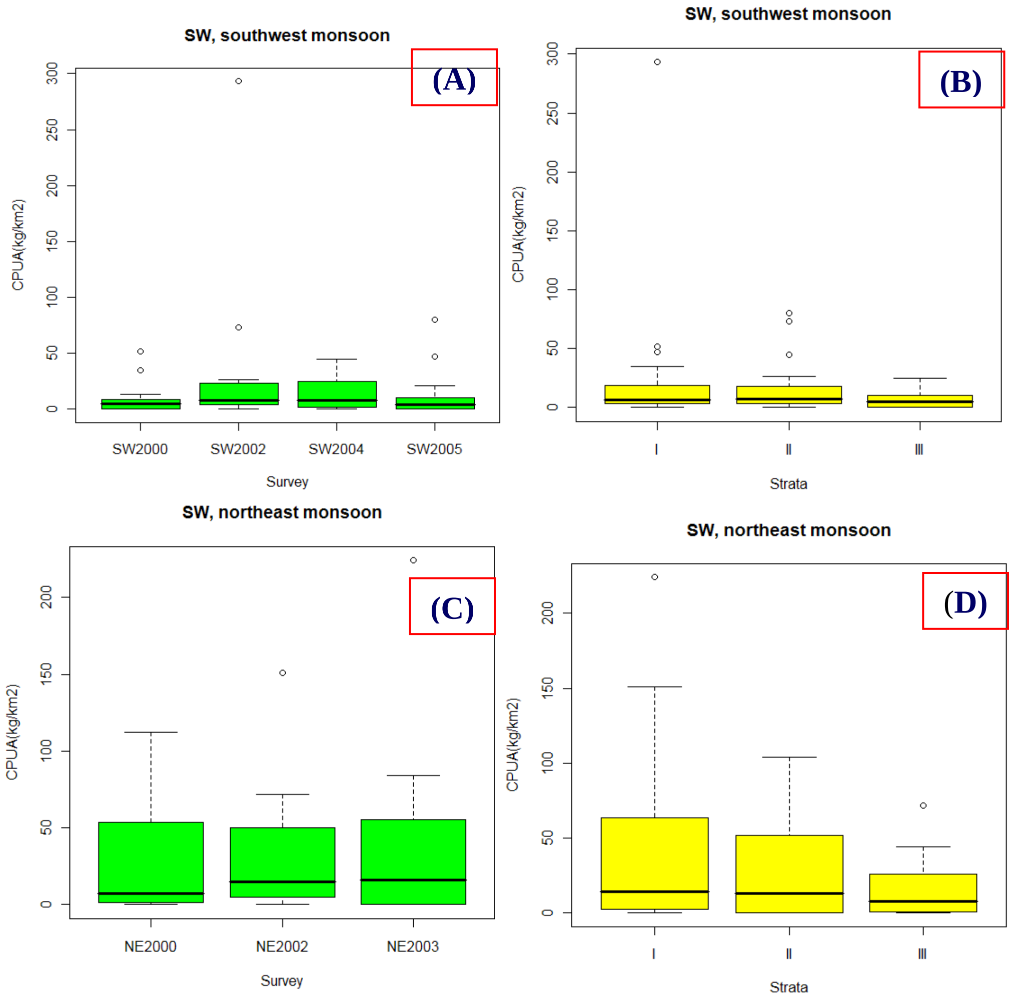

Figure 20: Changes in abundance (CPUA(kg/km^2) of ecologically sensitive species of the Southwest (SW) area of Vietnam based on the bottom trawl surveys performed during the Southwest (Sw) and the Northeast (Ne) monsoons, 2000-2005.

Table 9. Summary results of the mean relative abundance index (CPUA) of the demersal fish resource by groups in the Southeast and the Southwest waters of Vietnam in different monsoon seasons over time.

Areas	***Monsoon seasons***	***High economically important species***	***Low economically important species***	***Ecologically sensitive species***	***Overall abundance***
Southeast	*Southwest*				
	Northeast				
Southwest	*Southwest*				
	Northeast				

4.5 Biodiversity indices

The number of species which were identified in the Southeast and the Southwest waters of Vietnam by strata and surveys are very different. The Southeast area has considerably higher number of species compared to the Southwest area. There were about 240 - 300 species identified in the Southeast water during the Southwest monsoon and 230 - 260 species identified during the Northeast monsoon. In total, about 150 species were identified in each survey performed in the Southwest waterduring both monsoon seasons. In the stratum of 20-30 m in the Southeast water a substantially lower number of species was found than in the areas of greater than 30 m in depth.

In the Southwest area, a different pattern was observed with respect to number of fish species by depth strata. The greatest number of fish species was observed in stratum of 30 – 50 m depth (100 – 110 species), then the shallow water (20 – 30 m) with 90 – 100 species and offshore area (50 – 100 m) with 80 – 90 species.

There is a notable difference in the number of fish species found in the two monsoon seasons in the Southeast water. During the Southwest monsoon surveys, the number of fish species identified varied from 240 to 290 species while the number of species was in the range of 220 to 250 species during the Northeast monsoon. On the other hand, the number of fish species sampled in these seven surveys conducted in the Southwest water was stable. No seasonal variation in the number of the species identified was observed (Table 10).

Table 10: Number of species caught by strata and monsoon seasons (SW – Southwest and NE - Northeast) in the Southeast and the Southwest areas of Vietnam monitored by bottom trawl surveys conducted during 2000 – 2005.

Area	*Survey*	*20-30 m*	*30-50 m*	*50-100 m*	*100-200 m*	*Total*
Southeast	SW2000	60	194	152	104	279
	SW2002	65	181	157	108	263
	SW2004	64	185	158	149	295
	SW2005	84	171	160	104	237
	NE2000	56	152	158	99	243
	NE2002	77	175	147	117	255
	NE2003	25	152	168	90	225
Southwest	SW2000	79	100	82	na[1]	137
	SW2002	98	110	89	na	152
	SW2004	98	110	89	na	152
	SW2005	104	120	87	na	162
	NE2000	93	113	79	na	151
	NE2002	89	91	77	na	139
	NE2003	103	93	100	na	157

[1] na: this depth stratum is not available in the Southwest area, Vietnam

4.5.1 Shannon- Weiner index (H')

In the present study time period (2000 – 2005), the demersal fishery resource of the Southeast water showed a high variation in biodiversity, particularly in the offshore water (100 – 200 m depth). Large variations in the Shannon-Weiner index was observed in stratum 100 – 200 m in 2000 and 2005 during the Southwest monsoon. In both these surveys, the stratum of 100 – 200 m depth had 104 species identified; however, there was no balance or evenness among species either in terms of the number of individuals nor in biomass. This means that there were some species which were highly dominant in that depth stratum. For instance, in the stratum of 100 – 200 m depth, in the Southwest monsoon survey of the year 2000the fish species Japanese leatherjacket accounted for 96% total number of individuals sampled of 104 species identified. The value of index H' is only 0.40. Similarly, the fish species of Red bigeye (*Priacanthus macracanthus*) was also dominant in stratum of 100 – 200 m of the last survey implemented in the Southeast water which accounted for 95% of the total individuals caught. This was reflected in the very low value of H' in the year 2005 (0.5). Overall, high variation in H' was observed in the Southeast area and the value of H' tended to decrease over the time.

The Southwest water showed a lower biodiversity than the Southeast area, especially during the Northeast monsoon. There was no considerable seasonal difference in the Shannon-Weiner index of the demersal fish community in the Southwest area except for the stratum of 30 – 50 m depth (Table 11). The low values of H' index was observed at stratum of 50 – 100 m of the Southwest water because of the dominance of low economically important species, Ponyfish (*Leiognathus spp*.) which accounted for approximately 77% of total fish individuals sampled in both surveys the Southwest2005 and the Northeast2003.

Table 11: Changes in biodiversity index, Shannon-Weiner (H') of the demersal fish resource of the Southeast and Southwest waters, Vietnam, by depth strata monitored by bottom trawl surveys performed during Southwest (SW) and the Northeast (NE) monsoons, 2000 - 2005.

Area	*Survey*	*20-30 m*	*30-50 m*	*50-100 m*	*100-200 m*	*Total*
Southeast	SW2000	4.13	3.93	4.75	(0.40)	3.63
	SW2002	4.05	4.65	4.56	4.37	4.49
	SW2004	3.96	4.21	3.18	5.00	3.99
	SW2005	4.31	4.74	3.34	(0.50)	3.57
	NE2000	4.31	4.42	4.78	4.00	4.45
	NE2002	4.39	5.19	3.56	4.50	4.48
	NE2003	2.74	5.28	4.10	3.25	4.23
Southwest	SW2000	3.77	4.32	2.53	na	3.54
	SW2002	4.66	4.62	4.24	na	4.49
	SW2004	3.86	3.61	2.11	na	3.13
	SW2005	4.29	4.34	(1.82)	na	3.42
	NE2000	3.49	2.61	2.04	na	2.61
	NE2002	3.38	2.05	2.95	na	2.69
	NE2003	4.59	3.72	(1.88)	na	3.26

**The values in brackets demote very low compared to the other estimates.*

The dominance of some fish specific species mentioned above caused the decrease in values of biodiversity index (H') of the demersal fish resource distributed in the Southern water of Vietnam. If the fish Japanese leather jacket and Ponyfish are taken out of the sampling surveys namely Southwest2000; Southwest2004 and Southwest2005, the values estimated of H' of the stratum of 100 - 200 m in the year 2000 increases to 4.15 and the whole area is estimated at 4.64. Similarly, the H' index increases in value of the last two surveys respectively 4.92 and 4.76. In addition, if the dominant species are excluded from the Northeast monsoon surveys of the Southeast water, the same pattern in changing the value of H' is shown, for instances, biodiversity index of strata 20 – 30 m and 100 – 200 m depth of the survey Northeast 2003, are respectively 4.12 and 4.15 (Annex 3).

The same method applied for re-estimating the biodiversity index of the Southwest water also reflected a sharp increase of this index of most stratum and surveys which have an existence of the dominated fish species. In the Southwest water, the most dominant species during this period was Ponyfish, a very low commercially important species which is normally classed in group of "trash fish". Especially, the stratum of 50 – 100 m of the Southwest area in the four Southwest monsoon surveys, the estimates of H' in case of excluding the dominant species were respectively 4.49; 4.24; 4.79 and 4.54.Simultaneously , the shallow water (20 – 30 m depth) have higher values of H', in range of 3.71 to 4.66.

4.5.2 Margalef index (D)

Species richness is normally reflected by the number of species encountered in the samples taken by strata and surveys. The highest value of species richness index belongs to stratum of 30 – 50 m depth, the Southeast water. Additionally, in the Southeast area, the inshore water (20 – 30 m) and offshore water (100-200 m) have a significantly lower number of species.

The Margalef index of species richness of the Southwest area indicates the number of fish species distributing in the stratum of 50 – 100 m is less than it is in the area shallower than 50 m in depth. Moreover, the species richness of this area highly varies over time (Table 12). However, the number of samples taken should be taken into account for evaluation of species richness index. Normally, this index is very sensitive to sample size. Table 12 presents the trend in variation of species richness of the Southeast and Southwest waters over the survey time.

In order to analyse the effect of the dominant species on species richness of the Southern waters of Vietnam, these species were excluded from the samples taken by bottom trawl surveys. An increase in Margalef's index was observed in most cases which has a presence in the dominant species such as ponyfish and Japanese leather jacket fish. For examples, the Margalef 's index estimated of the stratum of 100 – 200 m depth during theSouthwest monsoon surveys the Southwest2000 and the Southwest2005 were respectively 10.53 and 10.59. It increased slightly in the survey Northeast2003, from 7.72 to 7.96. The more dominant the species the higher increase in the Margalef's index when the dominant species is excluded. Because a changing in the number of species is small while the change in the number of individuals is relatively large, the estimates of Magalef index for the demersal fish stocks in both sub-areas of the Southern waters, Vietnam are described in the Annex 4.

Table 12: Changes in species richness index, Margalef index (D) of the demersal fish resource of the Southwest and Southwest waters, Vietnam, by depth strata monitored by the bottom trawl surveys performed during Southwest (SW) and the Northeast (NE) monsoons, 2000 - 2005.

Area	*Survey*	*20-30 m*	*30-50 m*	*50-100 m*	*100-200 m*	*Total*
Southeast	SW2000	7.40	16.95	14.24	(7.96)	13.32
	SW2002	7.76	16.28	14.32	10.55	13.55
	SW2004	7.08	16.00	13.44	14.41	13.70
	SW2005	9.78	16.24	13.44	(8.19)	13.17
	NE2000	7.29	13.93	14.78	9.84	12.57
	NE2002	8.61	16.74	12.98	11.17	13.55
	NE2003	3.40	13.95	13.91	(7.72)	11.42
Southwest	SW2000	8.98	9.91	7.49	Na	8.82
	SW2002	10.68	10.33	9.12	Na	9.98
	SW2004	10.27	10.88	(6.57)	Na	9.18
	SW2005	11.09	12.13	(8.42)	Na	10.55
	NE2000	9.41	10.44	(7.37)	Na	9.09
	NE2002	8.36	8.16	(7.49)	Na	(7.97)
	NE2003	10.21	8.97	9.23	Na	9.36

4.5.3 Pielou's evenness index (J')

The Pielou's index (J') indicates the level of equality between species within a community. It means that in a certain area, if a few species are dominated the index is fairly low while it will have maximum value if all component species have equal numbers in the community. Therefore, an evenness index normally reflects one aspect or one side of the meaning the of Shannon – Weiner index.

In the Southeast area, most surveys had an evenness index of 0.5 – 0.6 (Table 13). The fairly low values of an evenness index was observed in stratum of 100 - 200 m in the surveys Southwest 2000 and Southwest 2005. As mentioned above, this is due to the dominance of two species Japanese leatherjacket and Red bigeye, respectively. Additionally, the increasing abundance of very low economically important species like Ponyfish was the main reason for the low evenness index. For instance, only one species belonging to Ponyfish, namely Slender ponyfish (*Leiognathus elongates*) accounted for 44% of the total individuals caught by bottom trawl at stratum of 50 – 100 m depth in the Southeast area (survey Southwest 2004).

Overall, the evenness indices of the demersal fish communities of the Southeast and the Southwest waters showed a decrease during the survey period (2000 – 2005). This J' index had a slight decrease in the stratum 20 – 30 m of the Southeast and the Southwest and in the stratum of 30 – 50 during the Southwest monsoon surveys. However, significant reduction of the index was observed in stratum of 50 – 100 m depth in both areas. This indicates an increase some species in these two areas e.g. some low commercially important species such as Ponyfish (*Leiognathus spp.).* The Ponyfish accounted for 73%, 77% and 77% total number of individuals encountered in stratum of 50 -100 m of the southwest water in surveys Southwest2004, Southwest2005 and Northeast2003. It was also estimated approximately 73% total individuals of all species sampled in the stratum of 30 – 50 m depth of the Southwest area during the survey Northeast2002.

Table 13: Changes in evenness index, Pielou's index (J') of the demersal fish resource of the Southwest and Southwest waters, Vietnam, by depth strata monitored by bottom trawl surveys performed during the Southwest (SW) and the Northeast (NE) monsoons, 2000 - 2005.

Area	***Survey***	***20 -30 m***	***30-50 m***	***50-100 m***	***100-200 m***	***Total***
Southeast	SW2000	0.70	0.52	0.65	(0.06)	0.51
	SW2002	0.67	0.62	0.62	0.65	0.63
	SW2004	0.66	0.56	0.44	0.69	0.56
	SW2005	0.67	0.64	0.46	(0.07)	0.50
	NE2000	0.74	0.61	0.65	0.60	0.64
	NE2002	0.70	0.70	0.49	0.66	0.63
	NE2003	0.59	0.73	0.55	(0.50)	0.62
Southwest	SW2000	0.60	0.65	0.40	na	0.55
	SW2002	0.70	0.68	0.66	na	0.68
	SW2004	0.57	0.53	(0.35)	na	0.47
	SW2005	0.64	0.63	(0.28)	na	0.51
	NE2000	0.53	(0.38)	(0.32)	na	0.40
	NE2002	0.52	(0.31)	0.47	na	0.42
	NE2003	0.69	0.57	(0.28)	na	0.49

The evenness index J' is depentent on the allocation of the number or biomass of each species components in the community. Hence, when the dominant species are excluded from the samples (surveys, strata) in the calculation of the species evenness – Pielou's index (J'), the estimated values will obviously increase. In more detail, the species evenness index of the stratum of 100 – 200 m depth in the Southeast water increased from 0.06 (Southwest 2000) to 0.62 (Southwest 2000) if the Japanese leather jacket fish is excluded from the sample. Similarly in the survey Southwest 2005, a significant increase in value of index J' of the same stratum, 100 – 200 m depth, from very low value (J' = 0.07) to relatively high value (J' = 0.65) results when Red bigeye (*Priacanthus macracanthus*) and Slender ponyfish (*Leiognathus elongates*) were not taken into account as component species of that sample.

In the Southwest water, the values estimated of species evenness (J') of the stratum of offshore water, 50 – 100 m depth, in the Southwest monsoon surveys co-called Southwest 2004, Southwest 2005 are respectively 0.35 and 0.38. However, these estimates increased to 0.79 and 0.71 respectively when the dominant fish species, Ponyfish is taken out of the samples. For the rest of three surveys performed during the Northeast monsoon, Ponyfish was also highly dominated in terms of number of individuals in the sampling community. The Pielou's index increased from 0.32 (Northeast 2000) and 0.28 (Northeast 2003) to 0.72 if the presence of Ponyfish was ignored from the estimating samples. The evenness index also showed the same direction in the stratum of 30 – 50m depth, a considerable increase in value of Pielou's index without this low economically important species (Ponyfish), fluctuated from 0.38 (Northeast 2000) and 0.31 (Northeast 2002) to 0.69 and 0.73 respectively. A more stable state of the index will be achieved if the dominant species are not taken into account. Annex 5 presents these estimates of the species evenness index without the dominant species.

4.6 Fish assemblage

- **The Southeast water**

Ward hierarchical clustering analysis with the estimated distance based on "correlation" method shows a seasonal difference in demersal fish assemblages of the Southeast water. In the Southwest monsoon, there were two main groups of fish families classified with the distance index of 20; however the number of fish species within each group (cluster) was considerably different (Figure 21 A). There were 24 most abundant fish families in this area which formed two main groups, the small group consisted of stingray (Dasyatidae) and small sharks such as Carpet sharks (Hemiscyllidae), Caesionidae, Plotosidae, Dactylopteridae and Peristerdiiddae while eeltail catfish (Plotosidae) and lunar fusilier (Caesionidae) which mainly live in coastal area and coral reefs form a sub-group (cluster). And, the two deeper demersal fish families, flying gurnards (Dactylopteridae) and armoured gurnards (Peristediidae) aggregate together. The rest of the 24 families tended to have closer linkages in terms of spatial distribution (Figure 21 A).

The demersal fish stocks tended to have isolation in spatial distribution, some fish families had the same distribution behaviour and formed a group or cluster. The Ward hierarchical cluster analysis showed four major groups of demersal fish of the Southeast area in the Northeast monsoon with the same distance index of 20 as measured in the Southwest monsoon. One group consisted of squid (Loliginidae), cuttlefish (Sepiidae), nemipterids (Nemipteridae), goatfish (Mullidae), lizardfish (Synodontidae) and redbig eye (Priacanthidae) (Figure 21 B). Number of fish families belonging to each cluster is fairly equal.

Boostraping technique presented asimilar output to the cluster analysis above, the demersal fish tended to widely distribute during the Southwest monsoon and seemed to mix welltogether. Two small groups significantly found are squid and cuttefish; the two deep demersal fish families flying gurnards (Dactylopteridae) and armored gurnards (Peristediidae) (Figure 22 A).

Similarly, four small clusters were significantly oberved in the demersal fish resource of the Southeast water duriingthe Northeast monsoon (Figure 22 B). Obvisoulsy, the demersal fish stock distributed in the Southeast water had a seaonal variation in fish assemblage. Fish stocks tended to form clusters during the cold season, the Northeast monsoon.

The Bray – Curtis technique applied for analysis the clusters of the demersal fish stock in this area also shows a relatively similar result. In the frame work of this paper, the furthur discusion of this technique is not included. The detailed dendrograms of this technique used for analysing the fish assembage in the Southeast and Southwest areas are presented in Annex 6 and Annex 7.

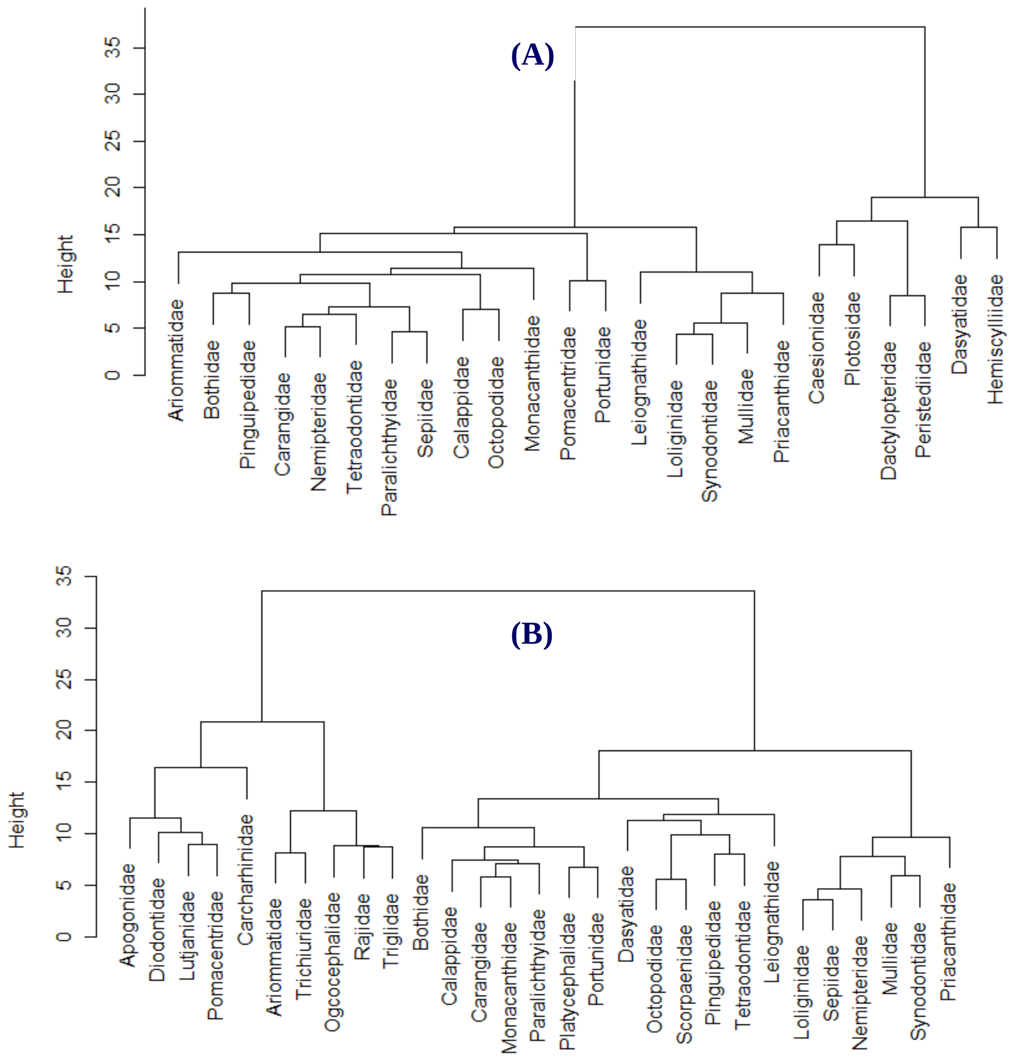

Figure 21: Assemblages of the main demersal fish family in the Southeast area of Vietnam, estimated by ward hierarchical cluster analysis with “correlation” distance metric measurement, in the Southwest monsoon (A) and the Northeast monsoon (B), based on bottom trawl surveys conducted in the period from 2000 to 2005.

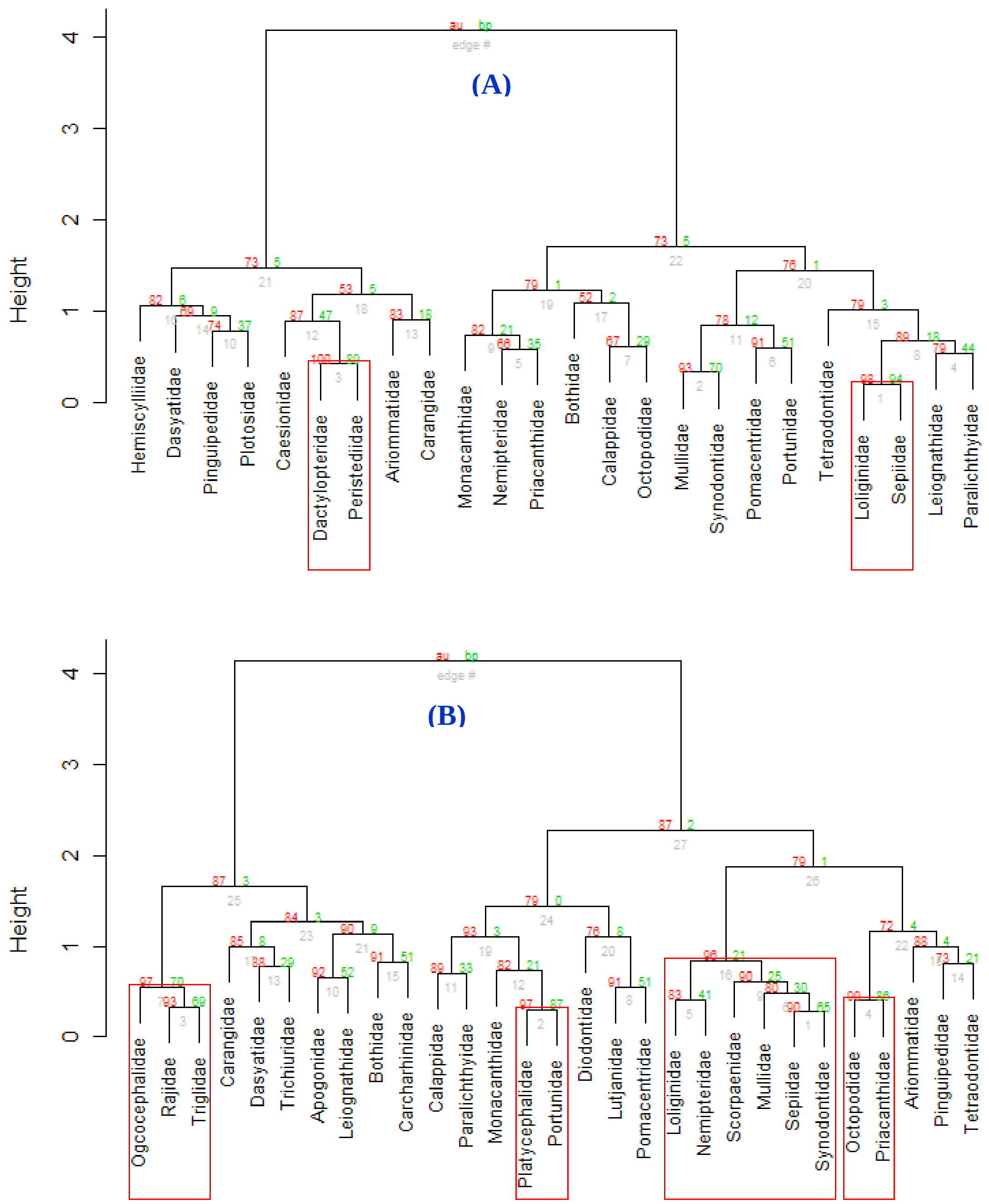

Figure 22: Assemblages of the demersal fish resource of the Southeast area, Vietnam, based on ward hierarchical cluster analysis using multiscale bootstrap resampling for the Southwest monsoon (A) and the Northeast monsoon survey (B), bottom trawl surveys during 2000 – 2005.

- **The Southwest water**

Three main clusters were formed by the demersal fish stocks of the Southwest area during the Southwest monsoon (Figure 23 A). Similarly, three main groups of demersal fish families clustered during the Northeast monsoon in the Southwest area (Figure 23 B). In general, there was no considerable difference in terms of the number of clusters separated of the demersal fish stock in the Southwest area during both monsoon seasons. However, bootstrapping techniques showed a relative difference in assemblage of the demersal fish resource between monsoon seasons. Six small clusters formed in the Southwest monsoon (Figure 24 A) while only two main cluster are significantly observed during the Northeast monsoon (Figure 24 B).

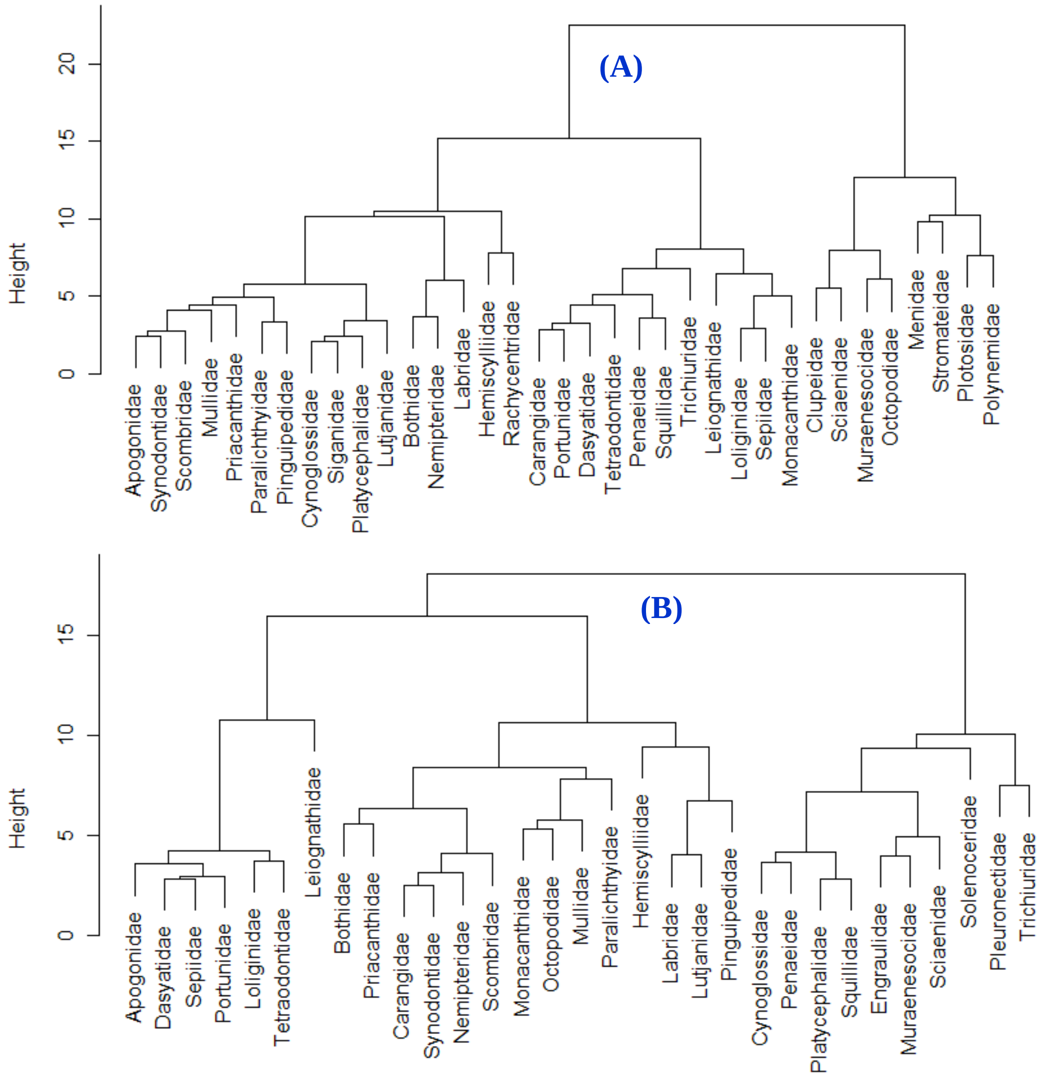

Figure 23: Assemblages of the main demersal fish family in the Southwest area of Vietnam estimated by ward hierarchical cluster analysis with “correlation” distance metric measurement, in the Southwest monsoon (A) and the Northeast monsoon (B), based on bottom trawl surveys conducted in the period from 2000 to 2005.

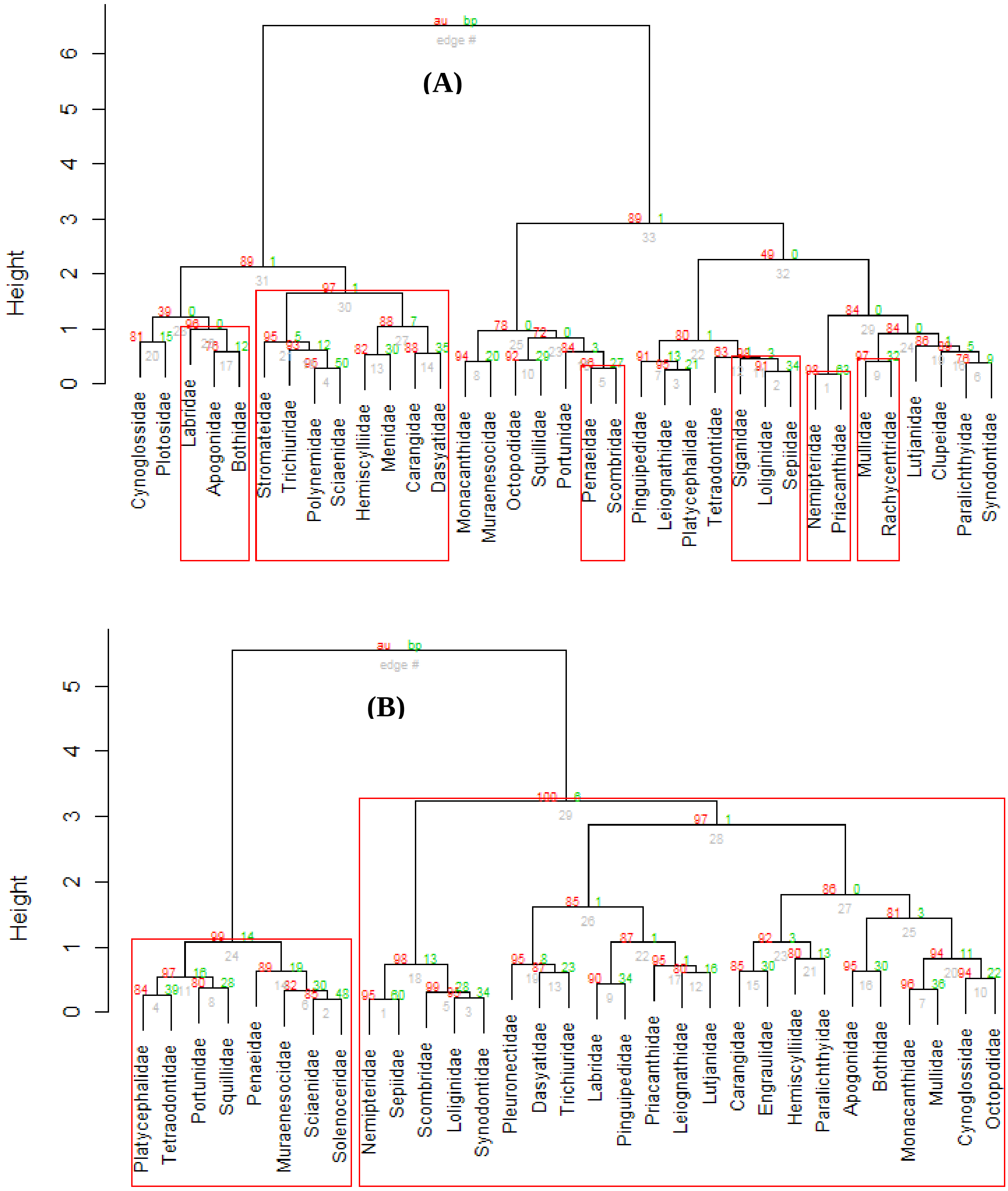

Figure 24: Assemblages of the demersal fish resource of the Southwest area, Vietnam, based on ward hierarchical cluster analysis using multiscale bootstrap resampling for the Southwest monsoon (A) and the Northeast monsoon survey (B), bottom trawl surveys during 2000 – 2005.

5 DISCUSSION

- **Spatial distribution**

No statistically significant difference in the mean catch rates of the demersal fish resource of the Southeast and the Southwest waters in the morning and the afternoon were observed. Fishe was mappedbased on the relative abundance index (CPUA(kg/km^2)) while this index is linearly proportion to the coefficient catchability (q) of the sampling gear. The distribution of the demersal fish stock in the Southeast and Southwest waters is possibly biased because of the assumption of a constant q value used for all fish species and surveys. However, this is only one method that is popularly applied in mapping fish distribution on the basis of data sources retrieved from bottom trawl surveys in Vietnam and the region. Based on the above assumption, the temporal maps of the demersal fish abundance of the survey area are plotted. These maps show a seasonal variation in fish distribution in both sub-areas, the Southeast and the Southwest. The high fish density was graphically presented in offshore waters where water depth is more than 100 m depth in the Southeast water and the area of over 50 m depth in the Southwest water. Some high dense fish abundance regions were situated at the shallow water close to the river outlets which are considered as high nutrient area and of high productivity.

During the Southwest monsoon, demersal fish stock tends to widely distribute in the whole area of the Southern marine waters of Vietnam. Nevertheless, some high concentration parts are observed, perhaps, they are mainly representing aggregations by some dominant species as Japanese leather jacket, Ponyfish etc. The area has a value of CPUA of 500 – 1000 kg/km^2 and accounts for the main proportion of the “trawlable” Southern water of Vietnam in most Southwest monsoon surveys. Conversely, demersal fish seems to aggregate together during the Northeast monsoon, especially the offshore waters. The complete differences in water flows between the two monsoon seasons can explain the deviation in fish distribution. During the Southwest monsoon, from April to September, the water current is weak and moving from the south to the northeast area and from the inshore to offshore area. During the Northeast monsoon, water current has different direction and speech, a strong current from the North moves Southward and divids into two sub-currents. One continuously moves to the South and one flows to the Western area (the Southwest area). Therefore, during the Northeast monsoon, the water current makes a twist with the centre situated at about 7^o N and 104^o E. Notably, under the dynamic of the current, the water column is variable with respect to salinity, transparency and nutrients which influence the behaviour and distribution of the fish stocks in the area

- **General abundance**

The overall demersal fish stock of the Southern waters including the Southeast and the Southwest fishing grounds have decreased considerably. Inference statistics also show that the decline is mostly significant and the higher fish density tends to locate in offshore areas. Nevertheless, catch ability of the sampling gear used, the bottom trawl should be considered with respect to possible bias. Practically, different fish species have different behaviours with regard to avoiding behaviours and the available towing gear. In this study, the assumption of the constant fishing catch ability (q) is made. The changes in towing speed may also have led to some bias in the analysis. During the two later surveys (Southwest2004, Southwst2005) the average towing speed was in range of 3.2 – 3.3 ± 0.2 knots while the five first surveys had towing speed of 3.4 – 3.7 ± 0.2 knots. The CPUA was estimated based on the basis of standardization of the swept area rather than fish escaping ability. In other words, the catch ability co- efficiency is still assumed constant in terms of survey time as well as fish species, fish size distribution and survey area, oceanographic conditions etc.

Groups of economically important species of the Southeast and Southwest water seem to have declined considerably. Based on the above assumption of the fishing gear selectivity, the highly commercially important species such as grouper, snapper, croakers, lizard fish, Carangids, Scombrids have decreased dramatically while the less important valuable species tended to increase and replace them in the demersal fish community. Particularly, Ponyfish (Leiognathidae), a very small size fish and some other small size fish species including Japanese leather jacket fish, cardinalfish (Apogonidae), toxic fish – Pufferfish (Tetraodontidae) have been becoming more dominant in the area, especially Ponyfish which has very short life span (Woodland and Cabanban, 2001). The replacement of low commercially important fish species have been reported in number of paper in Vietnam (Edwards *et al.*, 2004; Son *et al.*, 2005; Nguyen and Nguyen, 2008; Nguyen, 2008) and the Asian region (Ahmad, 2005; Chandrapal, 2005; Funge-Smith *et al.*, 2005; Grainger *et al.*, 2005). A number of low commercially important fish species captured by fishing gears, in different fishing areas and by number of nations was discussed in the international conference on "trash fish" matters held in Vietnam in 2005. The group of "trash fish" which is mainly comprised of low economically valuable species including leather jacket fish accounted for a relatively high proportion (80%) in landing of the trawler fleets of 141 – 300 HP in the Southwest and Southeast provinces during Southwest monsoon in 2000 (Nguyen and Nguyen, 2005a). According to the present study, the group of low commercially important fish species increased from about 20% of the total landing of these fleets and increased to approximately 40% in the period from 2002 to 2004. The main target species of the trawler fleets was Japanese leather jacket in the time period 2002 – 2004 with 52 – 82% total landing (Nguyen and Nguyen, 2005b). The present study showed a similar pattern in changes of the composition of the demersal fisheries resources as the above mentioned studies. The development of the contrary pattern of the high commercially important and low economically valuable species can be explained by the fast growth of fishing pressure and gear selectivity. The structure of aquatic community has been probably strongly affected by dramatic growth in fishing pressure in recent years.

Groups of ecologically sensitive species are representative for species having a long life cycle and low fecundity. They also have a low growth rate and high vulnerability caused by fishing activity and/or environment, even though high variation in sampling hauls was observed. The general trend in ecologically sensitive fish species seem to be an obvious decrease.

This is in line with a number of previous studies on general marine fish resources as well as the demersal fish stock of the region. Decreasing in abundance of the ecologically sensitive species is normally a result from rapid growth in fishing pressure and consequently can be drop the mean trophic level (TL_m) of the marine food web (Pauly *et al.*, 1998). Decline in abundance of the demersal ecologically sensitive fish species of the Northern fishing grounds and the Southern fishing grounds has been reported in some papers e.g. Nguyen and Dang (2005), Nguyen and Dang (2007), Nguyen (2007). Most of the sensitive fish species do not account for a high proportion of the catch composition of most fishing gears, however, they play very important roles in ecosystems. Sharks and stingrays are normally caught as “by catch”. But nowadays, fishermen are also targeting them as a consequence of the overall decline of the fisheries resources. Thus this fish group should be considered and paid attention to in fisheries management considerations.

- **Biodiversity**

The biodiversity indices indicate the wellbeing of the ecosystems. In assessing the demersal fish resource under the ecological aspect, species biodiversity index (Shannon-Weinner index, H’), species richness (Margalef’s index, D) and species evenness (Pielou’s index, J’) were used in the present work to analysis the demersal fish resources in the Southeast and Southwest waters of Vietnam. High variations in biodiversity indices imply unstable fish stock in terms of balance between component species. Certain fish species dominating in the demersal fish community there were observed. This also reflects the fishing effort with respect to the selectivity pattern and policy. In recent years, Puffer fish are not allowed to be caught, transported or marketed because of the high risk of poison content in their meat which can poison consumers, particularly species belonging to the family Tetraodontidae. Thus Puffer fish have become more and more abundant in most Vietnamese waters (Nguyen 2007). The migration of some fish species such as Japanese leather jacket fish from The Philippines water (from the southern part of South China Sea) to offshore water of the Southeast and Southwest Vietnam has also caused a strong influence with regards to the balance in individual number and/or biomass between component species in that water.

The sampling gear is probably highly selective in the sense of sampling species and inconsistencies in towing speed also create a bias in estimating indices. In addition, sample size or number of sampled hauls taken is normally sensitive to the final value estimated of biodiversity indices such as species richness, evenness index etc. The study results can describe the fish community structure of the demersal fish resource. Given that the sampling system is constant the research results give some indication of the status of the resource which could be useful to fisheries managers. Indication of unstable fisheries resources reflect in high fluctuation of indicators should encourage managers that the other relevant indicators including environmental, biological indicators, fishing efforts, consumer behaviours etc. should also be used. The interlinks between these indicators can help and/or assist to assess the status of the fisheries resource. Management policy should be made on the basis of these combined indicators.

- **Fish assemblages**

This paper is a preliminary study on the assemblage of the demersal fish stock of the Southeast and the Southwest areas of Vietnam regardless of habitats and depth zone. Samples taken by the seven bottom trawl surveys are categorized into Southwest monsoon and Northeast monsoon surveys. The average number of fish individuals by stations and survey seasons are used for the input data of Ward hierarchical cluster analysis. The parametric bootstrap technique applied for investigating cluster of fish families here show the seasonal patterns in the structure of the demersal fish community. During the Southwest monsoon, there are 08 main clusters of fish stock distributing in the Southeast area in which 02 groups are relatively isolated from the others. Fish stock tend to school or aggregate together during the Northeast monsoon, four main groups of fish are found based on the ward hierarchical analysis and one of them is fairly isolated from the rest of families.

The analysis indicated the existence of five main fish groups in the Southwest area during the Southwest monsoon as well as the Northeast monsoon. The results might be biased because of the relatively few number of sampling stations. No considerable change in the structure of the demersal fish assemblage in the Southwest water was detected when it comes to number of clusters between the two monsoon seasons. However, the number of fish families within each cluster was highly variable by monsoon season and the component fish families of each group showed seasonal fluctuations. Fish behaviour is a fairly complicated issue and has complex interlinks with the surrounding environment. This study is not focused on exploring in detail the structure of the demersal fish stocks of the Southern waters of Vietnam but rather to achieve a preliminary broad view of the structure of demersal fish resources there.

- **Sampling strategy**

In order to monitor the fish stock in the Southern waters of Vietnam, the routine annual or multi annual surveys have to be planned and carefully designed. Seasonal variation can be obtained by doing surveys during each monsoon season. The sampling gear, towing speed and vessel used should be strictly standardized. Samples of fish species composition should also be consistent in terms of sample size and species identification. The stratum of 20 – 30 m; 30 – 50 m, 50- 100 m and 100 – 200 m depth of the Southeast water correspond to 24,640 km^2; 68,120 km^2; 51,950 km^2, and 27,910 km^2. In percentages, they are respectively 14%; 39%; 30% and 16% of the total survey area. Number of stations allocated in each stratum is not corresponding to its proportion of area. Particularly, very few stations were assigned for the stratum of 20 – 30 m depth (3 stations, or 6% of the total numbers). The number of sampling stations allocated to the Southwest area a total of 16 stations which is relatively low. In the Southeast area every 3,100 km^2 has one sampling station while in the Southwest area this proportion is 4,800 km^2. Thus number of station in each survey area should be in proportion to the survey area.

- **Data analysis**

Coefficient of fishing catchability (q) is one of the most important coefficients in fish stock assessment. In the present context, not only Vietnam but also in other member countries of the Southeast Asian area, high diversity in number of fish species, complex fish size distribution and habitats are challenges for estimating the value of q for each single species. The assumption of the same constant q for all species should be taken into account in estimating and interpreting fish abundance, biodiversity and in mapping spatial distribution of fish resources. Ignoring potential differences in catch ability and availability by species or grounds can cause biases or systematic error. Consistent methods of sampling and data analysis are also of high importance for the quality of trawling indices and indicators.

Due to the high variation in samples taken by bottom trawl survey, confidence interval of each estimate should be calculated based on bootstrapping or relevant techniques. The confidence intervals are necessary for meaningful interpreting of the results and in decision with respect to policy issues.

6 CONCLUSION

- Abundance of the demersal fish stock of the Southeast and the Southwest areas of Vietnam has decreased considerably during the past five year period, 2000 – 2005.

- Economically important fish species have significantly dropped in abundance and replaced by low commercially valuable species.

- The CPUA of the ecologically sensitive fish species indicated a declining abundance both in the Southern sub-areas in the period from 2000 to 2005.

- The demersal fish resource of the Southern water of Vietnam shows the seasonal variations in both abundance and spatial distribution. During the Southwest monsoon, fish tend to have wider distribution while aggregations are observed during the cold season, the Northeast monsoon.

- Density of the demersal fish resources in offshore waters, over 100 m depth (the Southeast area) and over 50 m depth (the Southwest area) are significantly higher compared to the shallower area.

- The biodiversity of the demersal fish resource is highly variable by stratum and survey. Dominance of some low economically important fish species negatively affects the biodiversity index (H’), species richness index (D) and species evenness index (J’). General speaking, the demersal fisheries resource of the study area are not ecologically stable.

- Preliminary results of assessment on structure of the demersal fish community show a seasonal variation in fish assemblages in the Southeast area and a pronounced difference between the Southeast and the Southwest waters.

- For the future surveys scheduled should be timed continuously, annual surveys and survey grid or a station system should be considered the stratified areas. Number of sampling stations must be homogenously allocated in terms of the survey area.

- Potential future surveys should be carefully designed following the stratified random sampling theory and conducted annually or multi annually.

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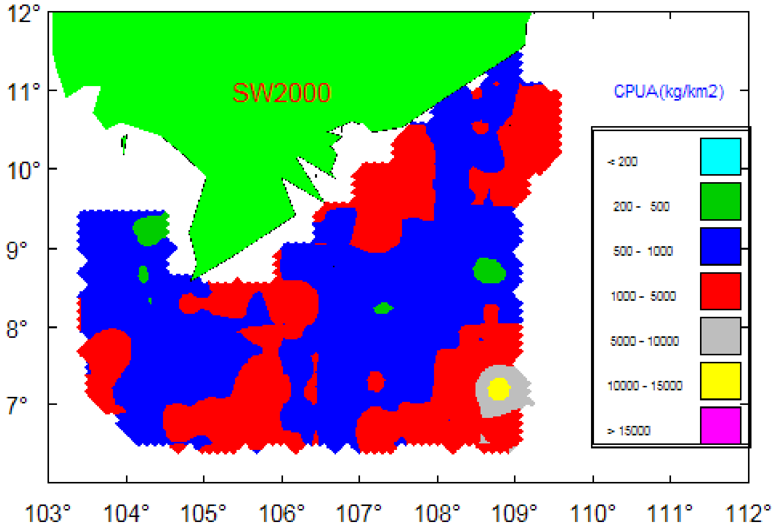
7 APPENDIX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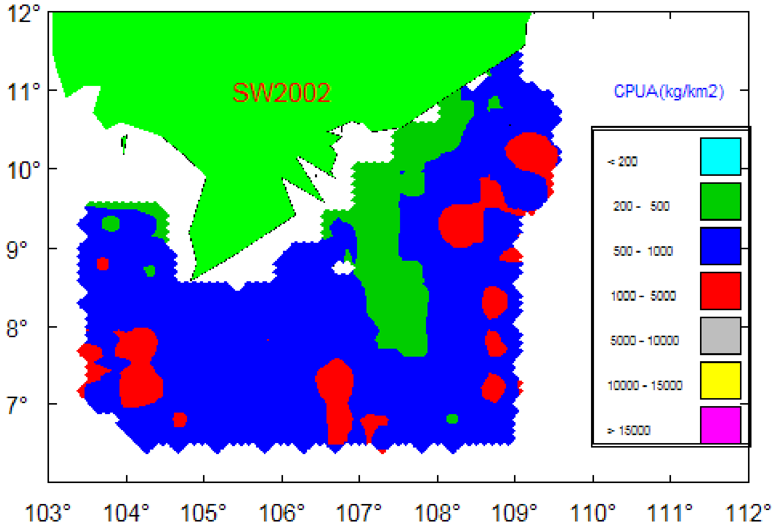
CPUA(kg/km2)
< 200
200 - 500
500 - 1000
1000 - 5000
5000 - 10000
10000 - 15000
> 15000
12°
11°
10°
9°
8°
7°
103° 104° 105° 106° 107° 108° 109° 110° 111° 112°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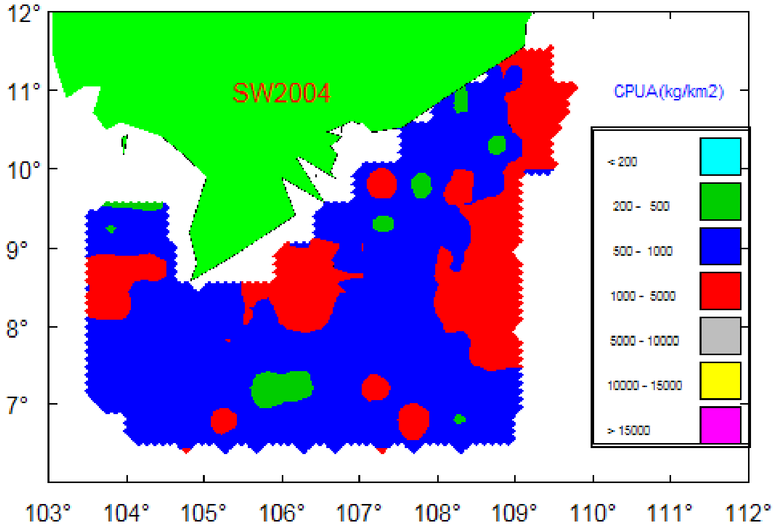
CPUA(kg/km2)
< 200
200 - 500
500 - 1000
1000 - 5000
5000 - 10000
10000 - 15000
> 15000
12°
11°
10°
9°
8°
7°
103° 104° 105° 106° 107° 108° 109° 110° 111° 112°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500 - 1000
1000 - 5000
5000 - 10000
10000 - 15000
> 15000
12°
11°
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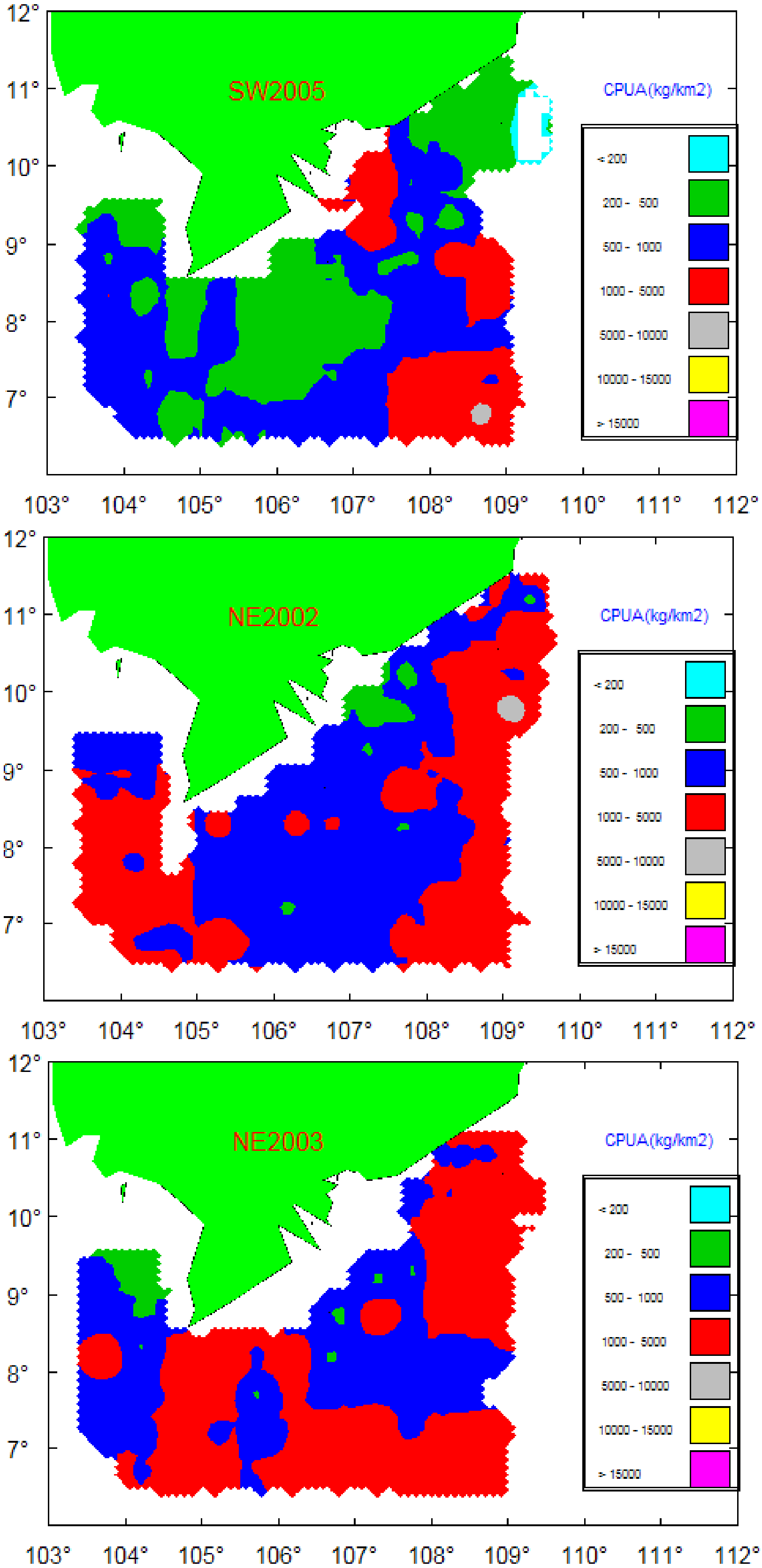
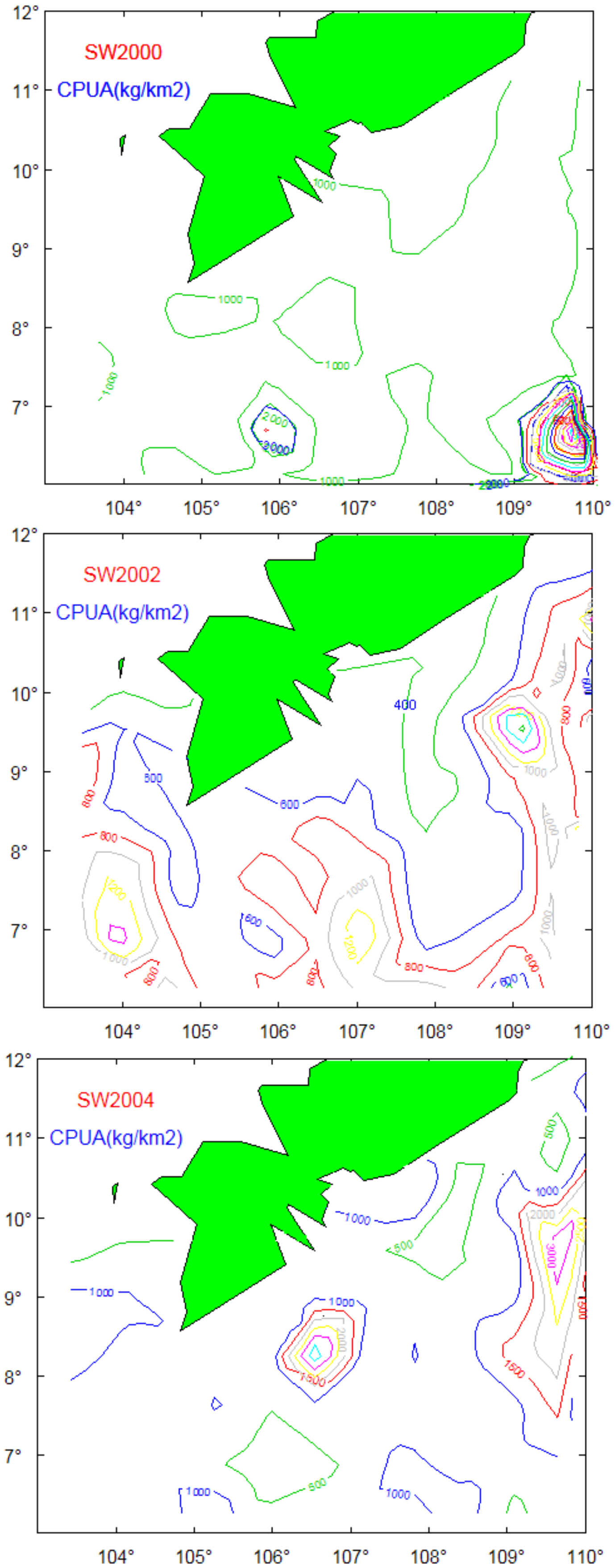
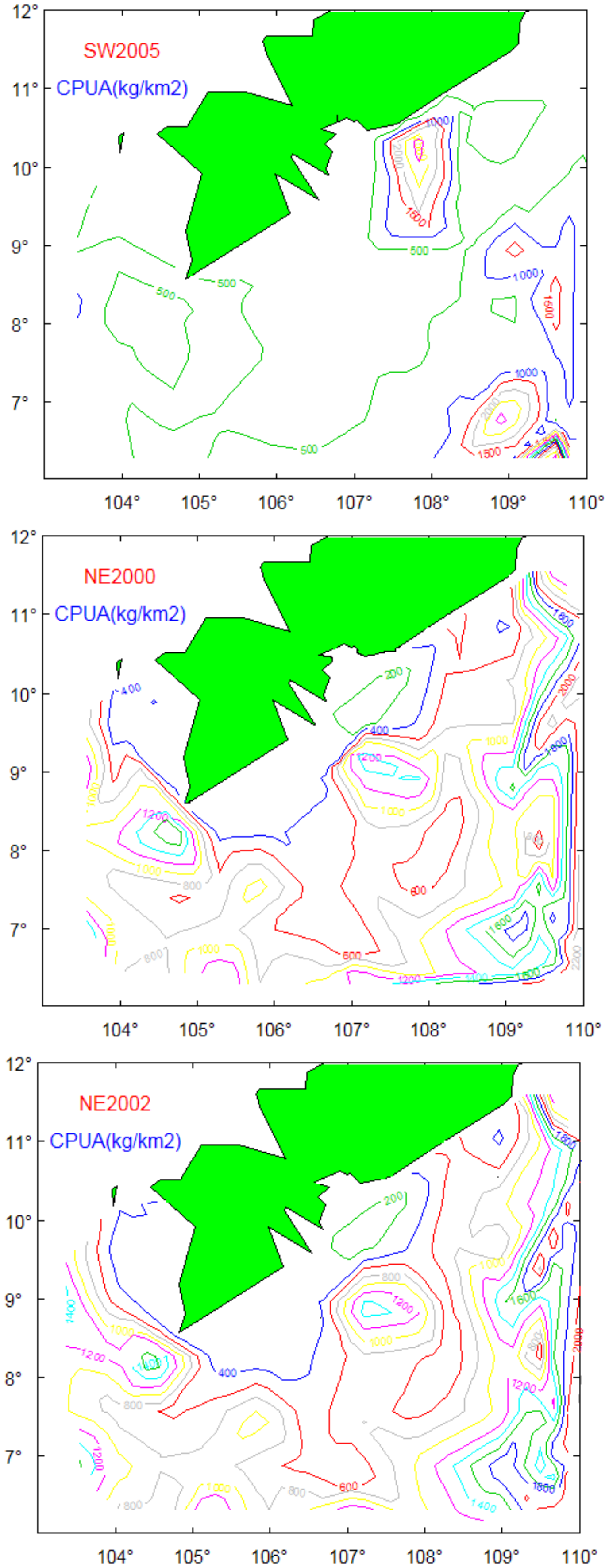
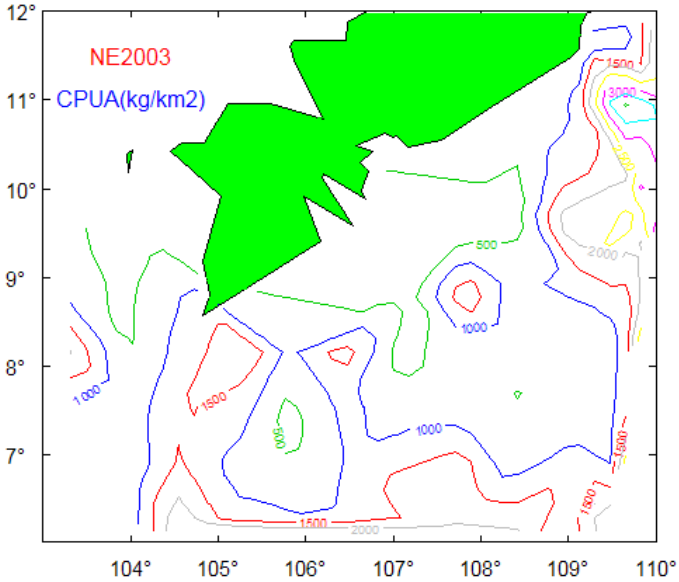
9°
8°
7°
103° 104° 105° 106° 107° 108° 109° 110° 111° 112°



Annex1. Kriging maps of the demersal fish stock (CPUA) of the Southern water of Vietnam based on the bottom trawl surveys conducted during 2000 – 2005 (cont.).


SW2000
CPUA(kg/km2)
SW2002
CPUA(kg/km2)
SW2004
CPUA(kg/km2)
12°
11°
10°
9°
8°
7°
104°
105°
106°
107°
108°
109°
110°


SW2005
CPUA(kg/km2)
NE2000
CPUA(kg/km2)
NE2002
CPUA(kg/km2)
12°
11°
10°
9°
8°
7°
104°
105°
106°
107°
108°
109°
110°



Annex 2. Contour maps of the demrsal fish resource (CPUA(kg/km^2)) of the Southern water, Vietnam, based on bottom trawl surveys, 2000 – 2005.

Annex 3. Shannon-Weiner index (H') of the demersal fish resource excluding the dominated species of the Southeast and Southwest areas of Viet Nam based on the bottom tral surveys monitored during 2000 – 2005.

Area	Survey	<30m	30-50m	50-100m	100-200m	Total
SE	SW2000	***4.13***	***4.98***	***4.70***	***4.15***	4.64
	SW2002	***4.05***	***4.65***	***4.56***	***4.37***	4.49
	SW2004	***3.87***	***4.86***	***5.36***	***5.18***	4.92
	SW2005	***4.25***	***4.75***	***5.26***	***4.31***	4.76
	NE2000	***4.31***	***4.42***	***4.78***	***4.00***	4.45
	NE2002	***4.41***	***5.15***	***4.55***	***4.50***	4.76
	NE2003	***4.12***	***5.29***	***4.80***	***4.15***	4.79
SW	SW2000	***3.71***	***5.12***	***4.49***	na	4.56
	SW2002	***4.66***	***4.62***	***4.24***	na	4.49
	SW2004	***4.23***	***5.27***	***4.79***	na	4.85
	SW2005	***4.29***	***4.58***	***4.54***	na	4.50
	NE2000	***4.57***	***4.57***	***4.53***	na	4.55
	NE2002	***4.16***	***4.49***	***3.49***	na	4.05
	NE2003	***4.59***	***4.78***	***4.74***	na	4.72

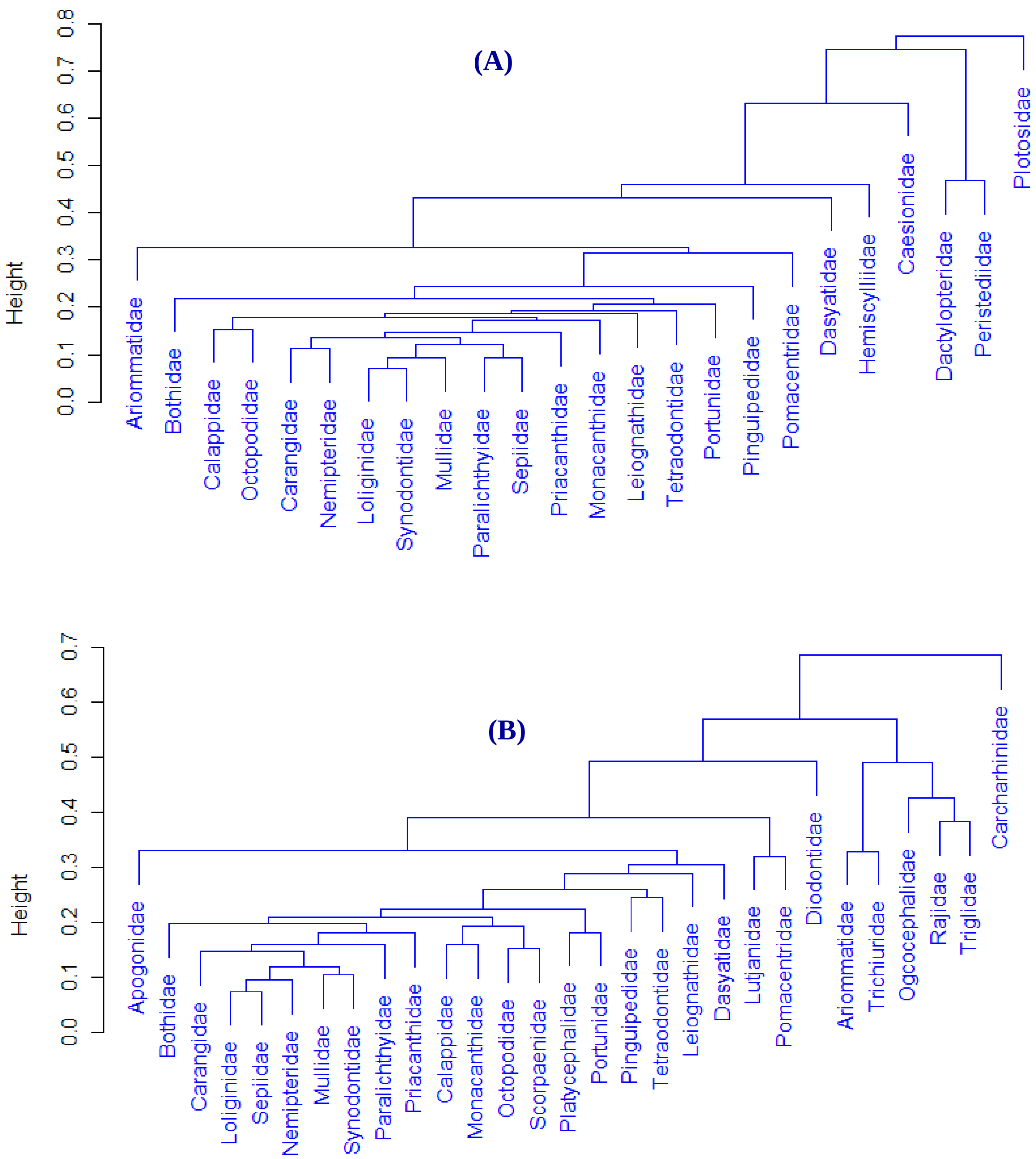
Annex 4. Margalef index (D) of the demersal fish resource excluding the dominated species of the Southeast and Southwest areas of Viet Nam based on the bottom tral surveys monitored during 2000 – 2005.

Area	Survey	<30m	30-50m	50-100m	100-200m	Total
SE	SW2000	7.40	17.67	14.23	10.53	14.02
	SW2002	7.76	16.28	14.32	10.55	13.55

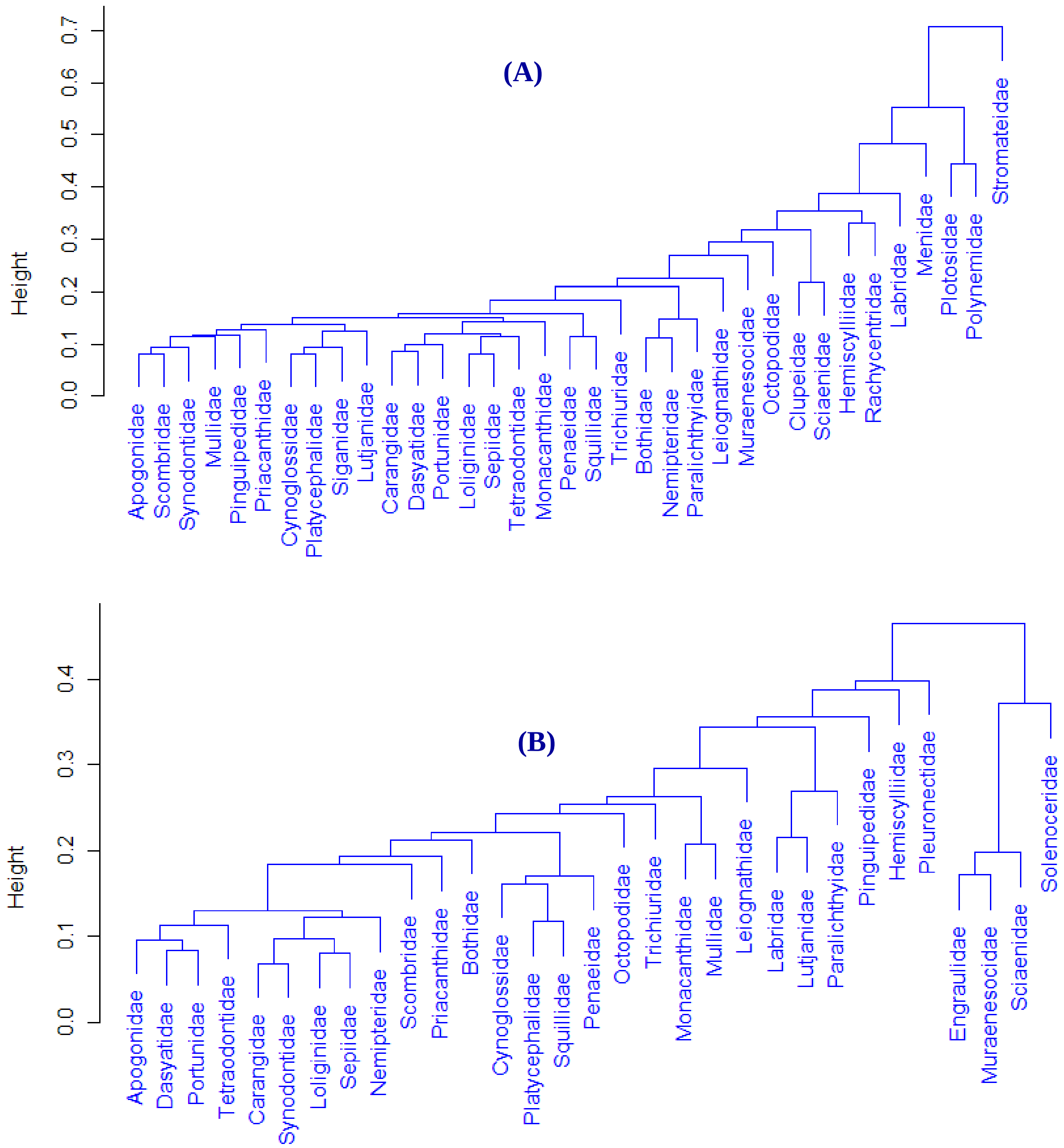
	SW2004	6.91	16.45	14.78	14.55	14.28
	SW2005	9.56	16.23	14.26	10.59	13.77
	NE2000	7.29	13.93	14.78	9.84	12.57
	NE2002	8.64	16.70	13.58	11.08	13.70
	NE2003	3.56	13.86	14.40	7.96	11.60
SE	SW2000	8.77	10.13	8.41	Na	9.18
	SW2002	10.68	10.33	9.12	Na	9.98
	SW2004	10.52	11.56	7.45	Na	9.83
	SW2005	11.09	12.34	9.72	Na	11.10
	NE2000	9.92	11.42	8.32	Na	9.95
	NE2002	8.72	9.17	7.83	Na	8.58
	NE2003	10.23	9.38	10.58	Na	10.01

Annex 5. Pielou's index (J') of the demersal fish resource excluding the dominated species of the Southeast and Southwest areas of Viet Nam based on the bottom tral surveys monitored during 2000 – 2005.

Area	**Survey**	**<30m**	**30-50m**	**50-100m**	**100-200m**	**Total**
SE	SW2000	0.70	0.66	0.65	0.62	0.65
	SW2002	***0.67***	***0.62***	***0.62***	***0.65***	0.63
	SW2004	***0.65***	***0.65***	***0.74***	***0.72***	0.69
	SW2005	***0.67***	***0.64***	***0.72***	***0.65***	0.67
	NE2000	***0.74***	***0.61***	***0.65***	***0.60***	0.64
	NE2002	***0.71***	***0.69***	***0.63***	***0.66***	0.67
	NE2003	***0.91***	***0.73***	***0.65***	***0.64***	0.72
SE	SW2000	0.59	0.77	0.71	na	0.71
	SW2002	0.70	0.68	0.66	na	0.68
	SW2004	0.63	0.77	0.79	na	0.75
	SW2005	0.64	0.66	0.71	na	0.67
	NE2000	0.70	0.67	0.72	na	0.70
	NE2002	0.64	0.69	0.56	na	0.63
	NE2003	0.69	0.73	0.72	na	0.72



Annex 6. Assemblages of the main demersal fish family in the Southeast area of Vietnam, estimated by ward hierarchical cluster analysis with Bray - Curtis distance metric measurement, in the Southwest monsoon (A) and Northeast monsoon (B), based on bottom trawl surveys conducted in the period from 2000 to 2005.



Annex 7. Assemblages of the main demersal fish family in the Southwest area of Vietnam, estimated by ward hierarchical cluster analysis with Bray - Curtis distance metric measurement, in the Southwest monsoon (A) and Northeast monsoon (B), based on bottom trawl surveys conducted in the period from 2000 to 2005.