Fishery Resources of the Gulf of Tonkin, Vietnam:
The state of indicator species monitored by bottom trawl surveys

By

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“ Xin cảm ơn!!! Tôi yêu tất cả mọi người!!!”

ABSTRACT

In the period 2001-2004 four bottom trawl surveys were carried out in the Gulf of Tonkin to investigate the aquatic stocks in the Vietnamese sector (67,370km^2). The Gulf has tropical characteristics and great diversity of commercial species, but lately fishing pressure seems to have grown excessively. The swept-area cruises followed a stratified random design, with a fixed station grid imposed on four depth intervals between 0 and 100m, and internationally accepted survey protocols. Three commercially important indicator species which differ in life-history and habit were selected for appraisal using commonly accepted single-species metrics. The methodology for data treatment included spatial statistics (kriging) to describe seasonal trends in distribution, and non-parametric re-sampling (bootstrapping) of station data combined with maximum likelihood analysis of maturation curves to estimate both total and spawning standing biomass. Chinese squid (*Loligo chinensis Gray 1849)*, a small pelagic resource with very high turnover rate, showed a marked decline in standing biomass, from 16,000 tones in 2001 to 3,000 tones in 2004 (CV 27-14%). Remarkably, spawning biomass remained at stable 1,000 tones, and large squid (13cm ML and above) dominate the population. The Greater lizardfish (*Saurida tumbil (Bloch, 1795))*, a very valuable, and slow growing, demersal species, showed stable levels of total biomass, at around 3,000 to 5,000 tones (CV 13-25%). However, spawning biomass showed a marked 22% decline to 732 tones in 2004, despite a decrease in the maturation size, which might be a compensatory mechanism. Simultaneously, most of the stock was comprised of fish in the 11- 24cm range, and this is a marked constriction from the original 5-35cm range. The Largehead hairtail (*Trichiurus lepturus Linaeus*, *1785*), a large pelagic, has become the major commercial pelagic species in the South China Sea. In the Gulf the total biomass declined from 3,600 to 2,600 tones (CV 24-29%), but a highly unreliable estimate (CV 50%) raises it to 15000 tones in 2004. The estimates of spawning biomass showed equal development, varying from 2,500 tones in 2001 to 1,500 tones in 2003, and raising to 4,000 tones in 2004. Largehead hairtail also shows a marked constriction of sizes in 2004, and the largest sizes are now about 1/3 of L_∞. Although the squid showed a permanent coastal affinity (20-30m deep) and is exposed to the extremely large and un-controlled coastal fleet year round, it seems to have the best potential for recovery. The Largehead hairtail and the Greater lizardfish showed coastal affinity during the NE monsoon but moved to offshore grounds in the SW monsoon. Management of these trans-boundary populations is not sole responsibility of Vietnam and requires co-ordination with China in the South China Sea.

ABREVIATIONS

ALMRV	Assessment of the Living Marine Resource in Vietnam
Bs	Total Stock Biomass
CPUA	Catch per Unit Area
CPUE	Catch per Unit Effort
DANIDA	Danish International Development Assistance
Eq.	Equation
HP	Horse Power
Lm50	Length at which 50 percents of the individuals fish in the population matured
Mapinfor 6.0	The software to work with map, delivered by Mapinfor Corporation
MOFI	Ministry of Fishery
NE	Northeast monsoon (lasting from November to March next year)
NE2001	Survey in Northeast 2001
NORAD	Norwegian Agency for Development Co-operation
Photoshop8.0	Software to edit pictures, copyright by Adobe Photoshop
RDMR	Department of Marine Resources, RIMF, Hai Phong, Vietnam
RIMF	Research Institute for Marine Fisheries, Hai Phong., Vietnam
q	Catchability, where $0 \leq q \leq 1$
SB	Spawning Stock Biomass
SLD	Stratified Length Distribution
SYSTAT11	Statistics software delivered by Systat Software Inc. (SSI) USA
Statplus	Tool in excel written by Berk-Carey
Stratum 1	0-20m depth
Stratum 2	20-30m depth
Stratum 3	30-50m depth
Stratum 4	50-100m depth
SW	Southwest monsoon (lasting from May to September)
SW2001	Survey in Southwest 2001
SW2003	Survey in Southwest 2003
SW2004	Survey in Southwest 2004

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INTRODUCTION

1.1. The Gulf of Tonkin and its environment

Located in the South China Sea, the Gulf of Tonkin is shared between Vietnam, in the northwest to southwest, and China, in the northeast (Figures 1 and 2). The gulf is relatively shallow, with an average depth of about 38.5m, and is less than 50m deep in 60% of its area (RIMF. and IMR. 1979). The shelf is relatively flat and hollow shaped offshore (Dao 2004). Thousands of small and large islands, including Bach Long Vi, Hon Me, Hon Mat, form a famous archipelago in the northern sector. Along with Halong Bay and Cat Ba Bay this archipelago is an important component of the gulf, affecting its oceanography and marine ecosystems. Another important geographical feature of the Gulf is large amount of estuaries. There is, on average, a major estuary every 20km of the Vietnamese coastline (Pham 2001). In addition, many river outlets permeate the coastline. These outlets belong to mainly two river systems, the Red River and the Thai Binh River. It has been estimated that during the rainy season these two river systems alone discharge 120 billion m^3 of freshwater into the gulf (Nguyen 1984), shaping much of its coastal regime (Vu *et al.* 1993; Vu 1997).

The climate of the gulf is strongly modulated by the monsoons. The Southwest monsoon (SW) and northeast monsoon (NE) are the two dominant regimes, with transition periods in April and October (Vu *et al.* 1993; Vu 1997). The Southwest monsoon occurs in the period of May to September, and the Northeast monsoon from November to March. During the Northeast monsoon, the weather is dry and cold, and during the Southwest monsoon the weather is wet, hot, and propitious to storms (Pham 2001). Average air temperatures during the SW and NE monsoons are 27-29^o C and 16-21^o C, respectively. The average rainfall is only 10-120 mm in northeast monsoon, and increases to 1,500 to 1,800 mm during the southwest monsoon when the salinity of coastal areas can drop to as low as 5‰ (Pham 2001). During the Southwest monsoon currents from the Gulf of Thailand flow northwards and clockwise along the western coast of Hainan Island (China), merging with other northeast currents (Uda and Nakao 1973; RIMF. and IMR. 1979; Dao 2004), as shown in Figure 1 (a). During the northeast monsoon, surface currents flow into the gulf from the Pacific Ocean. The water masses pass northwards along the western edge of the Hainan Island and flow counter-clockwise along Vietnam's coastline before they mix with warmer water in the central areas of the gulf (Wyrtki 1961), as shown in Figure 1 (b).

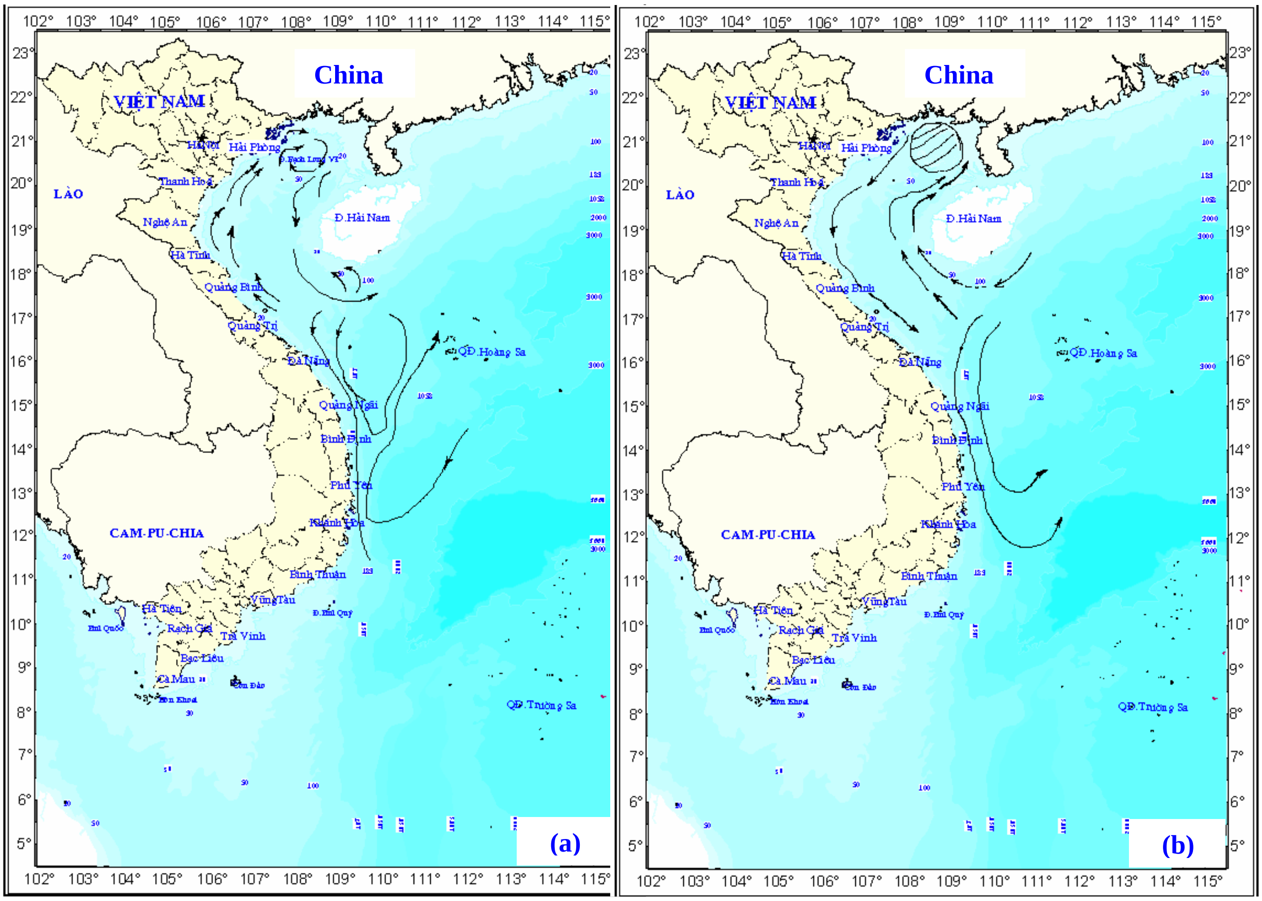


Figure 1. Water currents in the gulf of Tonkin in the southwest (a) and northeast monsoons (b) Source: (Nguyen *et al.* 1997; Pham 2001)

1.2. Marine Fish Resources in the Gulf of Tonkin

The living resources of the Gulf of Tonkin bear tropical characteristics and great species diversity. Fish species tend to be small in size, mostly in the range 10 to 20cm (Pham 2001), and relatively short lived. Most commercial species have longevities in the range 3 to 4 years. Normally fish occur in small shoals, but mixed-species aggregations are also often observed (RIMF. and IMR. 1979; Pham 2001; Dao 2002). Previous research indicated the existence of 960 fish species, belonging to 475 genus and 162 families, in this area (Nguyen 2002). According to Pham (2001), 80% of the fish species have demersal habit and 20% are pelagic and while some (20%) of them occur only offshore most fish (80%) inhabit coastal areas.

Fish resources in the gulf have been categorized into four main ecological groups: small pelagic fish, big pelagic fish, demersal and coral-reef associated fish. In addition to short life span, many fish species have high fecundity, several spawning peaks along the year (Bui *et al.* 2001), and short migratory routes (Pham *et al.* 2000; Dao 2002). Moreover, diurnal vertical migration is characteristic of most fish stocks (Bui *et al.* 2001; Nguyen 2001). Owing to lack of adequate fishery-dependant information, the abundance of fish resources in the Gulf of Tonkin has historically been estimated with basis on bottom trawl (research) surveys. A time-series of such estimates of total fish biomass exists, including (in metric tones) 250,000 tones (RIMF. and IMR. 1979), 681,166 tones (Bui 1997), 525,000 tones (Chu 1998), 505,972 tones (Pham *et al.* 2000) and 557,272 tones (Dao 2002).

1.3. Overview of the Fisheries in the Gulf of Tonkin

Fisheries is one of the most important economic sectors of Vietnam, and in recent decades fish production has ranked fourth in terms of total exports behind petroleum, textile, and footwear. The total export value of aquatic products soared from $205,000 in 1990 to $1,478,609 in 2000, and $2,240,000 in 2003 (MOFI 2004). Growing exports reflect also the increase in catches and fishing effort. In 1990, a total of 72,723 fishing boats contributed to landings of about 709,000 tones. Although the total number of boats only marginally increased to 79,768 and 83,122 units in 2000 and 2003, estimated landings have rocketed to 1,280,590 tones and 1,426,223 tones (RIMF. 2004).

The increased fishing effort has negatively affected many fish stocks. Signals of “over-fishing” such as declined catch rate (Russell 1931; Schaefer 1954, 1957) and size of the individual fish in the catches (Caddy and Mahon 1995) are now detected in many fisheries and fishing grounds (Pham 2001; Nguyen 2002), with particular incidence in coastal areas (Chu *et al.* 2001). Landings of high valuable species have dramatically declined and are being replaced by less valuable fish (Dao 2002; Nguyen 2002).

The Gulf of Tonkin has traditionally played an important role in Vietnamese fisheries, not merely in terms of total production but also in employments. In 2001, for instance, 21,600 active vessels accounted for the registered 182,229 tones of fish products (RIMF. 2004). Trawlers account for about 29% of these vessels, gill-netters 12%, long liners 13% and the rest for by other fleets (Nguyen 2001). Approximately 94% of the vessels operate in shallow waters (<20m depth), and 95% of the trawlers are small boats (engine <90HP) involved in prawn fisheries (Nguyen 2001). The most utilized cod-end mesh size of the trawls varies from 18mm to 25mm. The catches in coastal waters (<30m depth) account for approximately 96% of the total yield of the gulf (RIMF. 2004). A considerable proportion of the catches are non-target fish (or by-catch), ranging from 81% in the small fishing fleets (<90HP) to about 60% in the higher capacity fishing fleets (>90HP). According to the available fishery statistics, the total yield of the gulf has doubled in the course of ten years, from 93,120 tones in 1991 to 182,229 tones in 2001. Simultaneously, the average catch rate has plummeted from 1.34 ton/ HP/ year in 1985 to 0.34 ton/HP/year in 1997 (Nguyen 2001), and it is known that e.g. pair-trawlers have been operating with losses recently (Nguyen 2001, 2001).

1.4. Research history of the fish stocks in the Gulf of Tonkin

In the absence of reliable fishery-dependant data estimates of fish abundance from research surveys become an imperative to assess the development of exploited stocks (Smith 1990; Consquest *et al.* 1996; Chen *et al.* 2004). A number of research surveys has historically been conducted in the gulf, including demersal cruises under the auspices of the Vietnam-China Cooperation Program (1959-1962); the Vietnam-Soviet Union research programmes (1960-1961; 1979-1988); the Vietnam-Norway combined acoustic mid-water trawl surveys for small pelagic fish in the whole of Vietnamese waters, with the R/V Bien Dong (1977-1978); the National Project on Conservation of the Marine Resources (1990-1998); and notably, the Vietnam-Denmark assessment programme of offshore marine resources of the whole Vietnam, supported by the Danish government since 1996. Although a large number of surveys has been performed, the survey design and research objectives have changed, and the information on resource abundance lacks continuity and consistency. Since 2001, however, four bottom trawl surveys have been performed in the Gulf of Tonkin using the same protocol, vessel and gear, as well as a fixed-station stratified system. A potential drawback of this protocol is that all cruises, except one, have been conducted during the SW monsoon. The data may therefore miss the variable distribution in space and time typical of tropical fish assemblages (Dang 2002; 2004). Nonetheless, these four surveys represent an important reference for the long-term assessment and management of fish stocks (Korsbrekke 2000; Chen *et al.* 2004).

1.5. Objectives and approach

The two main questions that this work attempts to address is whether we can detect changes in the state of fish stocks in the Gulf of Tonkin, and whether seasonal changes in fish distribution may affect our perception of the state of the stocks. Rather than attempting a complex ecosystem or fish assemblage analysis, it was opted to follow a single-species approach with basis on three indicator species. The criteria for selection of these three species were that they should be representative of major resource groups (small pelagic, large pelagic and large demersal), that they should have economic and fishery importance, and, thereby, that an adequate amount of biological data could be found. The sources of information available were the four bottom trawl surveys performed in the Gulf of Tonkin in the period 2001 to 2004, as a part of ALMRV project supported by DANIDA (Danish International Development Assistance). These data were quality insured and made available by the ALMRV project, the Research Institute for Marine Fisheries (RIMF) and the Research Department for Marine Resources (RDMR).

Metrics normally utilized to assess the state of exploitation of single-species include the abundance of the total stock and spawning stock, as well as changes in size frequency distribution or mean size (e.g. Beverton & Holt 1957; Nikolski 1963; Jennings *et al.* 2001). Changes in the size at maturation were not thoroughly dealt with in traditional fishery theory, but impacts of fishing on life-history parameters are getting increasingly more attention (Jennings *et al.* 2001). These are the metrics that are dealt with in this work, with sole basis on fishery-independent observations (surveys).

The major drawback of relying only on bottom-trawl survey observations is the large uncertainty implicit in the resulting estimates. Research cruises are very costly and demanding in manpower and operational expertise (Sparre & Venema 2000). Therefore, the sampling coverage tends to be low, or very low. This is particularly unfortunate because fish populations are normally spread across large areas and the efficiency of sampling is very variable. Estimates obtained in bottom trawl surveys may be biased or imprecise owing to a multitude of factors, such as fishing time (Aglen *et al.* 1999; Korsbrekke and Nakken 1999; Stencholt *et al.* 2002), catchability of the gear (Prager 1994; Tho'rarinsson and Jo'hannesson 1997; Godo *et al.* 1999; Haddon 2001; Benoit and Swain 2003), water depth and topography (Maynou and Sarda' 2001; Zimmermann *et al.* 2003), weather (Swain *et al.* 2000), as well as the fish biology (Tho'rarinsson and Jo'hannesson 1997; Ragonese *et al.* 2005) and distribution, a very dynamic variable (Gulland 1969). Despite the widespread utilization of stratified sampling designs e.g. (Holden and Raitt 1974) many fishery statisticians still struggle to increase precision in survey-based resource estimates. A particularly difficult task is to find a means to calculate reliable confidence intervals of estimates when sample sizes are small and observations highly skewed. In line with recent developments in fishery statistics (Smith 1997; Philip 2001; Schnute and Haigh 2003), attempts were made in the present work to increase precision by utilizing non-parametric re-sampling methodology. In addition, spatial statistics were used in an attempt to describe changes in fish aggregation over time (seasons).

1.6. Brief description of the three indicator species

Following the suggested typology by Dao (2001), Pham (2001) and Dao and Dang (2002), the Greater lizardfish (*Saurida tumbil* (Bloch 1795)), is defined as a demersal fish, the Large-head hairtail fish (*Trichiurus lepturus,* Lineaus 1785), a large pelagic fish, and the Chinese squid (*Loligo chinensis* Gray 1849), a small pelagic species, were selected in this investigation. These three species account for a considerable proportion of the catches, normally within 3% to 8% in all surveys. Each species normally accounts for more than 1% in the landings and is, thereby, considered to be an economically important species (Pham 2001; Dang *et al.* 2002).

❖ *Largehead hairtail*

(Trichiurus lepturus Linaeus, 1785)
Source: (Jonney 2005)

Large-head hairtail (Trichiuridae family*)* occurs throughout tropical and temperate waters of the world between 60° N- 45° S and 180° W-180° E (Froese and Pauly 1997). This is one of the most important commercial species in China (Luo 1991) and Taiwan (Cheng *et al.* 2001), and accounts for 10-20 % of the total Chinese catches, or about 750,000 tones (Clause 1995). In Vietnamese waters this species is the target of a number of fisheries, notably bottom trawls, gillnet, long lines, driftnets and purse seines (Bui 1999; Dao 2001; Pham 2001; Dang and Dao 2002). Large-head hairtail is a relatively large pelagic fish species, with a maximum body length of 234cm (Calor, 1994), corresponding to a maximum weight of 5.0 kg and a longevity (t_{max}) of 15 years. This species is widely found in the waters of 0-400m depth. Juvenile fish feed on euphausiids, small planktonic crustaceans and small pelagic fish. Adults feed mainly on fish and squid, as well as crustaceans (Nakamura and Parin 1993). This species is known to perform diurnal migrations up and down the water column.

❖ *Greater lizardfish*

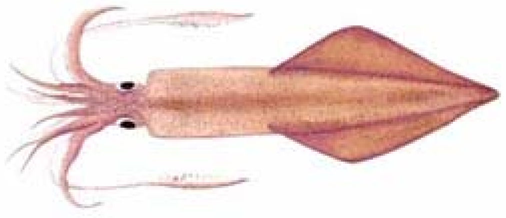
Greater lizardfish (Synodontidae family) is a demersal or reef-associated species that may perform migrations between freshwater and the sea (amphidromous) (Riede 2004). It is widely distributed in tropical areas between

(Saurida tumbil Bloch, 1795)
Source: (Randall 1995)

34° N and 28° S, including the Indo-West Pacific, east to southeast Asia, and Australia (Russell and Houston 1989). The maximum body size is approximately 60cm (Shindo 1972), corresponding to a t_{max} of 7 years. An important habitat of this species are muddy bottoms of the continental shelf down to about 100m deep (FAO 1974). It feeds on fishes, crustaceans and squid (Sommer *et al.* 1996). This species is mainly caught by bottom trawls (FAO 1974; Pham and Nguyen 1997; Dang *et al.* 2002; Nguyen 2002), but it is known to perform diel migrations from the bottom.

❖ *Chinese squid*

Chinese squid (Loliginidae) is a neritic species found at depths ranging from 15 to 170m. This is a very fast growing and short lived species: its longevity has been described as one year, and the adult stage is reached within only 120 to 220 days (Jackson and Choat 1992; Chotiyaputta 1997). The maximum mantle length is around 30cm (FAO 1980). This one of the most important squid species found in Vietnam where it accounts for a considerable part of the annual landings (Pham and Nguyen 1997; Nguyen 2001; Pham 2001; Dang and Dao 2002; Dang *et al.* 2002). Chinese squid are positively phototactic and are captured by many different gears, namely trawls, purse seines, cast nets, stick falling cast nets, hook and lines and others, often combined with light sources. In China it accounts for 90% of the loliginid catch, what probably resulted in its over-fishing (Guo & Pimao 2000), and in the Gulf of Thailand for approximately 40% of the catch of the trawler fleet fishing in waters 15 to 30m deep. Chinese squid are found in the Western Pacific, South and East China Seas to Japan, Arafuru Sea, and from North-eastern Australia to New South Wales. Chinese squid form large aggregations at certain periods of the year, and spawning takes place throughout the year with peaks in February to May, and August to November. This may result in two generations within a year.



(Loligo chinensis Gray, 1849)
Source: (FICen. 2003)

MATERIALS & METHODS

2.1. Research vessel and fishing gear

The commercial bottom trawler, “Dongnam 05” equipped with a 600HP engine, was used to carry out the four surveys in the Gulf of Tonkin in the period 2001 to 2004. The average towing speed ranged from 3.4 to 3.6 knots. The sampling gear was a single bottom trawl with head rope of 29m length and 11.6m width opening, and 35mm stretched mesh-size in the cod-end. The towing duration of each haul was normally one hour, and such a haul conducted in standardized conditions is here defined as a station or sample. All stations were performed in the daytime, normally between 05:00 and 18:00. A detailed drawing and specification of the sampling gear is given in Appendix 1.

2.2. Station system and stratified design

The Gulf of Tonkin is shared by Vietnam and China, and the survey area lies on the western (Vietnamese) side. The survey area, depth contours, and the fixed stratified station system adopted since 2001 are shown in Figure 2. The four strata cover the depth ranges 0-20m, 20-30m, 30-50m, and 50-100m, and have partial areas of 13,700km^2, 16,250km^2, 20,640km^2 and 16,780km^2, respectively, accounting for a total of 67,370km^2.

Three out of four surveys accounted for in this work were performed during the Southwest monsoons in 2001, 2003 and 2004, and are here called SW2001, SW2003, and SW2004. The second cruise, performed during the Northeast monsoon in 2001, takes the name NE2001. A total of 51, 49, 55, and 55 stations were performed in the four surveys SW2001, NE2001, SW2003, SW2004, respectively. The number of stations performed in each stratum varied slightly from survey to survey, depending on operational capabilities and state of the sea (Dao 2004). For instance, in the stratum 0-20m depth a total of 9, 5, 7, and 10 stations was carried out in the four surveys. Correspondingly, 7, 7, 12, and 11 stations were performed at 20-30m depth.

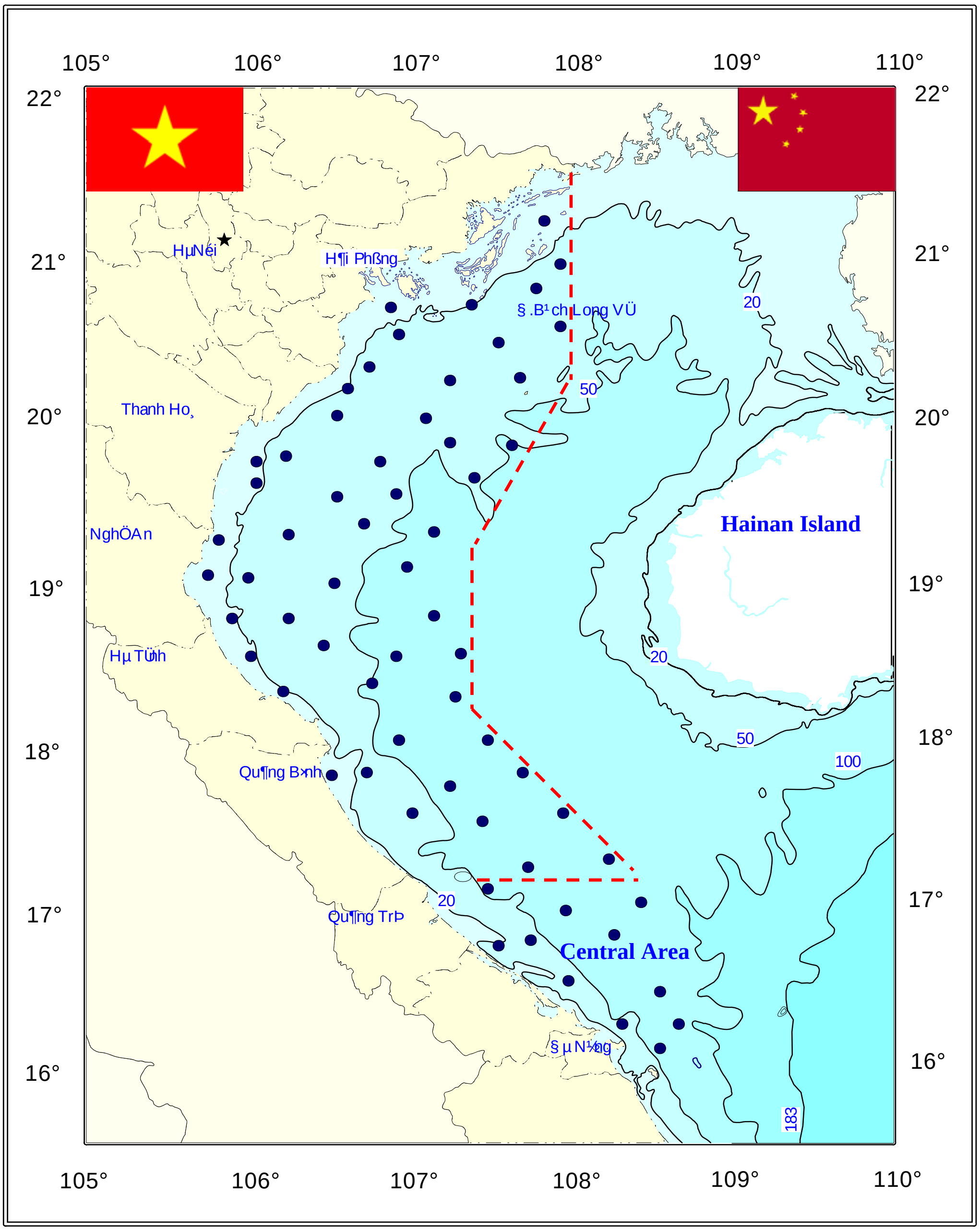


Figure 2. Fixed station grid utilized in the four bottom trawl surveys carried out in the Gulf of Tokin from 2001 to 2004. The red dashed line approximately indicates the mid-line separating Chinese and Vietnamese waters and includes all the stations considered in this work.

2.3. Data collection

- ***Environmental and sampling diary***

Information on sampling activities, including starting and stopping time and positions of hauling, as well as water depth and towing speed were immediately recorded in survey forms. Environmental data, including air and water temperatures, samples of phytoplankton and zooplankton, and biochemical samples were also routinely recorded along the course of the four surveys.

- ***Catch data***

In general, total catch of each haul was sorted by commercial groups, families, genus and species, and the detailed quantity and weight of organisms recorded. For high-catch hauls, sub-samples of many species had to be taken after sorting the catch. Species composition and weight were recorded in station forms. This included scientific name, number of individuals and total weight in the sub-sample. Finally, simple raising factors were used to estimate the composition of the whole catch from the sub-samples.

- ***Biological data***

Owing to the great number of species collected in a haul compromises as to what species could be fully analysed had to be made. Normally, groups of fish, shrimp and cephalopods of high commercial value were given priority. This included information on length, stomach fullness, maturity (gonadal) stage and individual weight, which was recorded in species forms and individual forms. If the catch of the relevant species is small all individuals were analysed. Otherwise, a random sub-sample of 25 or more individuals was taken and raising factors were used to extrapolate for the whole stratum or survey. Depending on morphology of the fish, size was measured as total length (TL), as in the case of the Largehead hairtail, or fork length (FL), as in Greater lizardfish, following the general recommendations of Sparre and Venema (1998). Mantle length or carapace length are used for squid or shrimps and crabs, respectively (Sparre 2000). Individual length was measured to the “nearest unit below” as suggested by (Sparre and Venema 1992). Depending on the maximum size of the species, the interval length group is either 0.5 or 1 cm for species that attain lengths smaller or larger than 30 cm, respectively (Sparre and Venema 1998). Fish maturity was defined with basis on six maturity stages (Nikolski 1963). Stages I and II correspond to immature individuals, stages III, and IV to maturing and mature individuals, and stages V, VI are reserved for post-spawners. Although the catch of the three indicator species was recorded in each haul, information on individual sizes (length and weight), size frequencies, and maturity stages could not obtained for all combinations of strata and survey.

- ***Data management and statistical analysis***

After disembarking, all catch and biological data were stored and managed in a specialist database, the "Vietfish Survey". This system was developed to run in the Microsoft Access environment by the Research Department of Marine Resources (RDMR). This database has a convenient interface that allows an easy access, import, and export of data. A number of quality control procedures are implemented in the database. This reduces the likelihood of mistakes during punching as well as, for instance, duplication of information or utilization of wrong scientific names. Data were retrieved from the database and subject to secondary treatment in Microsoft Excel. More advanced statistical analyses were performed in Systat11 (Kroeger 2004) and Statplus (Berk and Carey 2004). While many of the analyses followed standard built-in procedures in these statistical packages, some required additional user-defined procedures. The latter are here described in more detail.

2.4. Data treatment

2.4.1. Biomass estimation

- **Swept-area technique**

The design-based approach, or classical sampling theory approach, to spatial sampling is normally considered the most suitable for estimating global properties of a population of values, such as the population mean or total (Haining 2003). This is the most utilised approach in fisheries research, particularly in the assessment of the biomass of demersal resources by means of the swept-area method. Following this method the estimation of biomass is entirely based on the catches of sampling trawl hauls, which are the sampling units, extrapolated to whole areas (Sparre & Venema 1998). For a simple random survey the point-estimate of biomass would simply be defined as:

$$B = CPUA \frac{A}{q} \qquad \text{(eq. 2.4.1.1)}$$

where
$$CPUA = \frac{CPUE}{v.X} \qquad \text{(eq. 2.4.1.2)}$$

and
$$CPUE = \frac{C}{t} \qquad \text{(eq. 2.4.1.3)}$$

Where:

B	is biomass (tones)
CPUA	is the density (tones/km^2)
A	is the survey area (km^2)
q	is the catchability [0;1]
C	is the catch in the trawling station (tones)
X	is the width opening of the trawl (km)
t	is the trawling duration (hours)
v	is the towing velocity (km/ hour)

This estimate of biomass is dependent, among other variables, on the catchability *q*, i.e. the proportion of fish in the path of the gear that are captured. In contrast to the other variables catchability normally takes an assumed value, rather than a value measured in the survey. Following a proposition of the fishery staff of RIMF and fishery advisers of DANIDA the catchability in Vietnamese trawl surveys is normally taken to be 0.5 (Dang and Dao 2002; Nguyen 2002), irrespective of species and size. Normally, fishery surveys rely on stratified random designs with several point-estimates performed within each stratum. In this case the estimate of the biomass in the j^{th} stratum (B*j*) is:

$$B_j = \overline{CPUA}_j . \frac{A_j}{q} \qquad \text{(eq. 2.4.1.4)}$$

where *Aj:* is the area of the stratum j^{th}

$\overline{CPUA}_j$ is the mean density of the stratum j^{th}

The biomass of the whole survey area then becomes the sum of the individual estimates:

$$B_s = \sum_j Bj \qquad \text{(eq. 2.4.1.5)}$$

- **Stratified design and bootstrap estimates of variance**

Whereas computation of the total (or the mean) biomass estimate can be relatively straightforward, many authors have tried to improve the estimation of its variance and, in particular, of adequate confidence intervals. Several design-based approaches have been developed in fisheries research that provide similar best-estimates of total biomass, but vary largely with respect to its variance. Following the approach of classical sampling theory (Cochran 1977) swept-area observations were originally treated as random normal variables in the assessment of fish stock density (Gulland 1969). But fish count data rarely satisfy the random distribution pattern. Rather, they tend to distribute according to contagious patterns, and asymmetric confidence intervals are thereby expected. Recognition of this fact has led researchers to propose underlying distributions that are either more skewed, such as the log-normal distribution (Pauly 1984), or more flexible, such as the delta-distribution (Pennington 1983, 1986). The latter is, in fact, a combination of two frequency distributions, the binomial (presence / absence) and the log-normal (to represent the positive catches), and is widely used with survey data in the ICES area, as well as in Vietnam (Dang and Dao 2002; Nguyen 2002). Ecologists have, however, long recognized that statistical frequency distributions will hardly represent the dynamics of animal distribution and abundance (Krebs 1989), despite their usefulness in the investigation of adequate sampling strategies (e.g. Schnute & Haigh 2003). Thus, fishery researchers increasingly rely on non-parametric, or distribution-free, methods for the estimation of variance (Smith 1997; Haddon 2001), and this is the approach followed in the present work.

Total biomass in the surveyed area of Tonkin Bay was estimated according to the non-parametric random re-sampling with replacement method, hereafter called bootstrap. In equations 3 and 4 only one average CPUA measurement (x_0), obtained from *n* observations (stations) performed in one stratum of a survey, and the corresponding point-estimate of the total biomass $\hat{\theta}_0$ for that stratum, was considered. Consider now that a number *b* independent bootstrap samples x_1, x_2, $x_3 \ldots x_b$ is generated, and that each sample consists of *n* data values drawn randomly with replacement from the *n* values in the original sample. The bootstrap replicate of the parameter for each bootstrap samples x_b is also estimated as;

$$\hat{\theta}_b = f(x_b) \qquad \text{(eq. 2.4.1.6)}$$

Where $f(x_b)$ is given by the set of equations 2.4.1.1-2.4.1.3. $\bar{\theta}_b$ is the mean of the bootstrap replicates of θ, which is the bootstrap estimate of the statistic θ as

$$\bar{\theta}_b = \frac{\sum \hat{\theta}_b}{b} \qquad \text{(eq. 2.4.1.7)}$$

The bootstrap standard error of the quantity θ is

$$se_\theta = \sqrt{\frac{(\hat{\theta}_b - \bar{\theta}_b)^2}{b-1}} \qquad \text{(eq. 2.4.1.8)}$$

Different empirical and theoretical studies have shown that the bootstrap method provides adequate estimates of the total biomass and confidence intervals in stratified fishery surveys, provided that the re-sampling procedure takes into account the sampling design (stratification) and the degree of coverage of the survey (Smith 1997; Schnute & Haigh 2003). Further, it is important to choose an adequate strategy to calculate the confidence intervals, based on the percentiles, of the bootstrap replicates. The software Systat does not have an in-built two-stage routine for bootstrapping data from complex (stratified) surveys. However, Smith (1997) reviews and recommends three methods of increasing complexity and precision that can be implemented for the estimation of confidence limits in stratified surveys: the Naïve bootstrap, the Rescaling bootstrap and the Mirror-match bootstrap. Smith (1997) also shows that for the reduced number of samples and degree of coverage typical of fishery surveys (in the Tonkin surveys e.g. only about 0.005% of the total area is normally swept) the three approaches simplify to the Naïve bootstrap with a bootstrap sample size equal to the number of stations minus 1. This same procedure was followed in a user-defined procedure implemented in Systat: for each species and survey 1000 bootstrap replicates were taken within each of the four strata with a sample size of n_j-1 stations per replicate, where n_j is the number of stations performed for that particular stratum and survey; the process was repeated for all strata with seeded values of the random number generator to ensure replicability within a survey. The 4 x 1000 estimates of strata biomass were combined to give 1000 estimates of total biomass and its standard error. No finite population correction was utilized in the calculation of the bootstrap standard error (Schnute & Haigh 2003). The 95% confidence intervals of the biomass were based on either the 2.5% and 97.5% naïve percentiles (PC) directly calculated in Systat (Cleveland option), or on bias-corrected percentiles (BC, Haddon 2001). Accelerated percentiles (AC) are in principle more correct (Schnute & Haigh 2003), but also more demanding computationally, and in complex designs do not seem to perform better than naïve percentiles (Smith 1997). The abundance data are displayed in histograms with superimposed non-parametric kernel density curves. These are more in keeping with the distribution properties of the bootstrap estimates than normal theory-based density curves.

2.4.2 Size distribution

Length measurements performed in several stations and strata were, whenever available, used to estimate two (realized) quantities: the overall mean length and the length-frequency distribution of a species in a survey. Just like the estimation of abundance, estimation of the size-frequencies was made in accordance with the stratified design of the survey. All field stations were performed in approximately standard conditions (of tow duration, gear, etc.), and all stations were thereby given the same weight in the calculation of size distributions within a stratum. Therefore, in a given stratum j^{th}, the frequency of each length group was estimated as:

$$fi_j = \frac{n_{ij}}{N_j} \qquad \text{(eq. 2.4.2.1)}$$

Where f_i is the frequency of the length group i^{th} (measured as total length in fish and mantle length in squid*)*, n_{ij} is the number of individuals of the length group i^{th}, and N_j is the total number of individuals measured.

The mean size in the same stratum is estimated as:

$$\overline{L_j} = \frac{\sum_i L_i . n_i}{N_j} \qquad \text{(eq. 2.4.2.2)}$$

Where L_i is the mid-length of size-class i^{th}

Calculation of the frequency distribution or the mean size in the whole survey involves weighing the within strata estimates of length by the stratified estimates of biomass (B_j), so that strata that have more fish also carry more weight in the final size distributions. For the mean length in the survey this equates to:

$$\overline{L_s} = \frac{\sum_1^j \overline{L_j} . B_j}{\sum_1^j B_j} \qquad \text{(eq. 2.4.2.3)}$$

Correspondingly, the relative frequency of fish in any given size-class in the survey is estimated as:

$$F_{is} = \frac{\sum_1^j f_{ij} . B_j}{\sum_1^j B_j} \qquad \text{(eq. 2.4.2.4)}$$

2.4.3. Maturation

The dependency of reproduction on size is normally quantified with basis on the proportion of mature individuals in each length group. The probability of maturation with size is assumed to follow a logistic pattern in a population, and the fit of a logistic curve is often made by ordinary least-squares following (log) linearization of the data (Jennings *et al.* 2001; Frøysa *et al.* 2002). In the present work the symmetric selection curve proposed by Frøysa et al. (2002) was adapted to describe the proportion of mature fish (ml_i) at length L_i:

$$ml_i = \frac{1}{1 + e^{-2.\ln(3).(L_i - L_{50})/MR}} \quad \text{(eq. 2.4.3.1)}$$

This curve is governed by two parameters: the L_{50}, defined as the length at which 50 percent of all individuals are sexually mature, and the maturation range, MR, which corresponds to L_{75}- L_{25}. The smallest the MR, the sharpest the logistic curve is, and the highest is its slope. The basic assumption in the fit of the model is that the data are binomially distributed. Thus, if for any given size class *i* a total of n_{sxi} fish were sex-typed and n_{mi} were found to be mature (maturity stages III-VI), then n_{sxi} - n_{mi} were necessarily immature (maturity stages I and II). The non-linear model (eq. 2.4.3.1) was fitted to the data using maximum likelihood estimation. This is performed in Systat by minimising the negative of the log-likelihood (LL) function for the data, which is

$$LL = \sum_i n_{mi}.\ln(ml_i) + (n_i - n_{mi}).\ln(1 - ml_i) \qquad \text{(eq. 2.4.3.2)}$$

Several methods exist to fit curves by maximum likelihood estimation, and they differ in the adequacy of the standard errors obtained for the parameters (Engelman 2002). To avoid the additional assumption that the estimated parameters were normally distributed confidence intervals of L_{50} and MR were calculated with basis on 1000 bootstrap replicates from the original data. Bi-variate 95% confidence ellipses for the two parameters reveal the uncertainty in the fit and parameter values. As a rule of the thumb if the 95% confidence regions of a parameter overlapp they are considered to be statistically indistinguishable.

2.4.4. Spawning biomass

Whenever estimates of total biomass, size and maturity distribution, as well as length-weight relationships were available attempts were made to estimate the size of the spawning biomass. Sporadic measurements of individual length (L, cm) and weight (w, grams) were made in different surveys, and the allometric relationship:

$$w = a.L^b \quad \text{(eq. 2.4.4.1)}$$

where *a* (condition factor or 'density') and *b* (unitless) are parameters, fitted to the data using non-linear least-squares. Given this predictive relationship for a single year (but preferably for each survey) it is possible to convert the general length frequency distribution into a weight distribution:

$$Fw_i = F_i.a.L_i^b \quad \text{(eq. 2.4.4.2)}$$

To convert this length-class-based weight distribution into the biomass of length class *i* in the whole surveyed area (B_i) it is necessary to adjust it by a raising factor that includes the total biomass estimate B_s:

$$B_i = B_s \frac{Fw_i}{\sum_i Fw_i} \quad \text{(eq. 2.4.4.3)}$$

Finally, the Spawning biomass (SB) is the product of biomass at length (B_i) and the probability of maturation (ml_i), summed across all length classes:

$$SB = \sum_i B_i.ml_i \quad \text{(eq. 2.4.4.4)}$$

2.4.5. Mapping

The seasonal distribution of fish density was visualised by means of contour maps, and these were obtained by smoothing the fish density data, using the kriging technique. This is in line with Haining (2003) who recommends the utilisation of model-based approaches for mapping spatial stochastic processes. The basic information utilised in seasonal maps of the three species were the individual density estimates (cpua/q, with q=0.5) obtained in each trawl station. Kriging is a geostatistical technique to interpolate this type of spatial data, and consists of two steps. Firstly, the spatial structure of the observations is analyzed through the calculation and fitting of a variogram model. A variogram measures the level of dissimilarity between sampled points as a function of the distance between them. Secondly, this structure is utilized to estimate the values of the density surface at un-sampled points in the neighborhood of the sampled stations. Kriging is a linear estimation technique that accounts for both the spatial structure and the geometrical configuration of the data (Rivoirard and Wieland 2001). There are different kinds of kriging and they vary in the way the stochastic process is modeled to represent the target variable as a function of location. The application of this technique in fishery surveys is gaining widespread acceptance (Rivoirard *et al.* 2000).

Kriging was performed using the Spatial Statistics module of Systat 11, normally following its standard settings, which include a spherical variogram model with sill=1 and no nugget effect, and the option of Ordinary kriging with 10 x 10 nodes in the x-y directions. While the choice of the variogram model might not have critical influence, it is very important to conduct cross-validation of the data by kriging to ensure that the model and the kriging reproduce the data (Petitgas 1996). Therefore, some experimentation with different variogram models, anisotropic angles and kriging techniques was performed in order to check that the standard settings provided results that satisfied the distribution of the original data. During cross-validation the original data were represented as bubble plots, and these were checked by eye against the smoothed contour plots.

Finally, the contour maps were superimposed on a geographical map. The base geographic map was obtained after digitations of different layers, including border, depth, sea and land, and merging with Mapinfor 6.0 software. The fish density maps obtained in Systat 11 was then superimposed onto the base chart in Photoshop CS.

RESULTS

3.1. Stock of Largehead hairtail

3.1.1 Catch rate (CPUE)

The catch rate (kg per trawling hour) is the basic quantity utilised to calculate stock density and biomass in surveys (eq. 2.4.1.1-2.4.1.3), and these estimates are in turn utilised to derive other estimates. Variability in CPUE will therefore propagate as a major source of uncertainty to all derived quantities. The catch rates of Largehead hairtail varied strongly among strata and surveys, and this is shown in Figure 3 by means of box plots. These plots represent the mean (the dotted lines), medians (middle full lines), central quartiles (the sides of the box), as well as moderate and extreme outliers. The average CPUE of Largehead hairtail varied in the range 0.0 to 24.8kg/h in the different strata, and tended to be higher offshore than inshore. However, larger averages normally also corresponded to larger variability, and this was caused by extremely large catches in a few stations. This was particularly evident in the stratum 30-50m. In survey SW 2004 most stations had very low catches of Largehead hairtail, and therefore the overall mean CPUE was low in this stratum. However, in three out of 16 stations, catches in this stratum were high or very high, up to about 250kg/h. This statistically aggregated distribution is interpreted as Largehead hairtail being most abundant offshore where it occurs in dense, but relatively isolated, patches or schools.

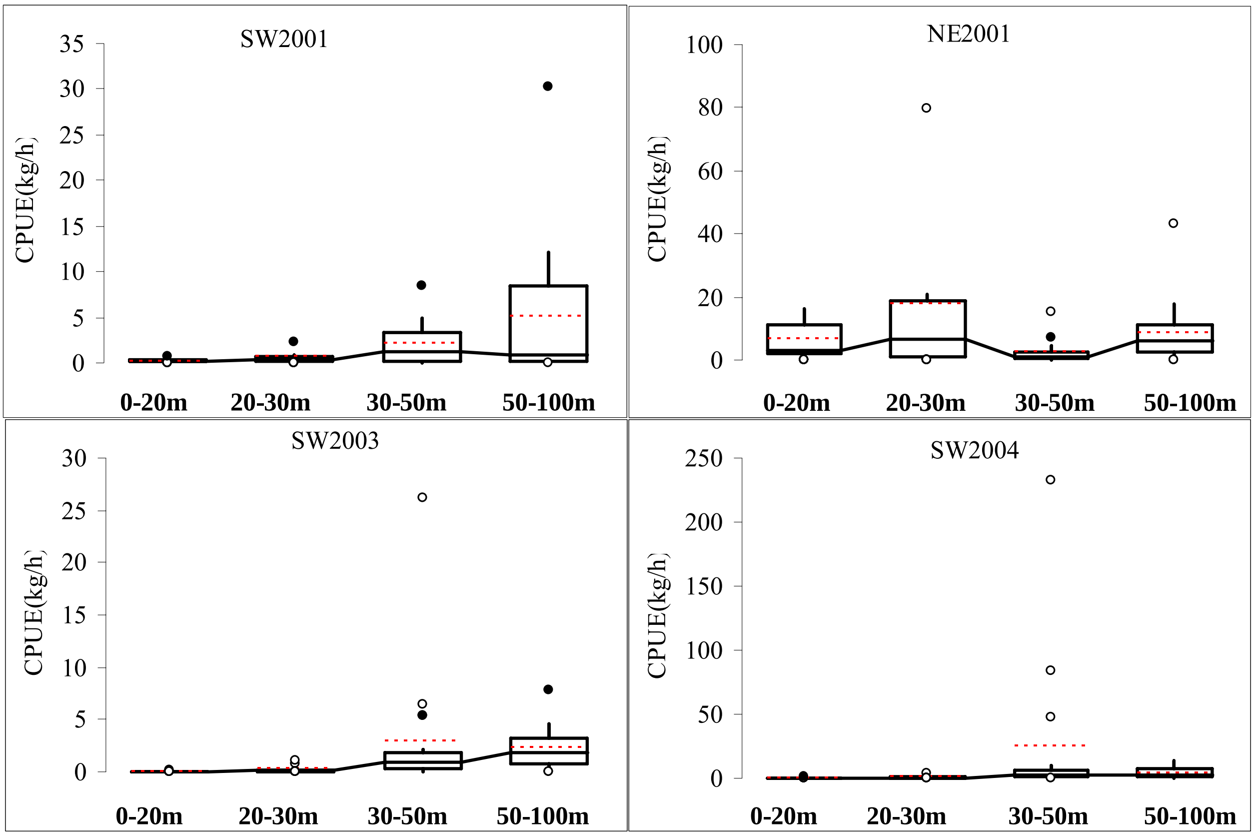


Figure 3. Box-plots of the catch rates (kg/h) of Largehead hairtail observed in the four surveys performed in the Gulf of Tonkin.

3.1.2. Seasonal distribution

Contour maps of the Largehead hairtail density observed in the four surveys are shown in Figure 4. The contour lines are based on the spatial statistics of catch per unit area adjusted for by the catchability of the gear (CPUA/q, with q=0.5). In general, Largehead hairtail densities increased eastwards, or away from the Vietnamese coast, in the surveys performed during the southwest monsoon. This corresponded to maximum isolines of 160kg/km^2, 60kg/km^2 and 125kg/km^2 in areas north of 19^o N and east of 107^o E. Contrastingly, during the survey performed during the NE monsoon in 2001, the densities of Largehead hairtail tended to increase westwards, and be highest close to the Vietnamese coast. The highest density (the isoline 400kg/km^2) observed in this survey was however greatly influenced by a single large catch performed in the 20-30m stratum, i.e. one of the extreme outliers observed in Figure 3.

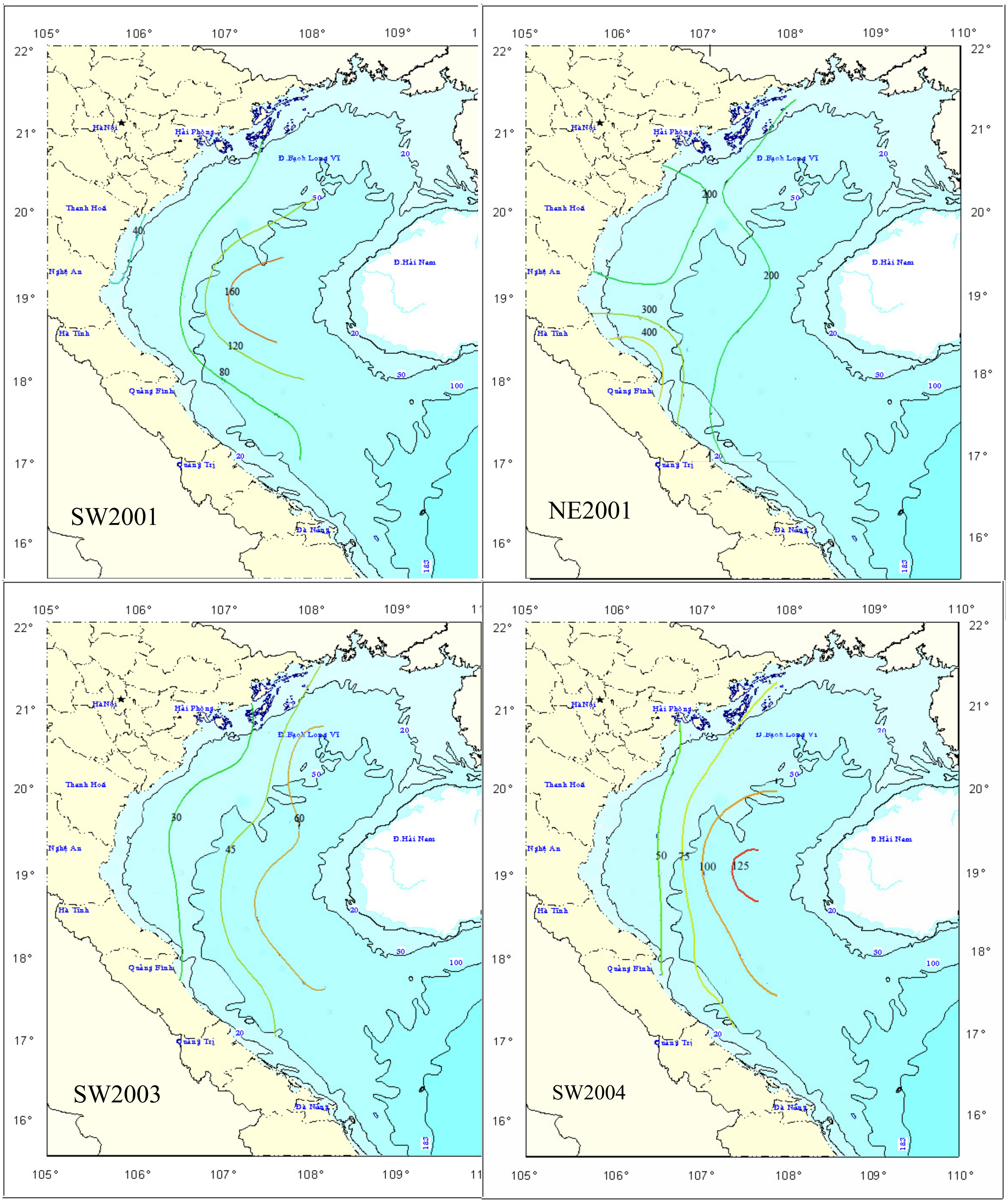


Figure 4. Contour maps of the spatial distribution of Largehead hairtail in the different seasons and surveys performed in the Gulf of Tonkin. Density estimates were based on catchability-adjusted CPUA (kg/km^2)

3.1.3. Biomass

The distribution of the bootstrapped estimates of standing biomass of Largehead hairtail by strata and surveys are presented in Figure 5. Non-parametric kernel curves were added to the histograms of the biomass estimates, and they seem to illustrate the fact that these estimates often fail to show symmetric or normal distributions. For convenience, the biomass values are shown in logarithmic scales, but this tends to compress the long tails towards large values. In general, the estimates of biomass reflect the information previously given in the catch rates and seasonal density distribution. During the southwest monsoon the highest biomass of Largehead hairtail is found in the deeper strata offshore. This trend was reversed in the NE2001 survey when very large biomass of fish was observed in the 20-30m depth stratum.

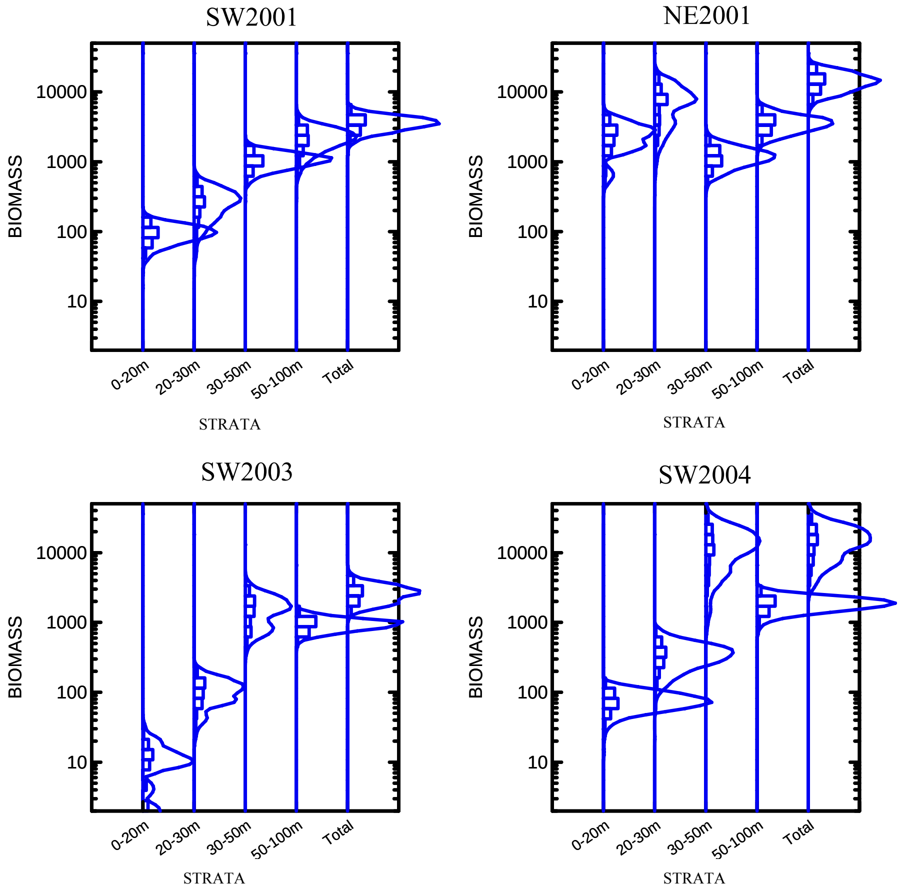


Figure 5. Histograms representing the distribution of the bootstrapped estimates of total biomass of Largehead hairtail in the four strata, and the total estimate for each of the four surveys performed in the Gulf of Tonkin.

The estimates of total biomass of Largehead hairtail seemed to alternate between low values, around 3,000 tones, in SW2001 and SW2003, and large values, around 15,000 tones, in NE2001 and SW2004 (Table 1). The existence of moderate and extreme outliers in the CPUE data, i.e. a few stations with large, or very large, catches of Largehea hairtail, greatly influenced the variance estimates of total biomass. In all cases the coefficient of variation (CV), an expression of the uncertainty of the total estimate, was relatively high, well above 20%. The coefficient of variation increased with the total estimate, and was particularly high in SW2004 (50%), a survey marked by three stations with extremely high catches. If these three stations were excluded from the calculations the estimate of total biomass would have been relatively low. In fact, the 2.5% percentile for this survey (3,715 tones) is very close to those obtained in surveys of low biomass, SW2001 and SW2003. It would, therefore, be difficult to state that there are significant differences between the different biomass estimates in the series.

Table 1. Mean estimates of total stock biomass, their standard error, coefficient of variation, and 95% confidence intervals, for Largehead hairtail in the four surveys performed in the Gulf of Tonkin.

Survey	***Biomass (tones)***				
	Mean	Percentile		SE	CV (%)
		2.5	97.5		
SW2001	3,570	2,026	5,329	856	24
NE2001	14,290	7,322	23,297	4,332	30
SW2003	2,623	1,447	4,259	767	29
SW2004	15,133	3,715	31,107	7,630	50

3.1.4. Size distribution

In the years 2001-2003 about 800 Largehead hairtail were length-measured in each survey, but this number increased to 5,456 specimens in the last survey, SW2004 (Appendix 13). Unfortunately, very few or no fish were length-measured in the shallowest strata in the surveys conducted during the southwest monsoons. However, abundance of Largehead hairtail in these two strata was low, and the lack of measurements is not expected to have greatly influenced the estimation of mean sizes or total size distributions in the SW surveys. The total length of Largehead hairtail sampled during the four surveys varied between 14 and 110cm. There was a clear overlap of fish sizes among strata, and both small and large fish could be found inshore and offshore. This occurred even during the NE2001 survey when large concentrations of Largehead hairtail were found close to the Vietnamese coast (Figure 6). The stratified mean length of the Largehead hairtail seems to have only slightly decreased, from approximately 49-52cm in 2001 to 49-51cm in 2003-2004. More dramatic was, however, the decrease in the range of sizes: fish larger than 60cm and smaller than 30cm became rarer from 2001 to 2004. The signal of decreasing width of the size-range of Largehead hairtail was already observed from the southwest (18-110cm) to the northeast monsoon in 2001 (14- 96cm), and was very clear in 2004 (30- 83cm).

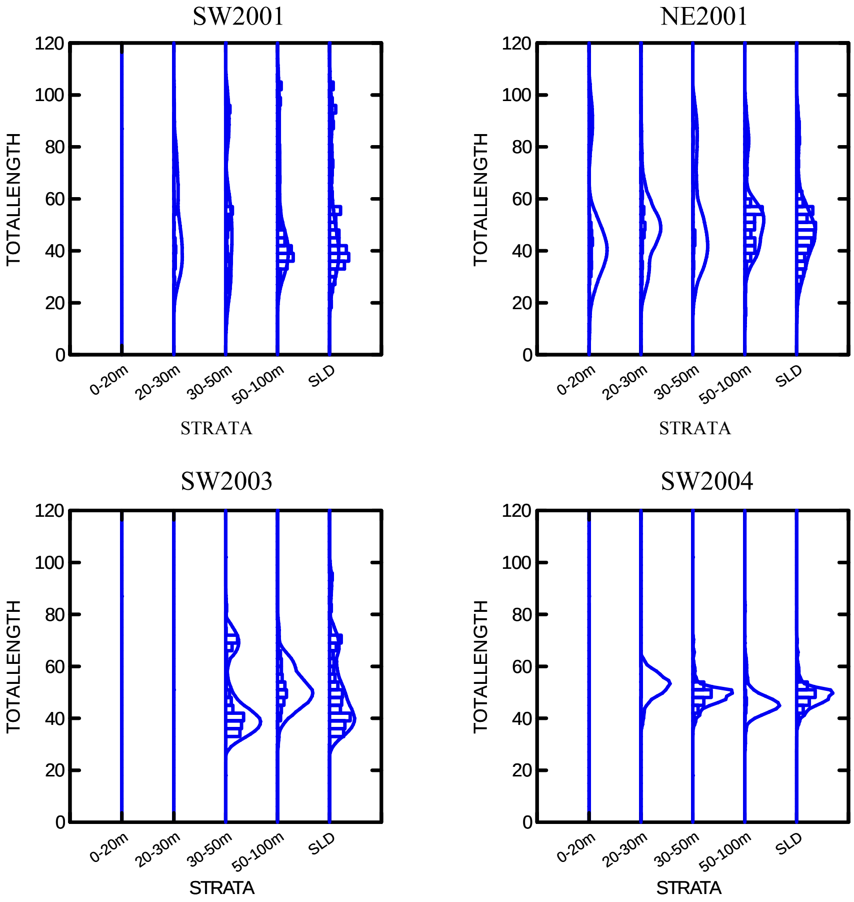


Figure 6. The length distribution of Largehead hairtail sampled in the four surveys performed in the Gulf of Tonkin. SLD is the overall length distribution in a survey, calculated with basis on the length-distributions in individual strata weighed by the respective biomass estimates

3.1.5. Maturity

Adequate biological sampling to perform a study of the maturity ogives in Largehead hairtail was only secured in the second survey, NE2001. In addition, owing to the scarce representation of males in the samples this analysis could only be performed for females and pooled sexes. For female fish, the best-estimate of maturity length (L_{m50}) was 58.8cm and maturity range (MR) was 12.8cm. For pooled sexes the best-estimates were 61.0cm and 20.0cm, respectively, and were therefore very close to the estimates obtained for females only. The best-estimates of the two parameters, together with the bi-variate 95% confidence ellipses are shown in Figure 7. The area of the ellipses, or the length of the main axes, is indicative of the uncertainty in the parameters. For the Largehead hairtail data these confidence ellipses are wide, indicating a very large unexplained variability in the data not accounted for by the logistic model. The original maturation data and the logistic curves fitted are shown in Appendix 15.

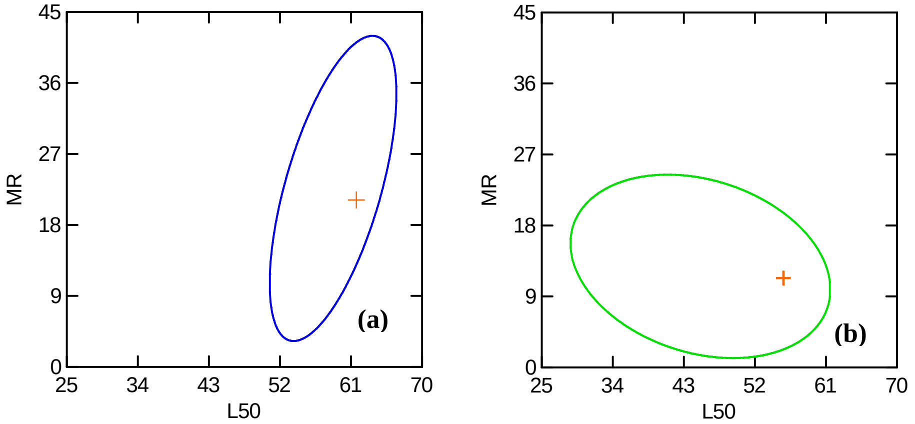


Figure 7. The best-estimates of maturation length and maturation range (crosses) and the bi-variate 95% confidence ellipses of these parameters for (a) pooled sexes and (b) female Largehead hairtail sampled in the Gulf of Tonkin in 2001.

3.1.6. Length-weight relationship

The individual length-weight relationship of the pooled sex Largehead hairtail sampled in the two last surveys in the Gulf of Tonkin can be expressed as $W=0.43*10^{-3} L^{3.00}$ (n=39, $R^2=0.84$) and $W= 0.72*10^{-3}L^{2.92}$ (n=16, $R^2=0.87$), respectively. The combined data of these two surveys gives a relationship as $W=0.17*10^{-3}L^{3.24}$ (n=55, $r^2=0.90$). The individual observations together with the fitted curves are shown in Figure 8. The two curves fitted are somewhat different, and the difference in the coefficients seems to be related to the different ranges of lengths and number of fish sampled in the two cruises.

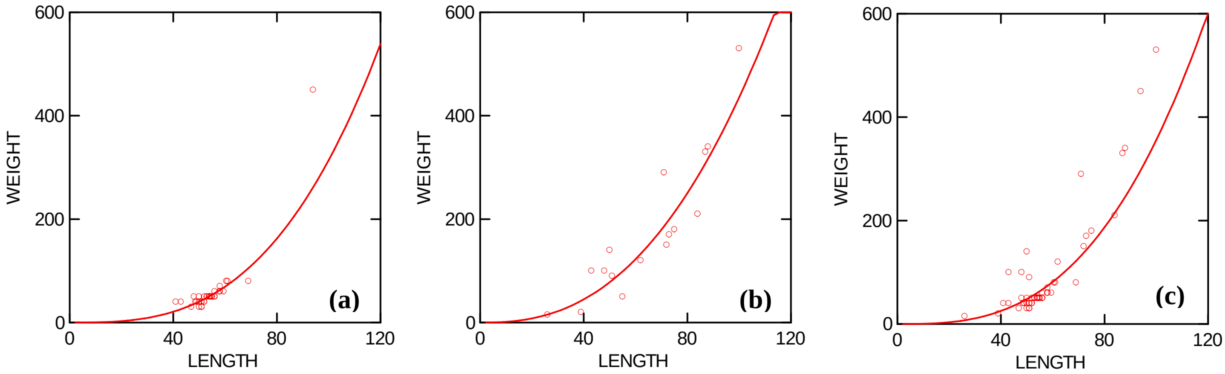


Figure 8. Plots of the total length (cm) - weight (gr) relationship of Largehead hairtail in (a) SW2003, (b) SW2004 and (c) for the combination of the two surveys performed in the Gulf of Tonkin.

3.1.7. Spawning Biomass (SB)

Owing to the low sampling intensity of biological variables, the few length-weight relationships and maturity ogives available had to be combined for the estimation of spawning stock biomass of Largehead hairtail. Therefore, the combined length-weight relationship for 2003 and 2004, together with the maturity ogive for pooled sexes from NE2001, were utilised for the four surveys. It was, therefore, necessary to assume that these relationships were constant in the three years. The estimated spawning biomasses in the three surveys performed during the southwest monsoons are shown in Figure 9. Spawning biomass seemingly varied from 2,487 tones and 7,274 tones in early and late 2001, to 1,416 tones in 2003, and 4,069 tones in 2004. This apparent great increase in 2004 is directly related to the very high estimate of total biomass, which is a basic variable utilised to calculate spawning biomass. As mentioned above, this was the most uncertain estimate of total biomass, and was enclosed by very wide confidence limits. If the estimate for 2004 is disregarded altogether the remaining trend is one of a dramatic (43%) decrease in spawning biomass from SW2001 to SW2003. The seasonal increase in spawning biomass observed from SW2001 to NE2001 is directly related to the large increment in total biomass, which forms the basis for the calculation of spawning biomass, from 3,570 tones to 14,290 tones in the period.

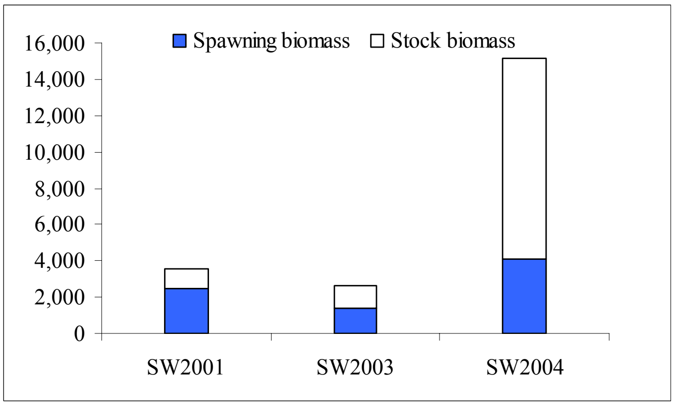


Figure 9. Trends in estimated Spawning Biomass (SB, tones) and Stock Biomass (Bs) of Largehead hartail in the three SW-surveys carried out in the Gulf of Tonkin.

3.2. Stock of Greater lizardfish

3.2.1. Catch rate (CPUE)

The catch rates of the demersal Greater lizardfish showed variations between seasons and strata. Overall these variations were, however, less extreme than those observed in Largehea hairtail, and CPUE in individual stations seldom exceeded 20kg/hour. The most extreme average catch rates were observed in the NE2001 survey, with minimum value of 0.0 kg/h in the shallowest stratum and a maximum value of 5.2kg/h in the 20-30m stratum. Some extreme and moderate outliers were observed in most strata and surveys, making the overall distribution somewhat skewed. Normally in these cases the average catch rate was larger than the median

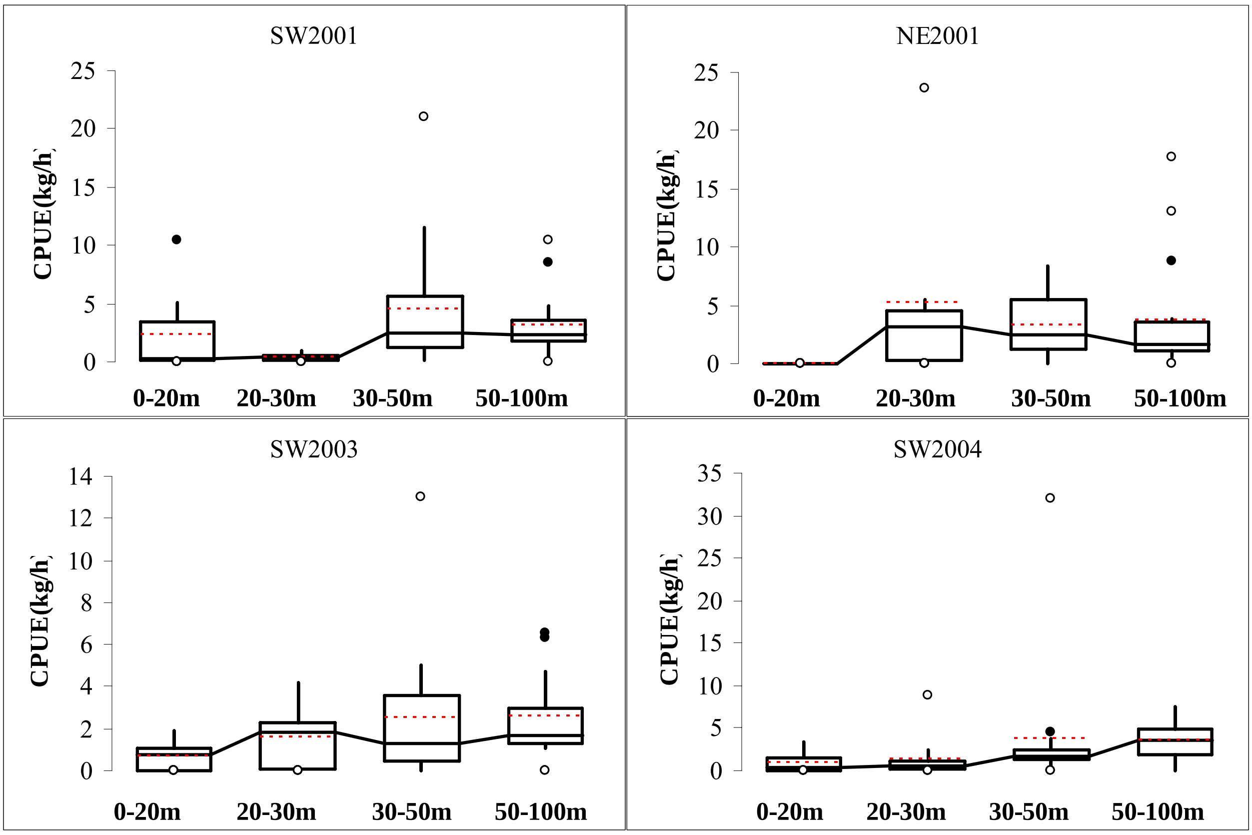


Figure 10. Box-plots of the catch rates (kg/h) of Greater lizardfish observed in the four surveys performed in the Gulf of Tonkin.

3.2.2. Seasonal distribution

Despite some yearly variations the trends in distribution of the Greater lizardfish seemed to be relatively consistent during the southwest monsoon. During this season the largest density estimates tended to occur at around 107°E, or slightly westward from this longitude. Density tended to increase eastwards (offshore), but the iso-lines of maximum density of lizardfish, 90kg/km^2, 75kg/km^2 and 120kg/km^2, occurred slightly closer to the shore than with Largehead hairtail.

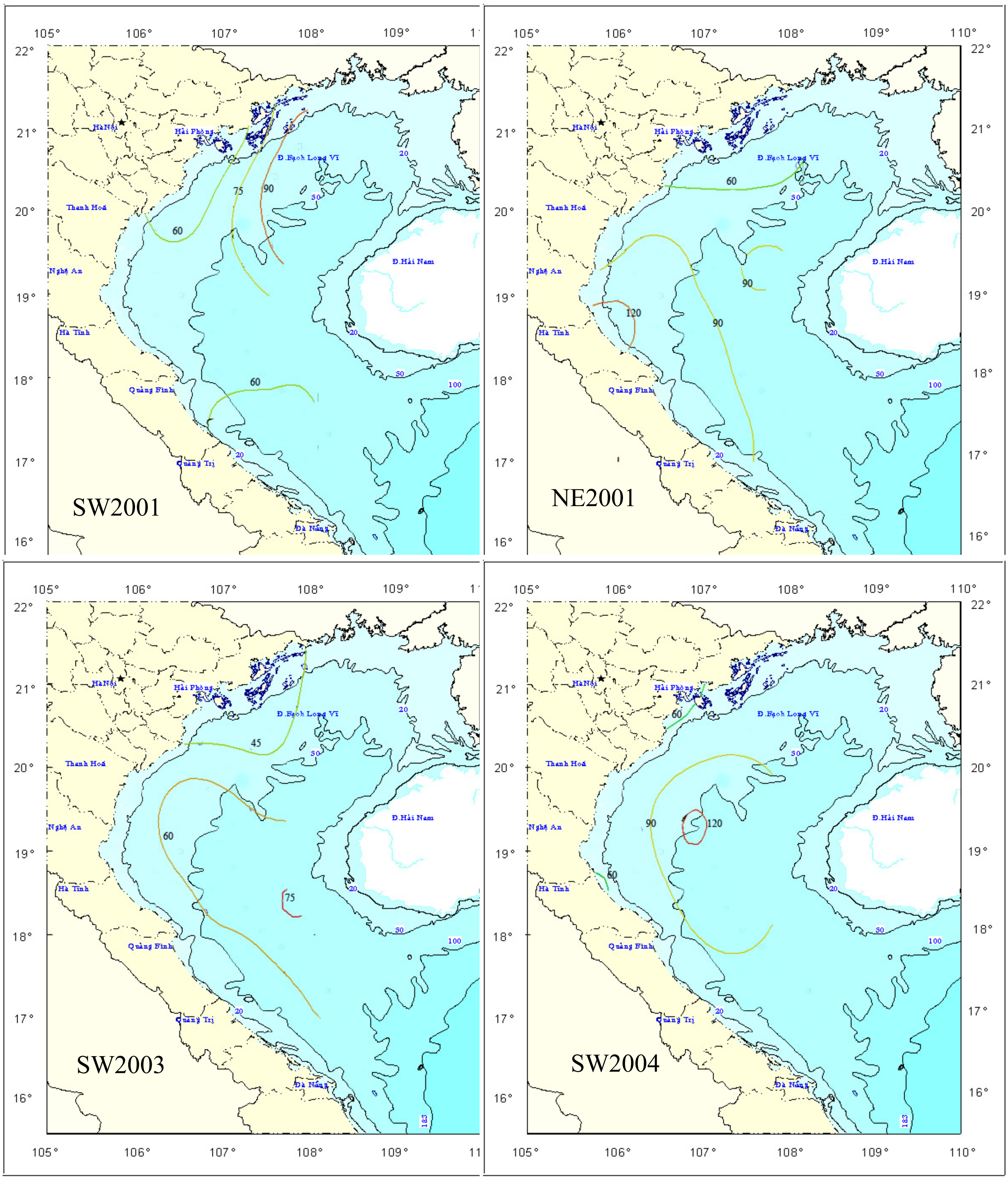


Figure 11. Contour maps of the spatial distribution of Greater lizardfish in the different seasons and surveys performed in the Gulf of Tonkin. Density estimates based on catchability-adjusted CPUA (kg/km^2).

The distribution changed during the northeast monsoon (NE2001) when the highest Greater lizardfish densities were observed westwards of longitude106°E30', and between 18°N and 19°N, fairly close to the shoreline. The Greater lizardfish seemed also to have a more northerly distribution trend in the Gulf than the Largehead hairtail.

3.2.3. Biomass

The estimates of biomass of Greater lizardfish had in general narrower distribution than those obtained for Largehead hairtail, but several of the estimates of within-strata biomass still showed skewed or even bi-modal distribution (Figure 12). During the southwest monsoons lizardfish were found in all strata, but the estimates of within strata biomass clearly increased with depth (offshore), with a maximum normally found in stratum 30-50m deep. During the northeast monsoon of 2001 biomass was highest in the 20-30m stratum, but it was negligible in the shallowest areas (0-20m).

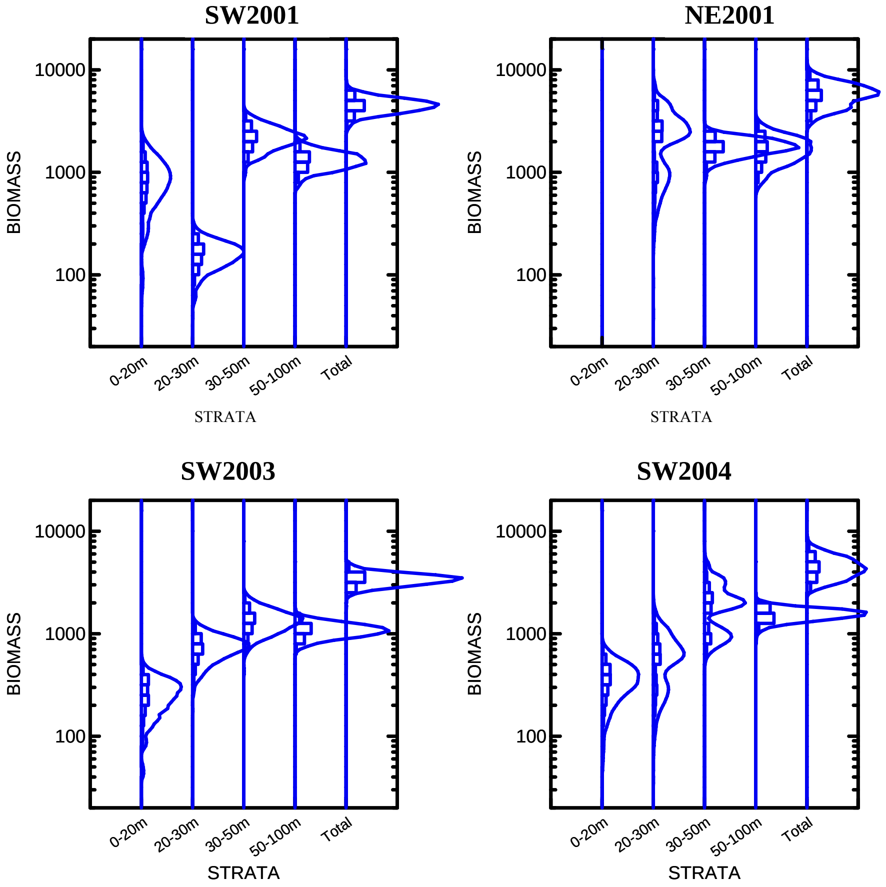


Figure 12. The distribution of the bootstrapped estimates of total biomass of Greater lizardfish in the four strata, and the total estimate for each of the four surveys performed in the Gulf of Tonkin

The total stock biomass of Greater lizardfish seemed to be relatively stable during the survey period, irrespective of year and season (Table 2). The estimate of total biomass varied between 3,394 and 5,789 tones, the highest estimate being obtained during the NW2001 survey when fish were distributed closer to the shore. The uncertainty in these estimates, measured as the coefficient of variation, tended also to increase with the total estimate, but to a much less extent than in the Largehead hairtail. The coefficients of variation never exceeded 25%, and the confidence limits of the estimates were therefore fairly narrow. This was expected owing to the absence of extremely high catches in single stations performed in the four surveys.

Table 2. Mean estimates of total stock biomass, their standard error, coefficient of variation, and 95% confidence intervals, for Greater lizardfish in the four surveys performed in the Gulf of Tonkin.

Survey	***Biomass (tones)***				
	Mean	Percentile		SE	CV (%)
		2.5	97.5		
SW2001	4,519	3,170	6,069	745	17
NE2001	5,789	3,383	8,884	1,461	25
SW2003	3,394	2,564	4,396	455	13
SW2004	4,459	2,801	6,805	1,078	24

3.2.4. Size distribution

A total of 2,739, 3,735, 622 and 466 Greater lizardfish were length-measured during surveys SW2001, NE2001, SW2003 and SW2004, respectively (Appendix 13). Fish were not measured in all combinations of strata and survey, but, as with the Largehead hairtail, size data were only lacking in strata where the Greater lizardfish were rarer. Therefore, inclusion of such data would not have changed substantially the stratified estimates of length-frequency. The fork length of Greater lizardfish sampled during the four surveys varied between 5.0 and 35.0cm. Within any given survey no marked trends in size distribution could be observed, but there was a trend for the largest fish to be found offshore rather than inshore. The size-distributions observed in the two seasons of 2001 were relatively similar, but an apparent increase in the frequency of small fish (5- 8cm) during the NE monsoon can be indicative of recruitment to the area. The overall mean size of Greater lizard fish increased slightly (1cm) from 2001 (about 16.5cm) to 2003 - 2004 (about 17.0 to 18.0cm). However, this was also a result of the clear narrowing of the range of sizes observed from 2001 (5 - 35cm) to 2003 (9 - 26cm) and 2004 (11 - 24 cm). The detailed statistics of the size distributions are given in Appendix 13.

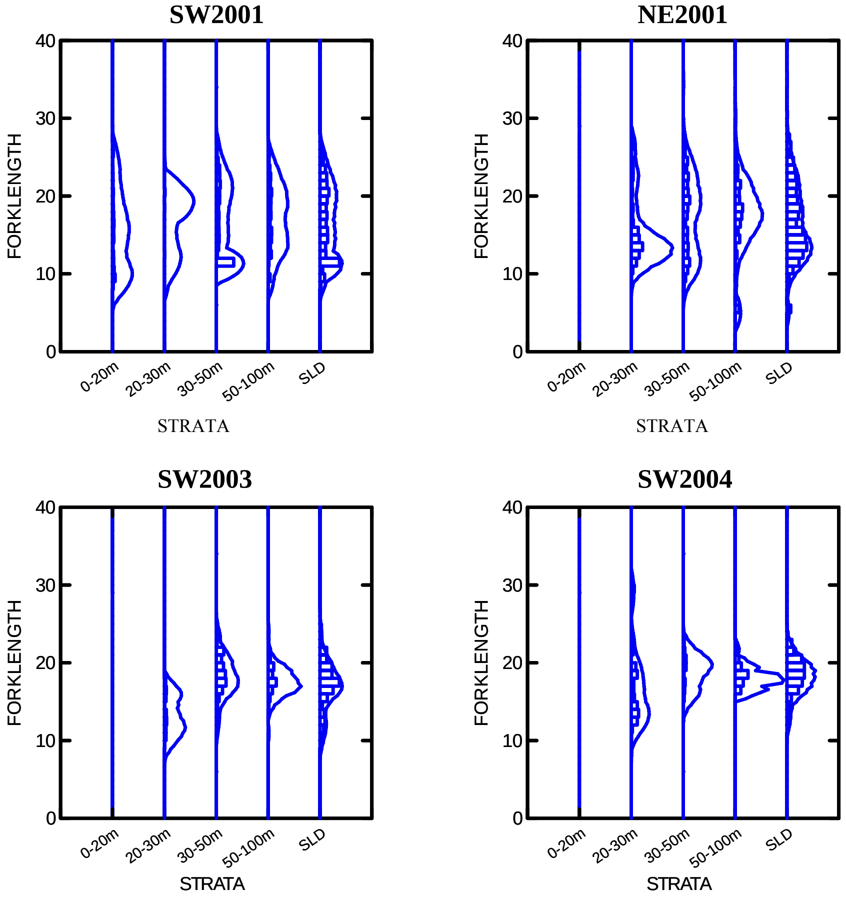


Figure 13. The length distribution of Greater lizardfish sampled in the four surveys performed in the Gulf of Tonkin. SLD is the overall length distribution in a survey, calculated with basis on the length-distributions in individual strata weighed by the respective biomass estimates.

3.2.5. Maturity

A total of 543, 436, and 431 fish were sampled and sex-typed during the SW cruises for studies of maturation. A large number of Greater lizardfish (n= 438) was also sexed during the NE2001 survey, but, despite the relatively large range of sizes analysed (10-30cm), few fish showed signs of gonad development or sexual activity. Owing to a lack of maturation signal the observations made in this particular survey were not considered here. The best estimates of the maturity parameters in the remaining three surveys, and their bi-variate confidence regions are shown in Table 3 and Figure 14, respectively. Along the four years there was a decline in the mean length at maturity for both male (by 1.5cm) and female (by nearly 3.5cm) lizardfish as judged from the present samples. Similarly, the maturity range became slightly sharper in males, but remained relatively stable in females. In contrast with the Largehead hairtail, the logistic curve resulted in a good fit to the maturity observations (Appendix 15).

Table 3. Estimates of maturity parameters of Greater lizardfish sampled in three surveys performed in the Gulf of Tonkin. (n_{sx} - number of fish sex-typed; n/a - analysis not performed.)

Year	***Parameter***	***Sex***		
		Male	Female	Pooled sexes
SW2001	L_{m50}(cm)	24.9	25.7	25.3
	MR(cm)	5.3	7.9	6.7
	n_{sx}	296	247	543
NE2001		n/a	n/a	n/a
	No			438
SW2003	L_{m50}(cm)	24.2	22.8	23.7
	MR(cm)	3.8	7.3	5.2
	n_{sx}	224	212	436
SW2004	L_{m50}(cm)	23.5	22.1	23.4
	MR(cm)	3.8	8.7	5.4
	n_{sx}	316	115	431

The improved fit of the logistic maturation curve was particularly evident in male Greater lizardfish for which the bi-variate confidence regions were small and short along the main axes. In females, determination of the maturation length was relatively precise, but the maturity range was more uncertain (confidence limits between about 2 and 15cm, for an average maturity range of 8cm.) The uncertainty around the two parameters tended to increase with time, i.e. from 2001 to 2004, irrespective of sex. Therefore, the decline in the size of the maturity parameters does not seem to be statistical significant. As with the Largehead hairtail, most Greater lizardfish in the present catches belonged to typically immature size-classes.

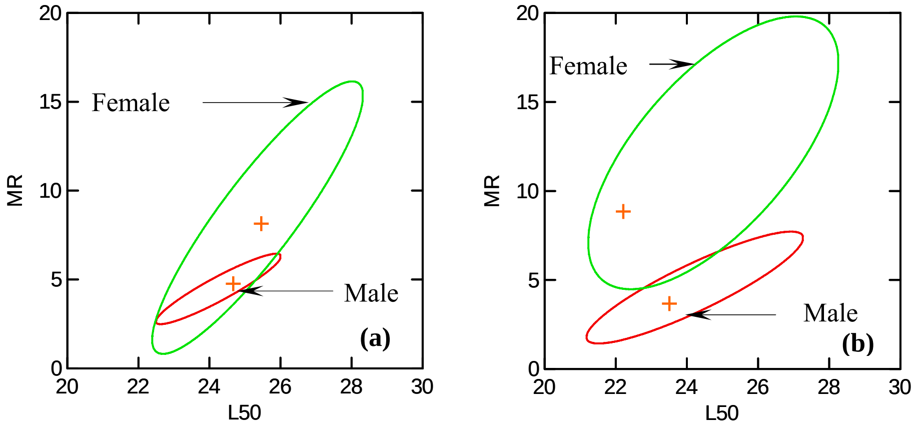


Figure14. The best-estimates of maturation length and maturation range (crosses) and the bi-variate 95% confidence regions of these parameters for female and male Greater lizardfish sampled in (a) SW2001 and (b) SW2004 in the Gulf of Tonkin.

3.2.6. Length-weight relationship

The individual length and weight observations, as well as the estimates of the coefficients of the length-weight relationships of Greater lizardfish in the four surveys are presented in Table 4 and Figure 15. The coefficients obtained in the last three surveys were relatively consistent, and resulted therefore in similar curves. The curve fitted for the observations collected in SW2001 seemed to be constrained by the un-balanced distribution of fish sizes (mostly in the 15-25cm size range) and a smaller number of observations, and these may be the causes for a slightly different (non-coincident) curve.

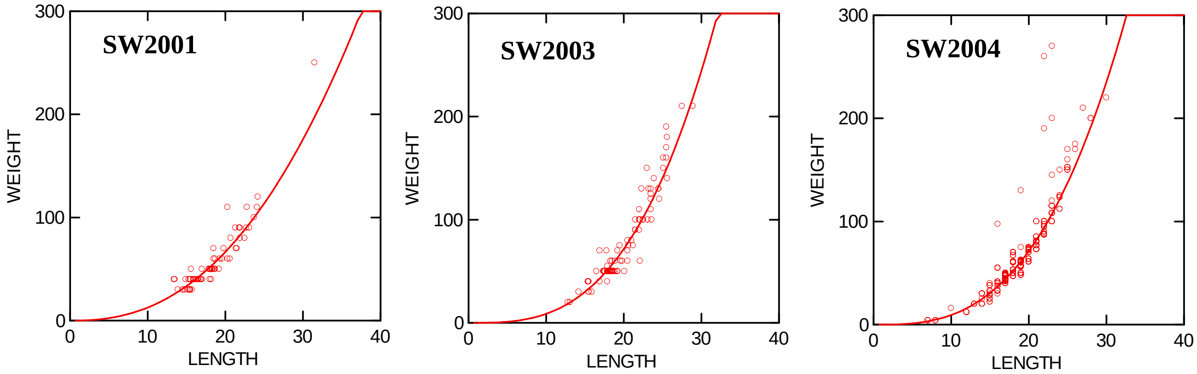


Figure 15. Plot of the length (cm)-weight (g) relationships for Greater lizardfish sampled in the Gulf of Tonkin in three surveys performed during the southwest monsoons.

Table 4. Coefficients of the length (cm)-weight (g) relationship of Greater lizardfish sampled in three surveys performed in the Gulf of Tonkin.

Year	*Coefficients*			
	a	b	r^2	n
SW2001	0.019	2.72	0.88	73
SW2003	0.005	3.22	0.92	84
SW2004	0.012	2.92	0.90	104

3.2.7 Spawning biomass (SB)

Survey-specific biological information of Greater lizardfish was available for most variables and parameters, and was utilised independently to calculate the spawning biomass in each survey. In parallel with the estimates of total biomass, the estimates of standing Spawning Biomass (SB) of Greater lizardfish showed some fluctuations during the four years (Figure 16), but the general trend was one of decline. The spawning biomass seemed to decrease from 934 tones in SW2001 to 489 tones in SW2003 and 732tones in SW2004, an overall decline of 22 %. This occurred despite a decrease in maturation size that could have partially compensated for the shortage of large fish. The spawning biomass estimated for NE2001 (1,342 tones) was clearly higher than earlier in SW2001. However, since the same maturation parameters were utilised in this calculation this increase seems to be directly related to the 1,200 tones higher total biomass observed in NE2001.

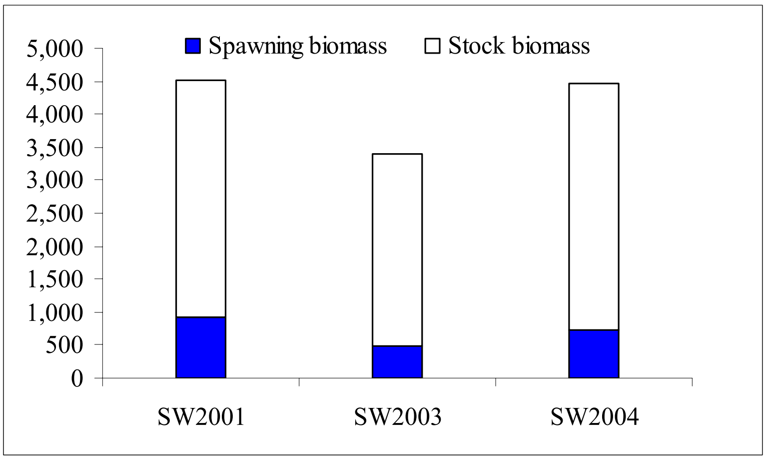


Figure 16. Trends in the estimated Spawning Biomass (SB) and Stock Biomass (Bs) of Greater lizardfish in three SW-surveys performed in the Gulf of Tonkin.

3.3. Stock of Chinese squid

3.3.1. Catch rate (CPUE)

In the offshore areas, the catch rates of Chinese squid were relatively stable during the survey period and the average catch rates fluctuated around 2.0kg/h. The highest mean catch rate observed, 19.5kg/h, in the 20-30m stratum of the first survey (SW2001), had 2.5 and 97.5 percentiles of 4.38 and 39.72kg/h, respectively. In general, the catch rates of squid in the waters of less than 50m depth in SW2001, were considerably high compared to those of offshore areas. Extreme outliers in the box plots of catch rates show, however, a high station-to-station variability in the abundance index of squid (Figure 17).

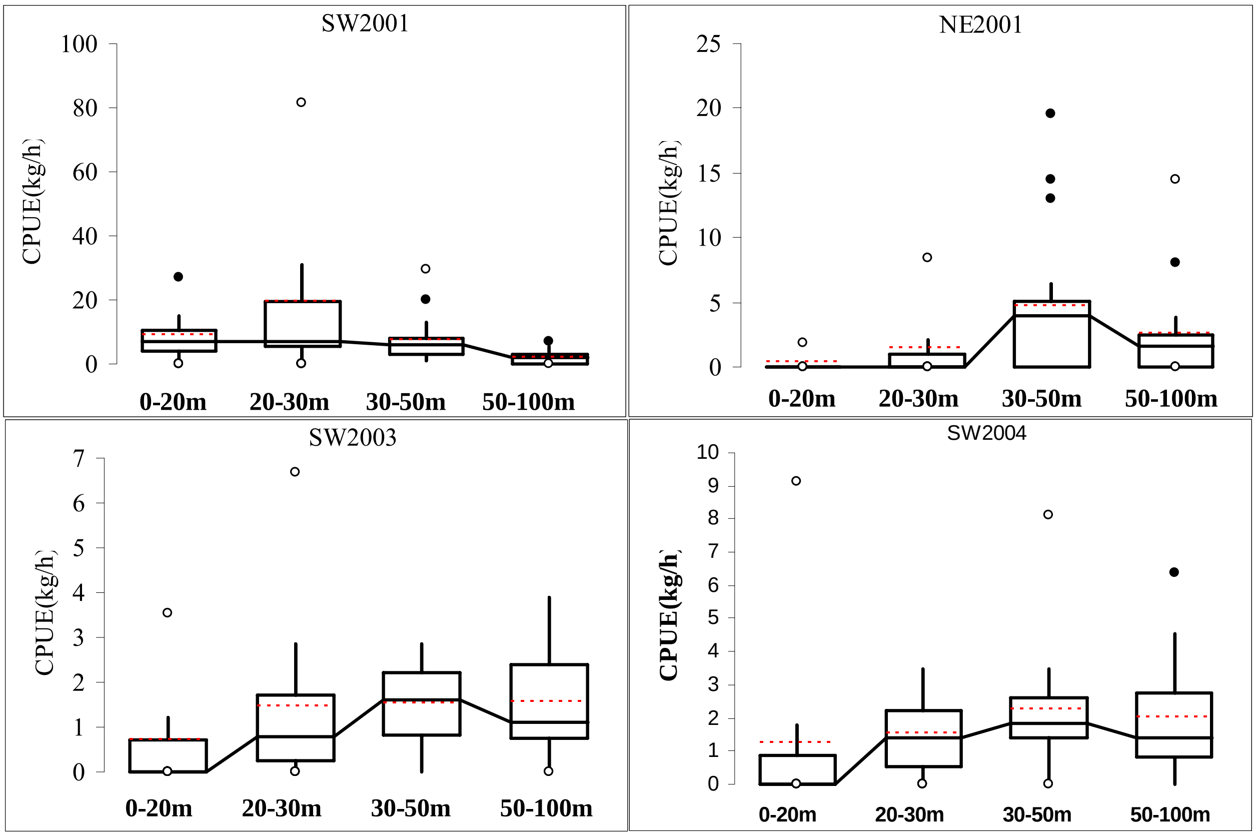


Figure 17. Box-plots of the catch rates (kg/h) of Chinese squid observed in the four surveys performed in the Gulf of Tonkin.

3.3.2. Seasonal distribution

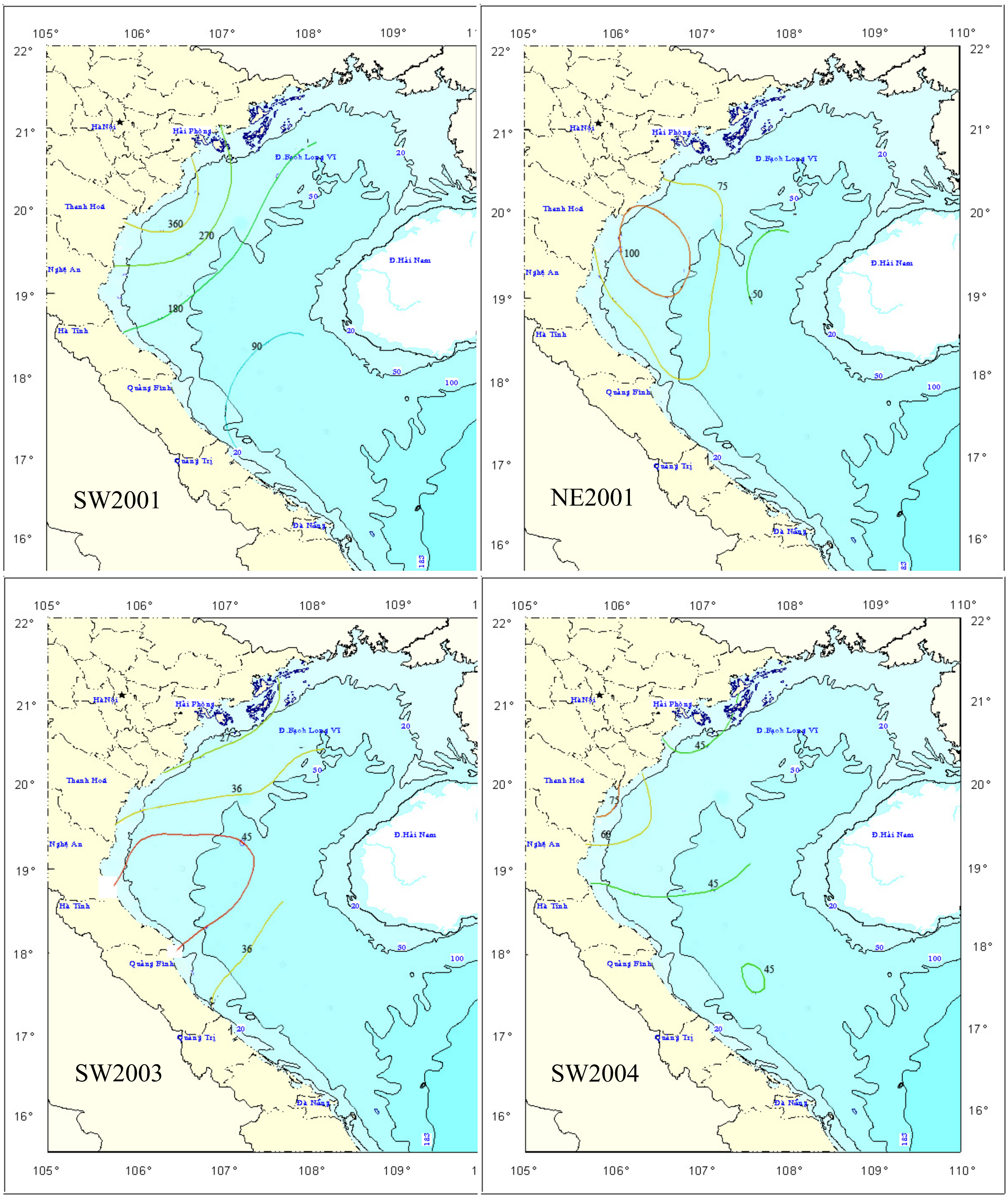


Figure 18. Contour maps of the spatial distribution of Chinese squid in the different seasons and surveys performed in the Gulf of Tonkin. Density estimates based on catchability-adjusted CPUA (kg/km^2).

The spatial distribution of squid differed from those observed in the fish species. The high density areas were normally located between latitudes of 19°N-20°N, and density tended to increase from the southeast to the northwest, irrespective of season. The highest density contours, corresponding to 360kg/km^2, 100kg/km^2, 45kg/km^2 and 60kg/km^2 in SW2001, NE2001, SW2003 and SW2004 tended to occur close to the coast at depths ranging from 20 to 50m.

3.3.3. Biomass

The best-estimates of total biomass of squid are summarised in Table 5, and the distribution of the estimates is shown in Figure 19. A strong variation in total biomass was observed between the first and second survey of 2001, decreasing from 16,134 tones in southwest monsoon to 4,342 tones in the northeast monsoon. Biomass continued apparently declining until 2003 (2,418 tones), but showed a slight recovery in SW2004 (3,191 tones).

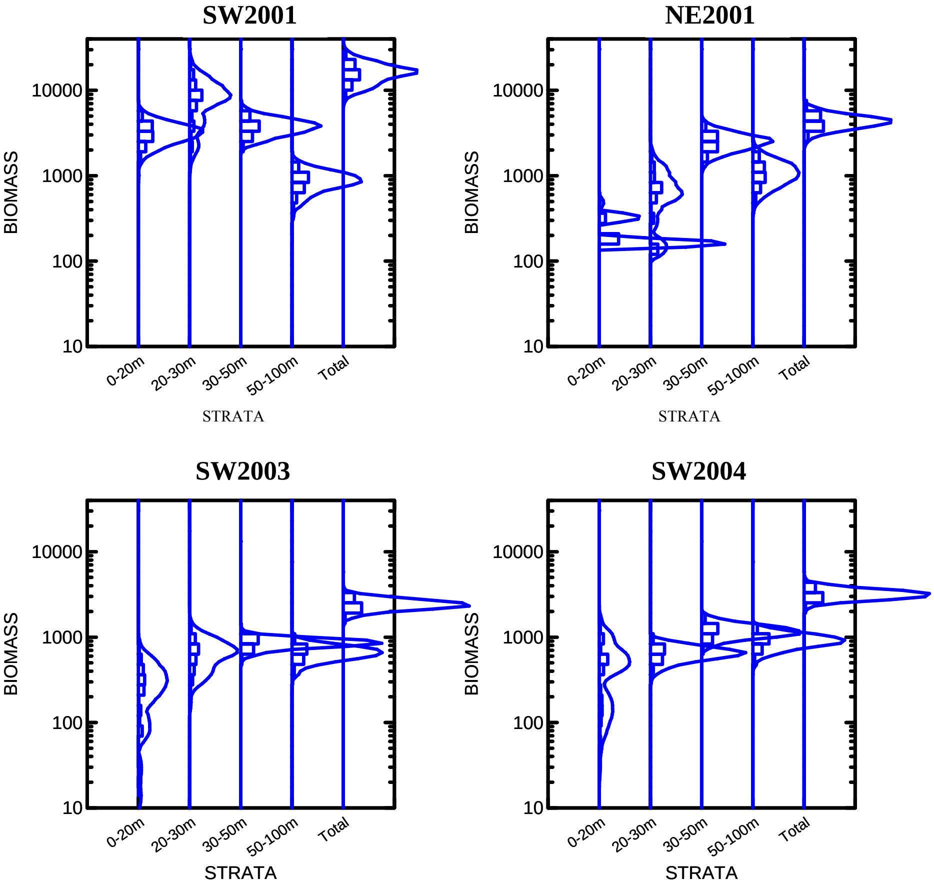


Figure 19. The distribution of the bootstrapped estimates of total biomass of squid in the four strata, and the total estimate for each of the four surveys performed in the Gulf of Tonkin

The estimates of standing biomass were relatively precise for all surveys, with the exception of the first survey, SW2001, where the coefficient of variation attained relatively high values (27%). Still the lower confidence bound of this estimate (9,257 tones) was far higher than the upper bounds of subsequent estimates (6,184 tones). There seems, therefore, to be little uncertainty with regard to the strong decline in standing biomass. More detailed information about the statistics of the estimates is given in Appendix 9 and 12.

Table 5. Mean estimates of total stock biomass, their standard error, coefficient of variation, and 95% confidence intervals, for Chinese squid in the four surveys performed in the Gulf of Tonkin.

Survey	***Biomass (tones)***				
	Mean	**Percentiles**		**SE**	**CV (%)**
		2.5	97.5		
SW2001	16,181	9,257	26,056	4,378	27
NE2001	4,318	2,809	6,184	830	19
SW2003	2,422	1,761	3,163	352	15
SW2004	3,190	2,406	4,166	451	14

3.3.4. Size distribution

Numerous squid were length measured (mantle length) in the two first surveys (7,696 and 1,458 individuals), but the sampling effort greatly decreased in the following surveys, to 93 individuals in SW2003 and 189 in SW2004. In the two first surveys, SW2001 and NE2001, length samples were taken in all strata. In the two later surveys coverage was poorer, in line with a decreased density of squid. For instance, in SW2003 squid were only sampled in stratum 30-50m and in SW2004 at depths of 30-50m and 50-100m. In the survey performed in the southwest monsoon of 2001, when the standing biomass was highest, squid ranged in size from 2 to 25cm, with a mean size in the survey of 8.7cm (Figure 20, Appendix 14). In later surveys, even the one performed soon after, during the Northeast monsoon in 2001, small squid were scarcer, and the range moved upwards to about 6 - 28cm. Therefore, and in contrast with the fish species, the average size of squid showed a clear increase: from 8.7cm in SW2001 to 11.8cm in NE2001, 15.5cm in SW2003, and 12.8cm in 2004. However, the limitations in length sampling in the two last surveys, particularly in 2003, should be taken into considerations. Except in the NE2001 survey no clear difference in size distributions could be found in inshore and offshore areas.

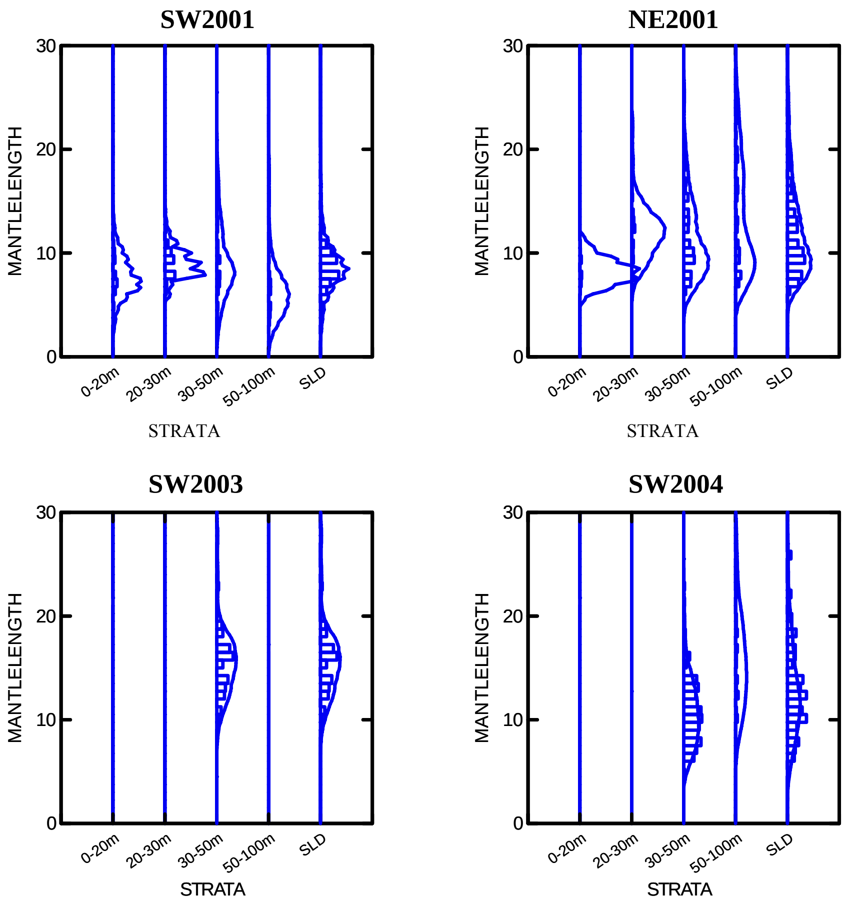


Figure 20. The length distribution of Chinese squid sampled in the four surveys performed in the Gulf of Tonkin. SLD is the overall length distribution in a survey, calculated with basis on the length-distributions in individual strata weighed by the respective biomass estimates.

3.3.5. Maturity

Maturation size (L_{m50}) of male squid apparently increased from 16.4cm to 19.8cm, while it remained relatively constant at 18.1-18.4cm for females, during the two last surveys (Table 6). The pooled-sex maturation sizes in the three southwestern surveys were estimated to be 16.7cm, 17.5cm, and 19.2cm, respectively. Therefore, the average sizes at maturation seem to have increased, and as judged from the confidence intervals the maturation length for male squid was significantly different in 2003 and 2004 (Figure 21). Simultaneously, the steepness of the maturity curves seems to have decreased considerably, with the maturity range (MR) rising from 1-2cm to about 5cm. Parallel to these changes the fit of the logistic became poorer and the confidence regions of the parameters, which were notably narrow in 2003, became increasingly larger. Therefore, while the maturity size increased, the L_{m25} estimated for the three surveys remained nearly constant (Figure 21). It is not understood whether or not these trends were a result of inadequate biological sampling. It is, however, evident that while the average size of the squid in the samples increased so did the maturation size. Therefore, the average-sized squid in the trawl catches continued to be immature individuals.

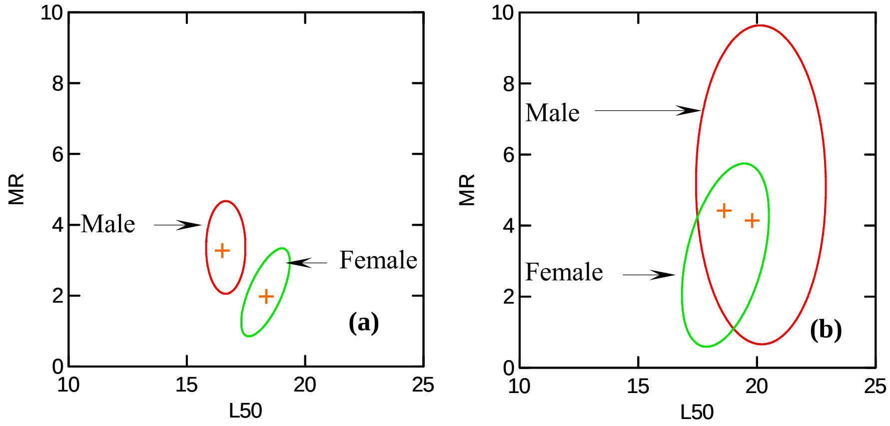


Figure 21. The best-estimates of maturation length and maturation range (crosses) and the 95% bi-variate confidence regions of these parameters for female and male Chinese squid sampled in surveys (a) SW2003 and (b) SW2004 in the Gulf of Tonkin

Table 6. Estimates of maturity parameters of Chinese squid sampled in three surveys performed in the Gulf of Tonkin. (n_{sx} - number of squid sex-typed; n/a - analysis not performed.)

Survey	***Parameter***	***Sex***		
		Male	Female	Pooled
SW2001	L_{m50} (cm)	n/a	n/a	16.7
	MR (cm)	n/a	n/a	1.4
	n_{sx}			25
SW2003	L_{m50} (cm)	16.4	18.4	17.5
	MR (cm)	3.1	2.1	2.6
	n_{sx}	125	178	303
SW2004	L_{m50} (cm)	19.8	18.1	19.2
	MR (cm)	4.2	4.5	5.6
	n_{sx}	69	90	159

3.3.6. Length-weight relationship

Length-weight relationships could be derived from material collected in all surveys, with the exception of the NE2001 survey for which these observations were not available. Despite the differences in sample sizes and size-spectrum of the squid measured, the three length-weight curves derived were fairly similar in shape and coefficients (Table 7 and Figure 22).

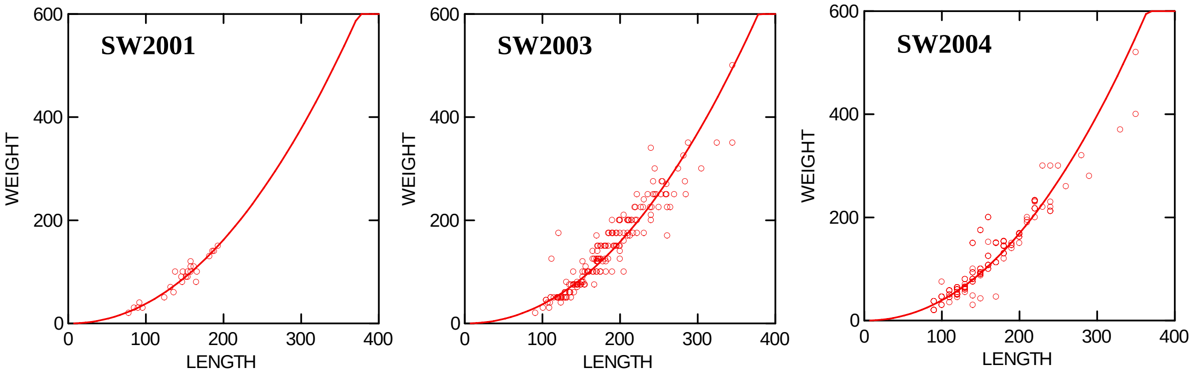


Figure 22. Plot of the length(cm) - weight(g) relationships for Chinese squid sampled in the Gulf of Tonkin in three surveys performed during the southwest monsoons.

Table 7. Coefficients of the length (cm) –weight (g) relationship of Chinese squid sampled in the three southwest surveys performed in the Gulf of Tonkin.

	Coefficients			
Year	**a**	**b**	**r^2**	**n**
SW2001	0.0026	2.085	0.94	25
SW2003	0.0024	2.093	0.89	184
SW2004	0.0024	2.107	0.88	167

3.3.7. Spawning biomass (SB)

The spawning biomass accounted for only approximately 5.9% of the total standing biomass of squid estimated in SW2001, but this ratio increased to 38.3% in SW2003 and 30.1% in SW2004. The estimates of spawning biomass were therefore relatively stable in the four surveys at 960, 1,711, 927, and 983 tones, respectively. This was a consequence of the changes in the size structure of the population that since the northeast monsoon of 2001 become increasingly composed of larger individuals, despite the large decrease in total biomass.

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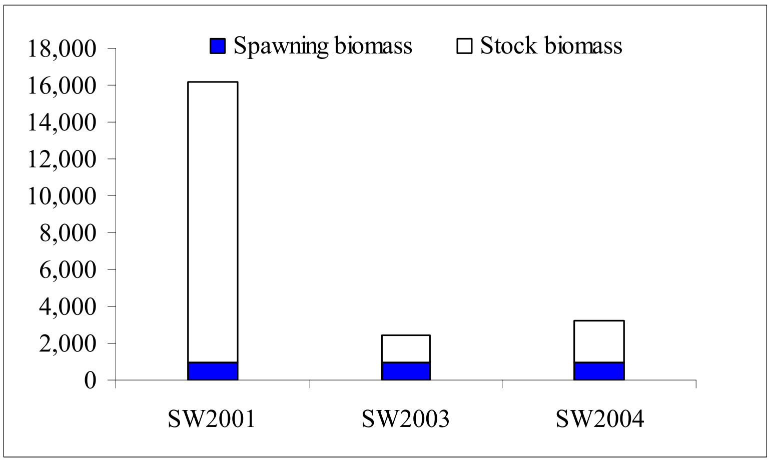

Figure 23. Trends in the estimated Spawning Biomass (SB) and Stock Biomass (Bs) of Chinese squid in three SW-surveys performed in the Gulf of Tonkin.

DISCUSSION

The scope of the data

The analyses conducted in this work rely on extensive sets of data, but the time series are limited in scope. The surveys performed during the season of the southwest monsoon were utilised as reference for the 'long-term' appraisal of the state of the standing stocks of three indicator species. However, a time span of four years (2001-2004) is very short to filter the long-term trends (signal) from possible natural yearly fluctuations (noise), particularly for populations with short longevity. The same applies to the analysis of seasonal trends, which could only be performed with basis on two surveys conducted in 2001. Therefore, even if it is known that the fishing pressure has largely increased in the last ten years in the Gulf of Tonkin, apparent signs of stock decline (or recovery) must be interpreted with the required caution. In addition to a continuation of the research surveys, following the protocols used so far, it would be very important to make attempts to recover information from surveys carried out in early years. This would greatly increase the information potential of the time series.

One of the major challenges in the recovery of historical survey data is that other types of trawl gear and protocols have been used in the past. This might require the utilisation of different catchability coefficients. Catchability is known to vary with the design characteristics of the trawl itself (Hjellvik *et al.* 2003), but also with the species and their seasonal physiological condition, stock size and several environmental characteristics (Tho'rarinsson and Jo'hannesson 1997; Benoit and Swain 2003). Attempts should be made to apply more adequate catchability coefficients to the different species, with basis on experimental work performed locally in Vietnam and elsewhere. In the present work a standard catchability coefficient was utilised for all species and seasons, and the effect of using q=0.5 is simply to double the biomass estimate and its standard error. The present estimates are therefore easy to correct for should a better coefficient be proposed for the present species or fishing conditions. In addition, all hauls were performed during daytime during these surveys. As a consequence, the complicating effects of nocturnal vertical migrations on biomass estimates can have been avoided, and do not require further correction.

In the lack of reliable fishery dependent data (fishery statistics and sampling of landings) research surveys are the only means to appraise the state of the stocks in the Gulf of Tonkin. The quality of the survey data for the three indicator species was, in general, adequate to estimate standing biomasses and to set reliable confidence intervals using re-sampling methodology. The sampling grid, composed of evenly (fixed) spaced stations, had a texture that was adequate to explore the advantages of spatial statistics. Interpolation by kriging was also a novel method utilised in Vietnamese fishery research that proved very useful, and illustrative of fish density distribution. Availability of length-frequency and other biological data, such as length-weight relationships and maturation ogives, made it possible to estimate standing stock biomasses. This is an important variable in stock assessment that has not been previously explored in the Gulf of Tonkin. Estimation of spawning biomass is the last step in a sequence of estimations: uncertainty implicit in the primary estimates, of e.g. total biomass or maturation curve will tend to propagate and accumulate in unforeseen ways. A better understanding of the precision (e.g. setting of confidence intervals) of the estimates of spawning biomass could only be obtained after simulation studies, normally called risk analysis, which take into account the uncertainty of all contributing parameters. This task should be performed in the future, and the present data can be a contribution in that direction.

New biological data

Previous knowledge of the fishery biology of the three indicator species in the Gulf of Tonkin, or in Vietnam, is small or non-existent. Despite the sampling limitations regarding maturation in Largehead hairtail it was possible to make preliminary estimates of the parameters of the allometric and maturation relationships of the three indicator species. Maturation size (L_{m50}) of Largehead hairtail in the Gulf was clearly smaller than in Cuba, but within the ranges observed in Thailand (Table 8). Similarly, the maturation sizes of male and female Greater lizardfish and Chinese squid were normally within 1-2cm of those observed in other parts of the South China Sea and Asia. Although the confidence intervals obtained for L_{m50} in the present work were relatively narrow, differences in this range are too small to be statistically significant.

The parameters of the allometric relationship were more variable than those of the maturation curve, both within this study and in comparison with investigations performed elsewhere in Asia. Part of this variation can be attributed to different, or inadequate, ranges of fish sizes sampled. In addition, other studies can have been performed in other seasons. Overall, however, there was an adequate similarity in the ranges of the parameters, particularly for the lizardfish (Table 9). On a world basis the different *Loligo* species have exponents (*b*) of the mantle length-weight relationship within the range 1.9 - 2.2 (*pers. com.* Dr. Teresa Borges, University of Algarve) and this clearly corresponds to the ranges observed in the present study and other investigations in Asia. From the above comparisons it seems, therefore, reasonable to conclude that the biological relationships utilised to calculate the spawning biomass (SB) of the three indicator species were based on reliable values.

Table 8. Estimates of maturation sizes in the Gulf of Tonkin and elsewhere for the three indicator species

Species	*Sex*	*L_{50} FL(cm)*	*Country*	*Locality*	*Source*
Largehead hairtail	*Female* *Pooled*	58.8 61.0	Vietnam	Tonkin Gulf	Present work
	Male *Female*	75.0 71.0	Cuba	Southern Region	(Garcia-Cagide 1994)
	Male *Female*	62.0 58.3	Thailand	Andaman	(Krajangadara and Yokoh 2004)
Greater lizardfish	*Male* *Female*	24.9 24.2 23.5 25.7 22.8 22.1	Vietnam	Tonkin Gulf	Present work
	Male	25.0 28.0	China	East China and Yellow Sea	(Shindo 1972) (Tiews *et al.* 1972)
	Female	21.0	Philippine	Manila Bay	(Tiews *et al.* 1972)
		29.0	India	Visakapatnam	(Rao 1983)
Chinese Squid	*Male* *Female*	16.4 19.8 18.4 18.1	Vietnam	Tonkin Gulf	Present work
	Male *Female*	12.9 16.2	Thailand	Eastern Coast Thailand Gulf	(Roongratri 1989)

Table 9. Estimates of length-weight relationships in the Gulf of Tonkin and elsewhere for the three indicator species

Species	*a*	*b*	*Country*	*Locality*	*Source*
Largehead hairtail	$0.43*10^{-3}$	3.00	Vietnam	Tonkin Gulf	Present work
	$0.72*10^{-3}$	2.92			
	$0.1*10^{-2}$	2.82	India	Karnataka	(Abdurahiman *et al.* 2004)
	$0.90*10^{-4}$	2.97	Indonesia	Western part	(Pauly *et al.* 1996)
	$0.10*10^{-4}$	3.45		East coast	(Chen and Lee 1982)
	$0.16*10^{-3}$	2.56	China	Taiwan	(Kwok and Ni 2000)
	$0.60*10^{-5}$	2.76			
Greater lizardfish	0.019	2.72	Vietnam	Tonkin Gulf	Present work
	0.005	3.22			
	0.012	2.92			
	$0.34*10^{-5}$	3.14	India	Karnataka	(Muthiah 1994)
	$0.50*10^{-2}$	3.21	Taiwan	Southeast China	(Tzeng *et al.* 2002)
	0.02	2.87	Bangladesh	Bengal Bay	(Mustafa 1999)
	$0.70*10^{-2}$	3.00	Philippine	Visayas	(Federizon 1983)
Chinese Squid	$0.26*10^{-2}$	2.09	Vietnam	Tonkin Gulf	Present work
	$0.24*10^{-2}$	2.09			
	$0.24*10^{-2}$	2.11			
	$0.50*10^{-2}$	2.39	Malaysia	West Coast	(Samsudin 2001)
	$0.12*10^{-2}$	2.22		East Coast	
	$0.13*10^{-2}$	2.24		Sarawark	
	$0.24*10^{-2}$	2.06	Thailand	Eastern Coast	(Roongratri 1989)
	$0.87*10^{-3}$	2.29		Thailand Gulf	

Long-term trends

The main question that this work attempted to address is whether we can detect changes in the state of fish stocks in the Gulf of Tonkin, as interpreted from the development of three indicator populations in three annual surveys performed during the southwest monsoon. The metrics utilised in the present work to judge the state of the populations relate to changes in standing biomass, in individual size, in a life-history parameter, the maturation size, and in regional distribution. These metrics are shown in a diagnostic table (Table 10).

Table 10. Long-term changes in the three indicator populations of the Gulf of Tonkin (n/a: information not available.)

Indicators	***Largehead hairtail***	***Greater lizardfish***	***Chinese squid***
Total Biomass (Bs)	High variation. Decrease?	Relative stability	Strong decline
Spawning Biomass (SB)	High variation. Decrease?	Some decline	Stable
Mean fish size	Stable	Stable	Increase
Size range	Width reduction	Width reduction	Increased upper tail
Maturation length and range	n/a	Decline	Increase
Spatial distribution trend	Relative stability	Relative stability	Locally variable

The Largehead hairtail is a mid-longevity species that is reportedly over-exploited in other parts of the South China Sea and East China Sea where senescent fisheries have been reported (Chen *et al.* 1997; Kwok and Ni 2000; Cheng and Fan 2001). However, it was this species that gave the most uncertain estimates of biomass sizes, a difficulty that was related to its possible tendency to form sparse, but very dense schools. Apparently both the total and the spawning biomass increased in 2004, but the estimate for this year is highly uncertain. The trends from 2001 to 2003 are those of strong decline in biomass. No particular changes were observed in both regional distribution or in the mean length in the catches. However, a sign of major concern is the large reduction in the frequency of both small (recruitment) and large fish in the samples. Therefore, both the mean size (49cm) and the maximum size (83cm) observed in the samples of 2004 clearly smaller than the maximum size reported for this species (235cm). Combined with a mid-range growth coefficient K, the reduction in large sizes leads to the impression that this population is also heavily exploited (Beverton and Holt 1956), and in lack of recruitment.

The Greater lizardfish is probably the most important species in the East China Sea (Shindo 1972), and is under strong protection from trawl fisheries (long closed season) in eastern Hainan Island, South China Sea, where catches comprised large numbers of 1-year old fish (Huang 2002). Of the three indicator species this was the one that provided the most precise estimates of biomass, maybe because it is a demersal species that forms less dense aggregations and is more suitable for bottom trawl surveying. While the total biomass remained relatively stable the spawning biomass seemed to incur a 22% long-term decline, and this is a signal of concern. Maybe as compensation this population showed a decrease in maturation size, but this difference was difficult to demonstrate statistically. As with the Largehead hairtail, this species did not show, however, particular changes in either regional distribution or mean fish size. But, it also showed a strong width reduction in size-frequency distribution, with a disappearance of both small and large fish in the samples. In 2004 the mean (18cm) and maximum (24cm) size in the catches fell short of the maximum size estimated for this species in the Gulf of Tonkin, 79cm (Yeh *et al.* 1977). Combined with a low to medium growth coefficient K, of about 0.1 (Yeh *et al.* 1977), this pattern also gives reason for concern, despite the apparently stable total biomass in the Gulf.

From the three species the expectedly most difficult to appraise was the Chinese squid, a small pelagic resource that probably is not suitably sampled by a bottom trawl. Owing to its great dynamics, with up to two generations within a year and short life-cycle, its development is particularly difficult to study in annual surveys. Despite these limitations the annual estimates of biomass seemed to have acceptable precision. The total biomass of the stock, as measured with a bottom trawl, seems to have decreased by 80% in the four years of the study. Surprisingly, the spawning biomass remained relatively stable, despite a clear increase in maturation size (which seems to be counteracted by a corresponding increase in maturation range.) The regional distribution of squid varied from year to year, up and down along the Vietnamese coast, but with no clear trend that could be related to standing biomass. While the size composition in the first survey of 2001 was dominated by small squid, in later surveys the biomass has been dominated by the large squid. This accounts for the stability in spawning biomass. Correspondingly, the mean (13cm) and maximum (26cm) length in the catches in 2004 do not deviate alarmingly from the reported maximum mantle length (30cm). This pattern combined with a very large growth potential, and a relative stability of the spawning biomass, indicates that the population might stand the highest chances of recovery, despite the low biomass state and apparent little recruitment in 2003 - 2004. In addition, it is known that for species with very short life-cycle, recruitment can be more severely affected by other factors than by the reduction in adult stock (Gulland 1982).

Seasonal trends and management

Other than providing new biological information, an important objective of this work was to analyse whether seasonal changes in fish distribution may affect our perception of the state of the stocks. Information about seasonal distribution of many pelagic and demersal species in the Gulf of Tonkin is lacking, and this may have also consequences for the management of the resources. The small pelagic Chinese squid was the only species that showed a clearer coastal affinity, and its abundance was highest in the 20-50m depth range, irrespective of season. There were no clear north-south migrations along the Vietnamese coast, and the size distribution was relatively similar inshore and offshore. Regarding the assessment and management of this resource this pattern has three main consequences. Research surveys can, in principle, be performed at any time of the year without major variation in the estimate of biomass. Owing to its geographical affinity this resource becomes more easily available to a coastal fleet that counts tenths of thousands of vessels. Management of such a resource becomes a sole responsibility of Vietnam. It is not clear how effort management of such geographically spread fleet can be performed in the lack of monitoring and control. Most probably this fishery will have to rely strongly on some form of self-control. It is a fast growing species with apparently good recovery potential: in poor seasons fishers will have to turn to other types of fishery or activities until a new cycle of good catches comes, provided that no incentive is given to keep fishing in the poor seasons.

The Largehead hairtail and the Greater Lizardfish showed similar movement patterns in the NE and SE monsoon surveys performed in 2001. During the NE monsoon the two populations approach the coast in the SW region of the Gulf and form a large concentration in the 20-30 m depth range. At this stage the populations are well mixed and both small and large fish are found inshore and further offshore. During the SW monsoon the largest concentration of the two species is found in the central part of the Gulf, in the 30-100m depth range, and about 90 nautical miles away from the Vietnamese coast. The two species differ slightly in the size composition along the inshore-offshore gradient. While Largehead hairtail showed a homogeneous length composition along the gradient, there is a weak trend for Lizardfish of larger sizes to be found further offshore during the SW monsoon. Probably as a consequence of the westward movement the two species showed peaks of biomass in Vietnamese waters during the NE monsoon, and this accumulation was more evident for Largehead hairtail. There are several consequences of these patterns for fishery management. Survey assessment of these two species would give fairly different results, but maybe the same trends, if they were routinely performed during the SW or the NE monsoon. But, due to the multi-species nature of the fisheries it is difficult to make any recommendation about the best time for the surveys. During the NE monsoon the two populations become available to the large coastal fleet, but during the SW monsoon they find shelter in deeper waters, where they are only available to a limited amount of Vietnamese offshore trawlers. From a management perspective this could be considered a form of more easily monitored seasonal 'closure'. Lastly, the offshore waters are not necessarily a refugium since the fish will probably become equally available to the potent Chinese trawler fleet. The two species have low to medium growth potentials and once depleted they make take years, rather than seasons, as in the case of the squid, to recover. It is therefore the responsibility of both Vietnam and China to find common mechanisms to control and monitor these important resources, and other that may show the same type of trans-boundary behaviour, in the South China Sea.

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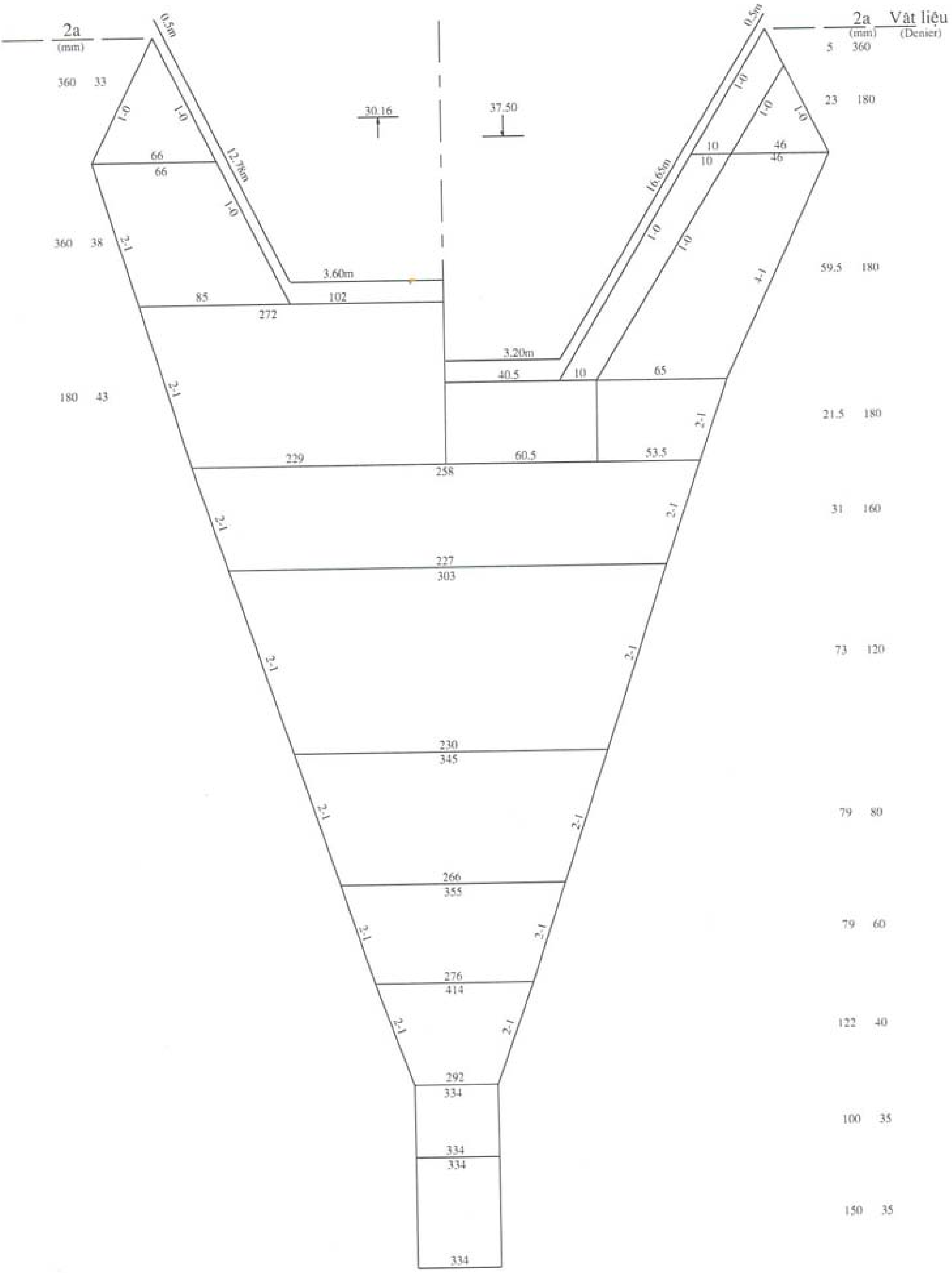
APPENDICES

Appendix 1. The drawn of the bottom trawl used in the four surveys performed in the Gulf of Tonkin



Appendix 2. Descriptive statistics of the catch rates (kg/hour) and catch per unit area (kg/ km^2) of Largehead hairtail sampled in the four surveys.

SW2003 stratum of 20-30m

```
                        CPUE        CPUA
  N of cases              12          12
  Minimum                0.0         0.0
  Maximum                1.1        13.8
  Range                  1.1        13.8
  Mean                   0.2         3.3
  Standard Dev           0.4         4.8
  Variance               0.1        23.1
  SW Statistic           0.7         0.7
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                1.1        13.8
```

SW2004 stratum of 20-30m

```
                        CPUE        CPUA
  N of cases              11          11
  Minimum                0.0         0.0
  Maximum                3.9        51.2
  Range                  3.9        51.2
  Mean                   0.8        10.5
  Standard Dev           1.2        15.4
  Variance               1.4       236.4
  SW Statistic           0.7         0.7
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                3.9        51.2
```

SW2001 stratum of 30-50m

```
                        CPUE        CPUA
  N of cases              18          18
  Minimum                0.0         0.0
  Maximum                8.5       109.5
  Range                  8.5       109.5
  Mean                   2.0        25.5
  Standard Dev           2.3        29.0
  Variance               5.2       840.7
  SW Statistic           0.8         0.8
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                8.5       109.5
```

NE2001 stratum of 30-50m

```
                        CPUE        CPUA
  N of cases              20          20
  Minimum                0.0         0.0
  Maximum               15.0       183.7
  Range                 15.0       183.7
  Mean                   2.3        28.8
  Standard Dev           3.5        42.8
  Variance              12.1      1835.2
  SW Statistic           0.6         0.7
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %               15.0       183.7
```

SW2003 stratum of 30-50m

```
                        CPUE        CPUA
  N of cases              19          19
  Minimum                0.0         0.0
  Maximum               26.2       358.7
  Range                 26.2       358.7
  Mean                   2.8        37.9
  Standard Dev           6.0        81.6
  Variance              35.8      6659.8
  SW Statistic           0.5         0.5
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %               26.2       358.7
```

SW2004 stratum of 30-50m

```
                        CPUE        CPUA
  N of cases              16          16
  Minimum                0.0         0.0
  Maximum              232.0      2999.8
  Range                232.0      2999.8
  Mean                  24.8       319.1
  Standard Dev          59.7       771.5
  Variance            3562.8    595241.1
  SW Statistic           0.5         0.5
  SW P-Value             0.0         0.0
  Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %              232.0      2999.8
```

SW2001 stratum of 50-100m

```
                          CPUE         CPUA
  N of cases                17           17
  Minimum                  0.0          0.0
  Maximum                 30.2        413.5
  Range                   30.2        413.5
  Mean                     5.0         65.3
  Standard Dev             7.7        103.4
  Variance                58.8      10687.9
  SW Statistic             0.7          0.7
  SW P-Value               0.0          0.0
Method = CLEVELAND
   2.5 %                   0.0          0.0
   97.5 %                 30.2        413.5
```

NE2001 stratum of 50-100m

```
                          CPUE         CPUA
  N of cases                17           17
  Minimum                  0.0          0.0
  Maximum                 43.0        526.7
  Range                   43.0        526.7
  Mean                     8.7        107.4
  Standard Dev            10.4        127.8
  Variance               107.5      16325.0
  SW Statistic             0.7          0.7
  SW P-Value               0.0          0.0
Method = CLEVELAND
   2.5 %                   0.0          0.0
   97.5 %                 43.0        526.7
```

SW2003 stratum of 50-100m

```
                          CPUE         CPUA
  N of cases                17           17
  Minimum                  0.0          0.0
  Maximum                  7.8         93.1
  Range                    7.8         93.1
  Mean                     2.3         28.1
  Standard Dev             2.0         23.9
  Variance                 4.0        573.0
  SW Statistic             0.9          0.9
  SW P-Value               0.0          0.0
Method = CLEVELAND
   2.5 %                   0.0          0.0
   97.5 %                  7.8         93.1
```

SW2004 stratum of 50-100m

```
                          CPUE         CPUA
  N of cases                18           18
  Minimum                  0.0          0.0
  Maximum                 14.0        186.2
  Range                   14.0        186.2
  Mean                     4.2         55.5
  Standard Dev             4.3         58.3
  Variance                18.8       3403.8
  SW Statistic             0.9          0.8
  SW P-Value               0.0          0.0
Method = CLEVELAND
   2.5 %                   0.0          0.0
   97.5 %                 14.0        186.2
```

Appendix 3. Descriptive statistics of the catch rates (kg/hour) and catch per unit area (kg /km^2) of Greater lizardfish sampled in the four surveys

SW2001 stratum of 0-20m

```
                        CPUE        CPUA
  N of cases               9           9
  Minimum                0.0         0.0
  Maximum               10.5       143.8
  Range                 10.5       143.8
  Mean                   2.3        30.6
  Standard Dev           3.6        48.7
  Variance              12.8      2373.1
  SW Statistic           0.7         0.7
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %               10.5       143.8
```

NE2001 stratum of 0-20m

```
                        CPUE        CPUA
  N of cases               5           5
  Minimum                0.0         0.0
  Maximum                0.0         0.0
  Range                  0.0         0.0
  Mean                   0.0         0.0
  Standard Dev           0.0         0.0
  Variance               0.0         0.0
  SW Statistic           0.6           .
  SW P-Value             0.0           .
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                0.0         0.0
```

SW2003 stratum of 0-20m

```
                        CPUE        CPUA
  N of cases               7           7
  Minimum                0.0         0.0
  Maximum                1.9        25.3
  Range                  1.9        25.3
  Mean                   0.7         9.0
  Standard Dev           0.8         9.9
  Variance               0.6        98.9
  SW Statistic           0.9         0.9
  SW P-Value             0.2         0.2
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                1.9        25.3
```

SW2004 stratum of 0-20m

```
                        CPUE        CPUA
  N of cases              10          10
  Minimum                0.0         0.0
  Maximum                3.3        44.2
  Range                  3.3        44.2
  Mean                   0.9        12.7
  Standard Dev           1.3        16.8
  Variance               1.6       283.5
  SW Statistic           0.8         0.8
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %                3.3        44.2
```

SW2001 stratum of 20-30m

```
                        CPUE        CPUA
  N of cases               7           7
  Minimum                0.1         0.6
  Maximum                1.0        12.3
  Range                  0.9        11.7
  Mean                   0.4         4.9
  Standard Dev           0.3         4.1
  Variance               0.1        17.0
  SW Statistic           0.9         0.9
  SW P-Value             0.4         0.4
Method = CLEVELAND
   2.5 %                 0.1         0.6
   97.5 %                1.0        12.3
```

NE2001 stratum of 20-30m

```
                        CPUE        CPUA
  N of cases               7           7
  Minimum                0.0         0.0
  Maximum               23.6       323.4
  Range                 23.6       323.4
  Mean                   5.2        68.6
  Standard Dev           8.4       115.3
  Variance              70.2     13286.5
  SW Statistic           0.7         0.7
  SW P-Value             0.0         0.0
Method = CLEVELAND
   2.5 %                 0.0         0.0
   97.5 %               23.6       323.4
```

SW2003 stratum of 20-30m

```
                          CPUE          CPUA
  N of cases                12            12
  Minimum                  0.0           0.0
  Maximum                  4.2          64.7
  Range                    4.2          64.7
  Mean                     1.6          22.6
  Standard Dev             1.5          21.7
  Variance                 2.2         469.5
  SW Statistic             0.9           0.9
  SW P-Value               0.1           0.1
Method = CLEVELAND
   2.5 %                   0.0           0.0
   97.5 %                  4.2          64.7
```

SW2004 stratum of 20-30m

```
                          CPUE          CPUA
  N of cases                11            11
  Minimum                  0.0           0.0
  Maximum                  8.9         118.8
  Range                    8.9         118.8
  Mean                     1.4          18.6
  Standard Dev             2.6          34.8
  Variance                 6.8        1210.2
  SW Statistic             0.6           0.6
  SW P-Value               0.0           0.0
Method = CLEVELAND
   2.5 %                   0.0           0.0
   97.5 %                  8.9         118.8
```

SW2001 stratum of 30-50m

```
                          CPUE          CPUA
  N of cases                18            18
  Minimum                  0.2           2.4
  Maximum                 21.1         239.0
  Range                   20.9         236.6
  Mean                     4.5          53.9
  Standard Dev             5.1          58.7
  Variance                26.5        3441.3
  SW Statistic             0.8           0.8
  SW P-Value               0.0           0.0
Method = CLEVELAND
   2.5 %                   0.2           2.4
   97.5 %                 21.1         239.0
```

NE2001 stratum of 30-50m

```
                          CPUE          CPUA
  N of cases                20            20
  Minimum                  0.0           0.0
  Maximum                  8.4         108.6
  Range                    8.4         108.6
  Mean                     3.3          43.1
  Standard Dev             2.8          36.7
  Variance                 8.0        1345.7
  SW Statistic             0.9           0.9
  SW P-Value               0.0           0.0
Method = CLEVELAND
   2.5 %                   0.0           0.0
   97.5 %                  8.4         108.6
```

SW2003 stratum of 30-50m

```
                          CPUE          CPUA
  N of cases                19            19
  Minimum                  0.0           0.0
  Maximum                 13.0         163.5
  Range                   13.0         163.5
  Mean                     2.5          32.4
  Standard Dev             3.0          37.9
  Variance                 9.0        1438.9
  SW Statistic             0.7           0.7
  SW P-Value               0.0           0.0
Method = CLEVELAND
   2.5 %                   0.0           0.0
   97.5 %                 13.0         163.5
```

SW2004 stratum of 30-50m

```
                          CPUE          CPUA
  N of cases                16            16
  Minimum                  0.0           0.0
  Maximum                 32.0         413.8
  Range                   32.0         413.8
  Mean                     3.7          47.4
  Standard Dev             7.6          98.7
  Variance                58.2        9749.1
  SW Statistic             0.4           0.4
  SW P-Value               0.0           0.0
Method = CLEVELAND
   2.5 %                   0.0           0.0
   97.5 %                 32.0         413.8
```

SW2001 stratum of 50-100m

```
                          CPUE        CPUA
  N of cases                17          17
  Minimum                  0.0         0.0
  Maximum                 10.5       128.6
  Range                   10.5       128.6
  Mean                     3.2        39.6
  Standard Dev             2.7        33.1
  Variance                 7.4      1098.3
  SW Statistic             0.8         0.8
  SW P-Value               0.0         0.0
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                 10.5       128.6
```

NE2001 stratum of 50-100m

```
                          CPUE        CPUA
  N of cases                16          16
  Minimum                  0.7         7.7
  Maximum                 17.8       229.5
  Range                   17.1       221.8
  Mean                     4.0        50.2
  Standard Dev             4.9        62.7
  Variance                24.5      3928.4
  SW Statistic             0.7         0.7
  SW P-Value               0.0         0.0
Method = CLEVELAND
   2.5 %                   0.7         7.7
   97.5 %                 17.8       229.5
```

SW2003 stratum of 50-100m

```
                         CPUE        CPUA
  N of cases                17          17
  Minimum                  1.1        13.5
  Maximum                  6.5        82.4
  Range                    5.4        68.9
  Mean                     2.6        32.4
  Standard Dev             1.8        22.2
  Variance                 3.3       491.2
  SW Statistic             0.8         0.8
  SW P-Value               0.0         0.0
Method = CLEVELAND
   2.5 %                   1.1        13.5
   97.5 %                  6.5        82.4
```

SW2004 stratum of 50-100m

```
                          CPUE        CPUA
  N of cases                18          18
  Minimum                  0.0         0.0
  Maximum                  7.5        91.9
  Range                    7.5        91.9
  Mean                     3.5        45.8
  Standard Dev             2.1        25.6
  Variance                 4.3       655.3
  SW Statistic             1.0         1.0
  SW P-Value               0.9         0.9
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                  7.5        91.9
```

Appendix 4. Descriptive statistics of the catch rates (kg/hour) and catch per unit area (kg/km^2) of Chinese squid sampled in the four surveys

SW2001 stratum of 0-20m

```
                         CPUE        CPUA
  N of cases                9           9
  Minimum                 0.0         0.0
  Maximum                27.0       349.1
  Range                  27.0       349.1
  Mean                    8.9       116.4
  Standard Dev            8.2       105.9
  Variance               66.5     11215.7
  SW Statistic            0.9         0.9
  SW P-Value              0.2         0.2
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                27.0       349.1
```

NE2001 stratum of 0-20m

```
                         CPUE        CPUA
  N of cases                5           5
  Minimum                 0.0         0.0
  Maximum                 1.8        23.7
  Range                   1.8        23.7
  Mean                    0.4         4.7
  Standard Dev            0.8        10.6
  Variance                0.7       112.3
  SW Statistic            0.6         0.6
  SW P-Value              0.0         0.0
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                 1.8        23.7
```

SW2003 stratum of 0-20m

```
                         CPUE        CPUA
  N of cases                7           7
  Minimum                 0.0         0.0
  Maximum                 3.5        46.9
  Range                   3.5        46.9
  Mean                    0.7         9.4
  Standard Dev            1.3        17.5
  Variance                1.7       306.1
  SW Statistic            0.6         0.6
  SW P-Value              0.0         0.0
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                 3.5        46.9
```

SW2004 stratum of 0-20m

```
                         CPUE        CPUA
  N of cases               10          10
  Minimum                 0.0         0.0
  Maximum                 9.1       128.9
  Range                   9.1       128.9
  Mean                    1.2        17.1
  Standard Dev            2.8        40.0
  Variance                8.0      1598.3
  SW Statistic            0.5         0.5
  SW P-Value              0.0         0.0
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                 9.1       128.9
```

SW2001 stratum of 20-30m

```
                       CPUE        CPUA
  N of cases                7           7
  Minimum                 0.0         0.0
  Maximum                81.5      1053.8
  Range                  81.5      1053.8
  Mean                   19.7       257.6
  Standard Dev           29.0       375.3
  Variance              840.8    140844.0
  SW Statistic            0.7         0.7
  SW P-Value              0.0         0.0
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                81.5      1053.8
```

NE2001 stratum of 20-30m

```
                         CPUE        CPUA
  N of cases                7           7
  Minimum                 0.0         0.0
  Maximum                 8.4        95.4
  Range                   8.4        95.4
  Mean                    1.5        17.5
  Standard Dev            3.1        35.8
  Variance                9.9      1282.3
  SW Statistic            0.6         0.6
  SW P-Value              0.0         0.0
Method = CLEVELAND
   2.5 %                  0.0         0.0
   97.5 %                 8.4        95.4
```

SW2003 stratum of 20-30m

```
                             CPUE         CPUA
  N of cases                   12           12
  Minimum                     0.0          0.0
  Maximum                     6.7        103.4
  Range                       6.7        103.4
  Mean                        1.5         20.4
  Standard Dev                1.9         28.9
  Variance                    3.6        836.4
  SW Statistic                0.7          0.7
  SW P-Value                  0.0          0.0
Method = CLEVELAND
   2.5 %                      0.0          0.0
   97.5 %                     6.7        103.4
```

SW2004 stratum of 20-30m

```
                             CPUE         CPUA
  N of cases                   11           11
  Minimum                     0.2          1.9
  Maximum                     3.5         42.9
  Range                       3.3         41.0
  Mean                        1.5         19.7
  Standard Dev                1.1         13.8
  Variance                    1.3        191.7
  SW Statistic                0.9          0.9
  SW P-Value                  0.4          0.5
Method = CLEVELAND
   2.5 %                      0.2          1.9
   97.5 %                     3.5         42.9
```

SW2001 stratum of 30-50m

```
                            CPUE         CPUA
  N of cases                   18           18
  Minimum                     1.0         11.3
  Maximum                    29.5        361.1
  Range                      28.5        349.8
  Mean                        7.5         92.3
  Standard Dev                7.1         87.3
  Variance                   50.4       7615.9
  SW Statistic                0.8          0.8
  SW P-Value                  0.0          0.0
Method = CLEVELAND
   2.5 %                      1.0         11.3
   97.5 %                    29.5        361.1
```

NE2001 stratum of 30-50m

```
                             CPUE         CPUA
  N of cases                   20           20
  Minimum                     0.0          0.0
  Maximum                    19.5        252.1
  Range                      19.5        252.1
  Mean                        4.7         61.0
  Standard Dev                5.3         67.4
  Variance                   27.9       4543.1
  SW Statistic                0.8          0.8
  SW P-Value                  0.0          0.0
Method = CLEVELAND
   2.5 %                      0.0          0.0
   97.5 %                    19.5        252.1
```

SW2003 stratum of 30-50m

```
                             CPUE         CPUA
  N of cases                   19           19
  Minimum                     0.0          0.0
  Maximum                     2.9         38.3
  Range                       2.9         38.3
  Mean                        1.5         20.6
  Standard Dev                0.9         12.6
  Variance                    0.9        159.7
  SW Statistic                0.9          0.9
  SW P-Value                  0.2          0.2
Method = CLEVELAND
   2.5 %                      0.0          0.0
   97.5 %                     2.9         38.3
```

SW2004 stratum of 30-50m

```
                             CPUE         CPUA
  N of cases                   16           16
  Minimum                     0.0          0.0
  Maximum                     8.1        101.9
  Range                       8.1        101.9
  Mean                        2.3         28.6
  Standard Dev                1.8         23.0
  Variance                    3.4        529.2
  SW Statistic                0.8          0.8
  SW P-Value                  0.0          0.0
Method = CLEVELAND
   2.5 %                      0.0          0.0
   97.5 %                     8.1        101.9
```

SW2001 stratum of 50-100m

```
                          CPUE        CPUA
  N of cases                17          17
  Minimum                  0.0         0.0
  Maximum                  7.2        92.6
  Range                    7.2        92.6
  Mean                     2.1        26.6
  Standard Dev             2.3        29.5
  Variance                 5.5       872.1
  SW Statistic             0.8         0.8
  SW P-Value               0.0         0.0
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                  7.2        92.6
```

NE2001 stratum of 50-100m

```
                          CPUE        CPUA
  N of cases                17          17
  Minimum                  0.0         0.0
  Maximum                 14.5       187.5
  Range                   14.5       187.5
  Mean                     2.6        32.7
  Standard Dev             3.6        46.7
  Variance                13.3      2179.5
  SW Statistic             0.7         0.7
  SW P-Value               0.0         0.0
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                 14.5       187.5
```

SW2003 stratum of 50-100m

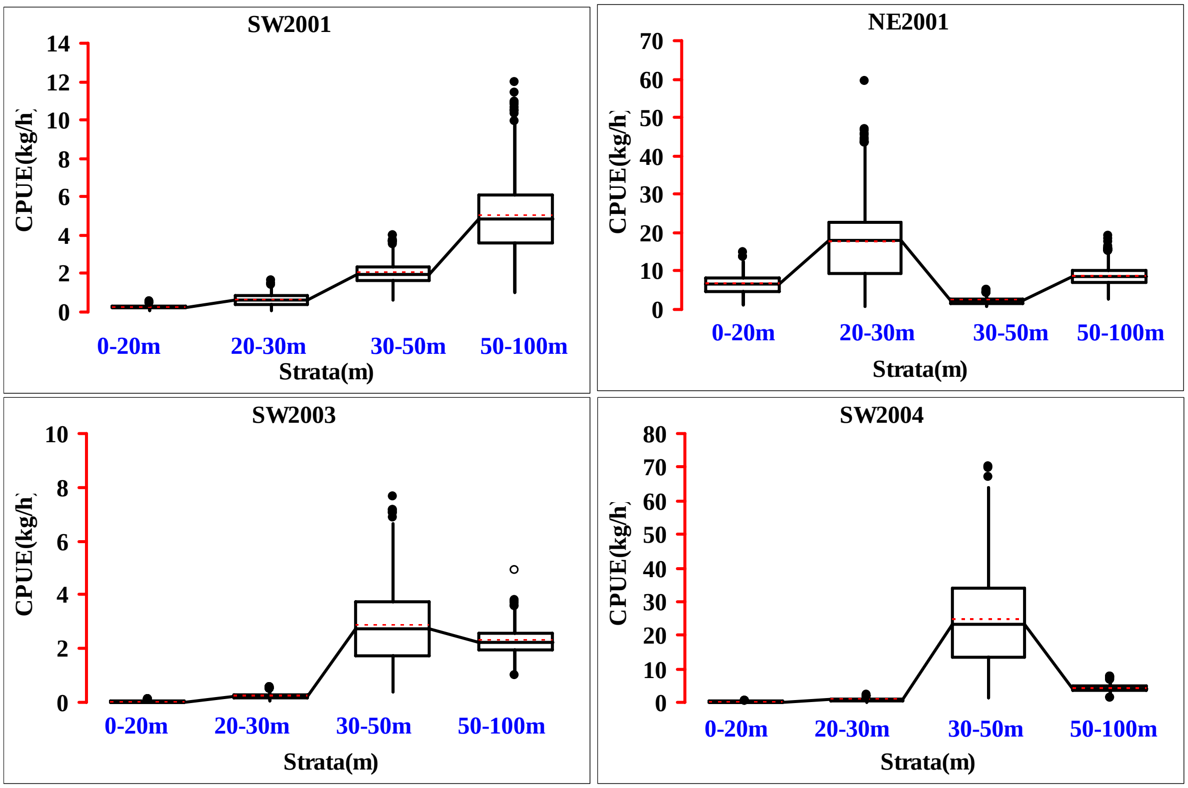
```
                          CPUE        CPUA
  N of cases                17          17
  Minimum                  0.0         0.0
  Maximum                  3.9        46.5
  Range                    3.9        46.5
  Mean                     1.6        19.7
  Standard Dev             1.3        15.9
  Variance                 1.7       251.9
  SW Statistic             0.9         0.9
  SW P-Value               0.1         0.1
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                  3.9        46.5
```

SW2004 stratum of 50-100m

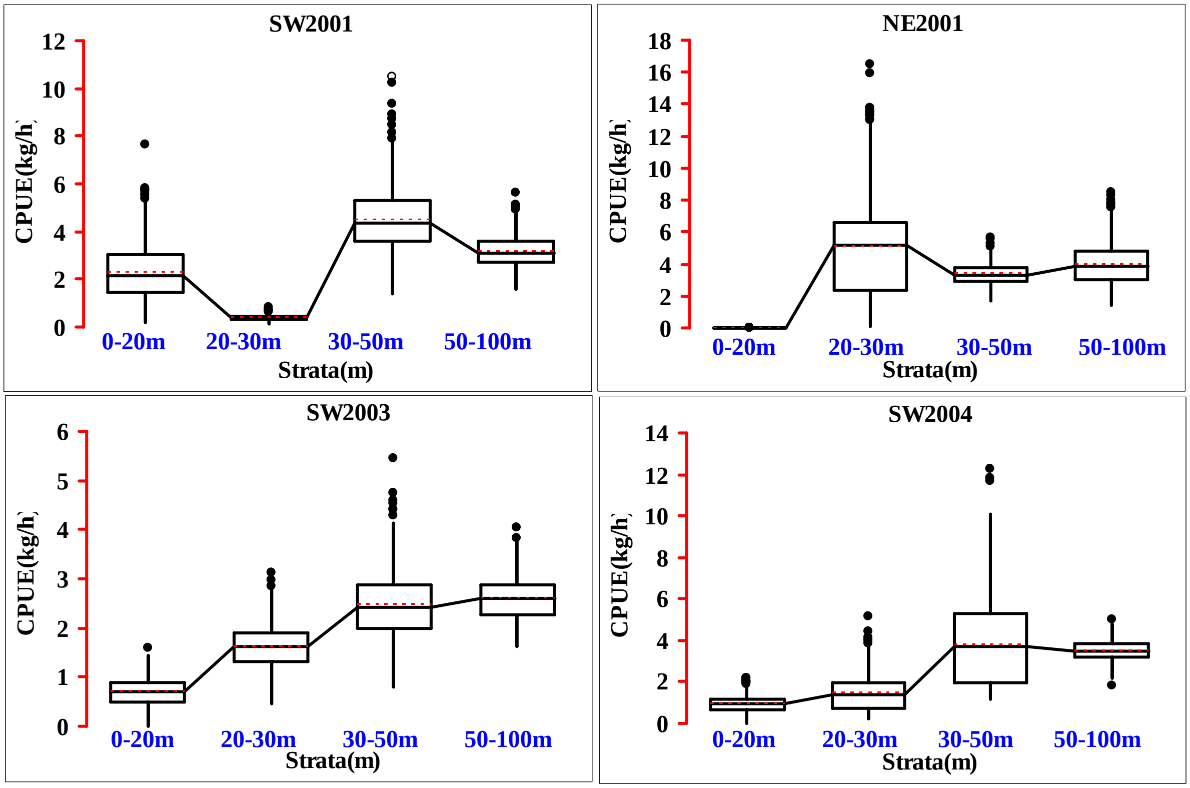
```
                          CPUE        CPUA
  N of cases                18          18
  Minimum                  0.0         0.0
  Maximum                  6.4        77.9
  Range                    6.4        77.9
  Mean                     2.0        26.7
  Standard Dev             1.7        22.5
  Variance                 3.0       507.3
  SW Statistic             0.9         0.9
  SW P-Value               0.1         0.1
Method = CLEVELAND
   2.5 %                   0.0         0.0
   97.5 %                  6.4        77.9
```

Appendix 5. Box plot of bootstrapped samples of catch rates of the three indicator species

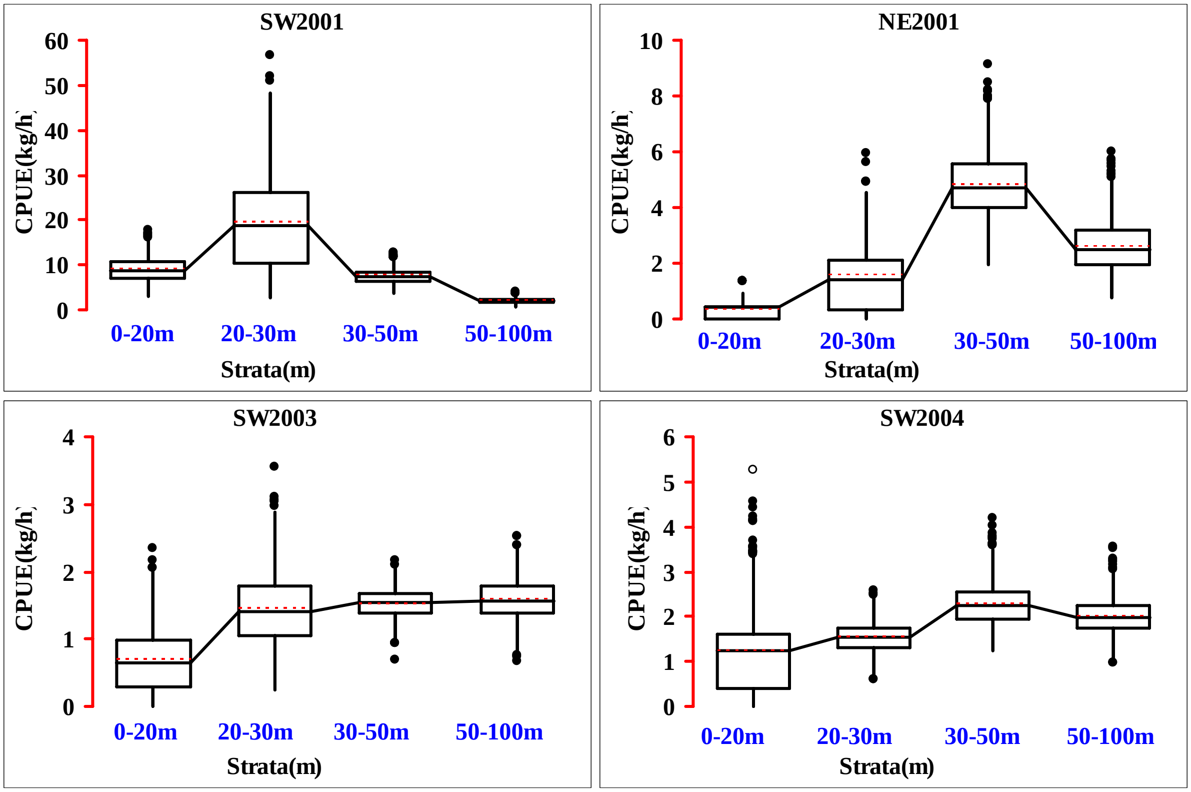
Largehead hairtail



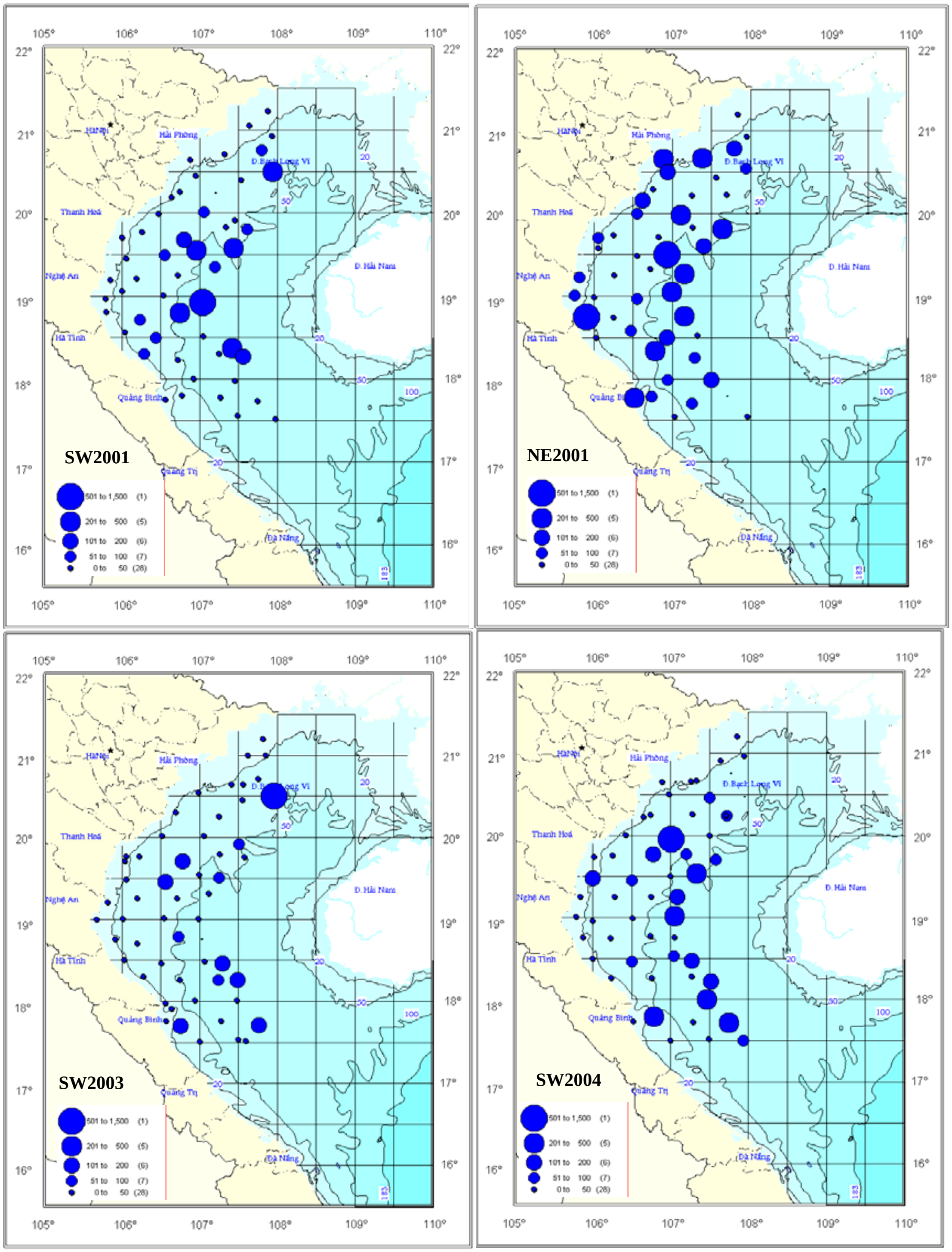
Greater lizardfish



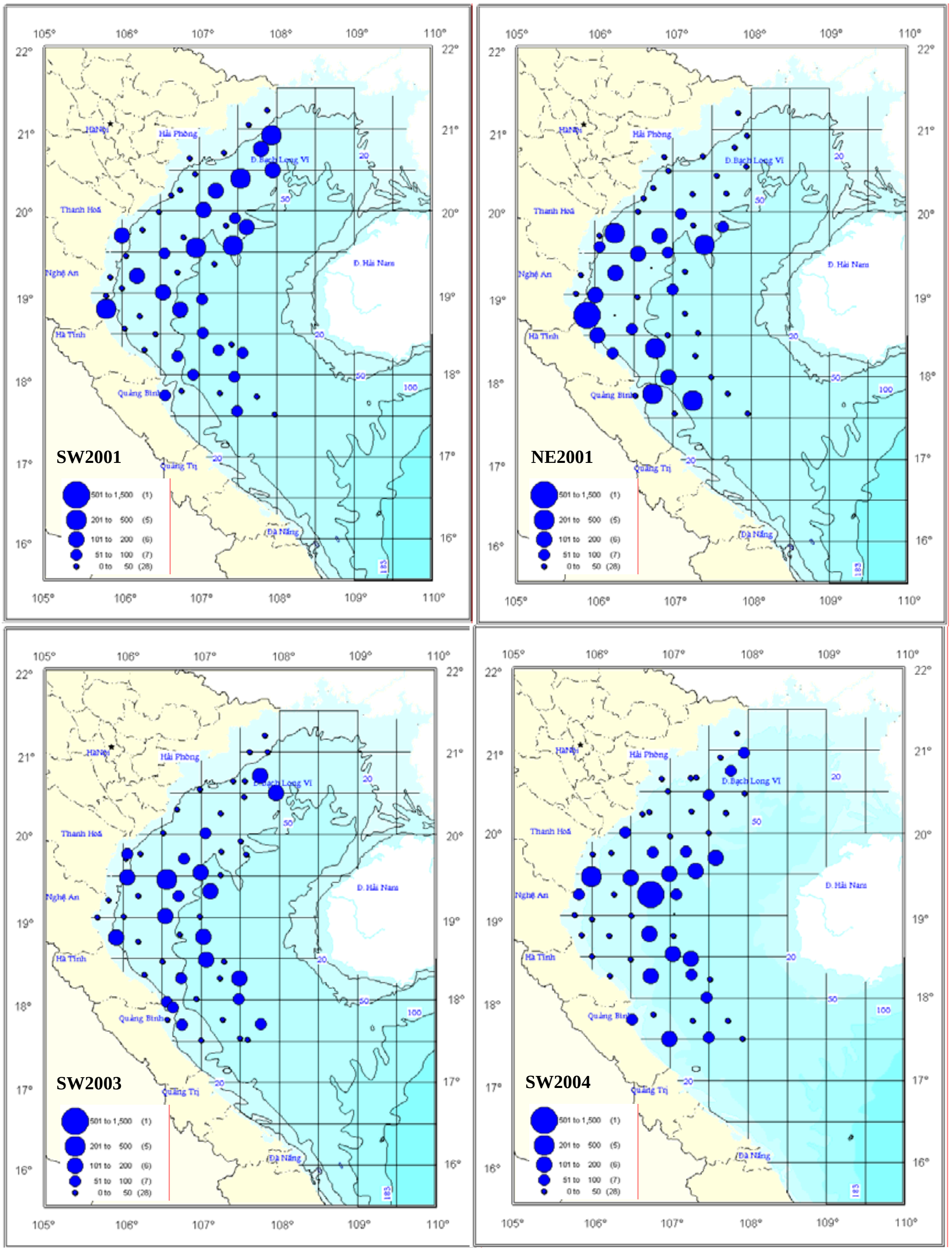
Chinese squid (*Loligo chinesis*)



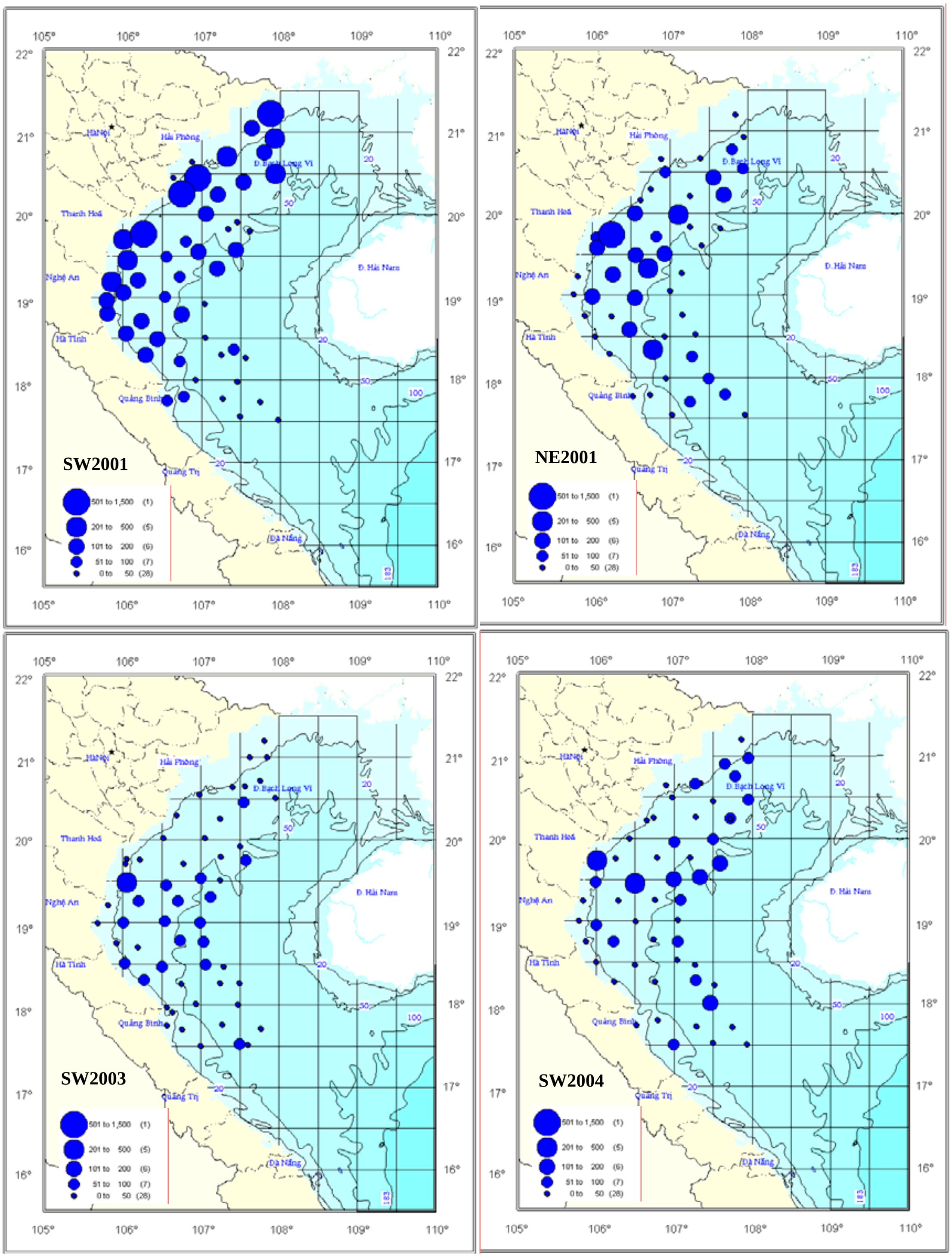
Appendix 6. Plots of fish density (kg/km^2) with the adjusted catchability of 0.5 of Largehead hairtail sampled in the four surveys performed in the Gulf of Tonkin



Appendix 7.Plots of fish density (kg/km^2) with the adjusted catchability of 0.5 of Greater lizardfish sampled in the four surveys performed in the Gulf of Tonkin



Appendix 8. Plots of fish density (kg/km^2) with the adjusted catchability of 0.5 of Chinese squid sampled in the four surveys performed in the Gulf of Tonkin



Appendix 9. The bootstrapped estimates of total biomass of the three indicator species in the four surveys performed in the Gulf of Tonkin

Largehead hairtail

SW2001

```
                      STRATA1      STRATA2      STRATA3      STRATA4        TOTAL
  N of cases             1000         1000         1000         1000         1000
  Minimum               17.00        15.00       272.00       292.00      1326.00
  Maximum              189.00       723.00      2008.00      5224.00      6932.00
  Mean                  94.18       266.86      1047.41      2161.57      3570.03
  Std. Error             0.88         3.99         8.54        25.22        27.06
  Standard Dev          27.88       126.17       270.07       797.39       855.85
  C.V.                   0.30         0.47         0.26         0.37         0.24
  SW Statistic           0.99         0.98         1.00         0.99         0.99
  SW P-Value             0.00         0.00         0.00         0.00         0.00
   2.5 %                44.00        63.00       558.00       762.00      2025.50
   97.5 %              152.50       544.00      1582.50      3874.00      5329.00
```

NE2001

```
                      STRATA1      STRATA2      STRATA3      STRATA4        TOTAL
  N of cases             1000         1000         1000         1000         1000
  Minimum              392.00       336.00       392.00      1441.00      4909.00
  Maximum             5231.00     22824.00      2923.00      8017.00     30355.00
  Mean                2326.08      7202.95      1198.88      3563.04     14290.94
  Std. Error            31.40       128.42        12.31        32.49       136.99
  Standard Dev         992.87      4061.01       389.40      1027.44      4332.08
  C.V.                   0.43         0.56         0.32         0.29         0.30
  SW Statistic           0.98         0.96         0.97         0.98         0.98
  SW P-Value             0.00         0.00         0.00         0.00         0.00
   2.5 %               555.00      1168.00       579.50      1940.00      7322.00
   97.5 %             4356.00     15992.00      2062.50      5935.50     23296.50
```

SW2003

```
                       STRATA1      STRATA2      STRATA3      STRATA4        TOTAL
  N of cases             1000         1000         1000         1000         1000
  Minimum                0.00        18.00       269.00       426.00      1063.00
  Maximum               37.00       290.00      5248.00      1586.00      6119.00
  Mean                   9.07       104.43      1569.79       939.72      2622.87
  Std. Error             0.21         1.38        23.51         6.17        24.24
  Standard Dev           6.66        43.75       743.61       195.19       766.59
  C.V.                   0.73         0.42         0.47         0.21         0.29
  SW Statistic           0.92         0.98         0.96         0.99         0.97
  SW P-Value             0.00         0.00         0.00         0.00         0.00
   2.5 %                 0.00        32.50       525.00       598.50      1447.00
   97.5 %               26.00       196.00      3259.00      1361.50      4258.50
```

SW2004

```
                      STRATA1      STRATA2      STRATA3      STRATA4        TOTAL
  N of cases             1000         1000         1000         1000         1000
  Minimum               13.00        22.00       673.00       694.00      2573.00
  Maximum              145.00       856.00     47969.00      3356.00     49748.00
  Mean                  74.99       343.04     12866.46      1848.39     15132.86
  Std. Error             0.72         4.49       241.14        13.79       241.30
  Standard Dev          22.74       141.99      7625.41       436.06      7630.46
  C.V.                   0.30         0.41         0.59         0.24         0.50
  SW Statistic           0.99         0.98         0.96         1.00         0.96
  SW P-Value             0.00         0.00         0.00         0.01         0.00
   2.5 %                35.00       113.50      1554.00      1053.00      3715.00
   97.5 %              124.00       663.00     28703.00      2723.50     31107.50
```

Greater lizardfish

SW2001

```
                     STRATA1      STRATA2      STRATA3      STRATA4        TOTAL
```

```
 N of cases              1000          1000          1000          1000          1000
 Minimum                51.00         36.00        924.00        703.00       2539.00
 Maximum              2235.00        316.00       3999.00       2382.00       7742.00
 Mean                  845.84        159.06       2199.63       1314.37       4518.86
 Std. Error             13.45          1.48         17.65          8.47         23.59
 Standard Dev          425.20         46.90        558.22        267.82        745.90
 C.V.                    0.50          0.29          0.25          0.20          0.17
 SW Statistic            0.98          1.00          0.99          0.99          0.99
 SW P-Value              0.00          0.00          0.00          0.00          0.00
  2.5 %                154.50         67.00       1290.00        831.50       3170.00
  97.5 %              1758.50        256.00       3450.00       1883.00       6069.50
```

NE2001

```
                     STRATA1       STRATA2       STRATA3       STRATA4         TOTAL
 N of cases              1000          1000          1000          1000          1000
 Minimum                 0.00         42.00        778.00        621.00       2874.00
 Maximum                 0.00       7624.00       2748.00       3651.00      11552.00
 Mean                    0.00       2316.96       1779.18       1692.97       5789.06
 Std. Error              0.00         42.87         10.63         15.76         46.20
 Standard Dev            0.00       1355.73        336.15        498.50       1461.06
 C.V.                       .          0.59          0.19          0.29          0.25
 SW Statistic               .          0.95          1.00          0.99          0.98
 SW P-Value                 .          0.00          0.17          0.00          0.00
  2.5 %                  0.00        417.00       1149.00        841.50       3382.50
  97.5 %                 0.00       5580.00       2451.50       2751.00       8884.00
```

SW2003

```
                     STRATA1       STRATA2       STRATA3       STRATA4         TOTAL
 N of cases              1000          1000          1000          1000          1000
 Minimum                 0.00        171.00        416.00        608.00       1832.00
 Maximum               526.00       1474.00       2581.00       1684.00       4979.00
 Mean                  249.48        730.13       1335.09       1079.11       3393.72
 Std. Error              3.01          6.47         11.11          5.41         14.40
 Standard Dev           95.31        204.75        351.43        171.15        455.31
 C.V.                    0.38          0.28          0.26          0.16          0.13
 SW Statistic            0.99          1.00          0.99          1.00          0.99
 SW P-Value              0.00          0.04          0.00          0.00          0.00
  2.5 %                 83.00        355.00        736.50        759.50       2564.00
  97.5 %               434.50       1162.50       2106.50       1435.00       4395.50
```

SW2004

```
                     STRATA1       STRATA2       STRATA3       STRATA4         TOTAL
 N of cases              1000          1000          1000          1000          1000
 Minimum                28.00         38.00        574.00        817.00       2402.00
 Maximum               791.00       1806.00       6376.00       2152.00       8790.00
 Mean                  351.14        603.02       1965.29       1539.73       4459.19
 Std. Error              4.45         10.38         31.04          6.55         34.10
 Standard Dev          140.86        328.38        981.44        207.23       1078.32
 C.V.                    0.40          0.54          0.50          0.13          0.24
 SW Statistic            0.99          0.96          0.92          1.00          0.97
 SW P-Value              0.00          0.00          0.00          0.93          0.00
  2.5 %                 93.00        128.00        720.00       1131.00       2800.50

  97.5 %               645.00       1367.50       4217.00       1953.50       6805.00
```

Chinese squid

SW2001

```
                     STRATA1       STRATA2       STRATA3       STRATA4         TOTAL
 N of cases              1000          1000          1000          1000          1000
 Minimum               980.00        965.00       1943.00        185.00       7163.00
 Maximum              6178.00      25642.00       6944.00       1735.00      34038.00
 Mean                 3196.98       8320.43       3783.36        880.23      16180.98
 Std. Error             28.47        133.72         27.25          7.57        138.46
 Standard Dev          900.19       4228.50        861.69        239.24       4378.53
```

```
  C.V.                  0.28        0.51        0.23        0.27        0.27
  SW Statistic          0.99        0.97        0.98        1.00        0.98
  SW P-Value            0.00        0.00        0.00        0.00        0.00
   2.5 %             1675.00     1828.00     2357.00      445.00     9204.50
   97.5 %            5201.00    18458.00     5732.00     1403.50    26056.00
```

NE2001

```
                     STRATA1     STRATA2     STRATA3     STRATA4       TOTAL
  N of cases            1000        1000        1000        1000        1000
  Minimum               0.00        0.00      979.00      367.00     2229.00
  Maximum             487.00     2214.00     4632.00     2663.00     7116.00
  Mean                129.93      575.33     2515.95     1097.04     4318.34
  Std. Error            3.82       13.32       19.08       11.66       26.25
  Standard Dev        120.86      421.28      603.24      368.65      830.21
  C.V.                  0.93        0.73        0.24        0.34        0.19
  SW Statistic          0.81        0.94        0.99        0.97        0.99
  SW P-Value            0.00        0.00        0.00        0.00        0.00
   2.5 %                0.00        0.00     1496.00      519.00     2809.50
   97.5 %             325.00     1550.00     3833.00     1939.50     6184.00
```

SW2003

```
                     STRATA1     STRATA2     STRATA3     STRATA4       TOTAL
  N of cases            1000        1000        1000        1000        1000
  Minimum               0.00      137.00      487.00      251.00     1391.00
  Maximum             784.00     1893.00     1238.00     1060.00     3654.00
  Mean                262.31      655.68      850.83      652.76     2421.58
  Std. Error            5.34        8.21        3.60        4.11       11.13
  Standard Dev        168.90      259.66      113.74      129.89      352.00
  C.V.                  0.64        0.40        0.13        0.20        0.15
  SW Statistic          0.96        0.98        1.00        1.00        0.99
  SW P-Value            0.00        0.00        0.58        0.63        0.00
   2.5 %                0.00      251.50      617.00      394.50     1761.00
   97.5 %             643.00     1212.00     1076.50      909.00     3163.00
```

SW2004

```
                    STRATA1     STRATA2     STRATA3     STRATA4       TOTAL
  N of cases            1000        1000        1000        1000        1000
  Minimum               0.00      294.00      667.00      448.00     2032.00
  Maximum            1664.00     1036.00     1930.00     1416.00     5173.00
  Mean                464.22      643.32     1180.10      902.78     3190.39
  Std. Error           10.33        4.08        6.87        5.65       14.29
  Standard Dev        326.68      129.09      217.27      178.56      451.88
  C.V.                  0.70        0.20        0.18        0.20        0.14
  SW Statistic          0.93        1.00        0.99        1.00        0.99
  SW P-Value            0.00        0.15        0.00        0.10        0.00
   2.5 %               34.00      393.50      787.50      572.00     2405.50
   97.5 %            1251.00      902.00     1663.00     1265.50     4166.00
```

Appendix 10. Estimates of the stock biomass of Largehead hairtail in the four surveys performed in the Gulf of Tonkin.

Surveys	***Strata*** (m)	***Biomasses (tones)***				
		Mean	**Percentiles**		**Std**	**CV (%)**
			2.5	**97.5**		
SW2001	*0-20*	94	44	152	28	30
	20-30	266	63	544	126	47
	30-50	1,047	558	1,582	271	26

	50-100	2,162	762	3,874	797	37
	Total	**3,570**	**2,026**	**5,329**	**856**	**24**
NE2001	*0-20*	2,326	555	4,356	993	43
	20-30	7,203	1,168	15,992	4,061	56
	30-50	1,199	579	2,063	389	32
	50-100	3,563	1,940	5,936	1,027	29
	Total	**14,290**	**7,322**	**23,297**	**4,332**	**30**
SW2003	*0-20*	9	0	26	7	73
	20-30	104	33	196	44	42
	30-50	1,569	525	3,259	744	47
	50-100	939	598	1,362	195	21
	Total	**2,623**	**1,447**	**4,259**	**767**	**29**
SW2004	*0-20*	75	35	124	23	30
	20-30	343	114	663	142	41
	30-50	12,866	1,554	28,703	7,625	59
	50-100	1,848	1,053	2,723	436	24
	Total	**15,133**	**3,715**	**31,107**	**7,630**	**50**

Appendix 11. Estimates of the stock biomass of Greater lizardfish in the four surveys performed in the Gulf of Tonkin.

Surveys	***Strata*** (m)	***Biomasses (tones)***				
		Mean	**Percentiles**		**Std**	**CV (%)**
			2.5	**97.5**		
SW2001	*0-20*	846	155	1,759	425	50
	20-30	159	67	256	47	29
	30-50	2,199	1,290	3,450	558	25
	50-100	1,314	832	1,883	268	20

	Total	**4,519**	**3,170**	**6,069**	**745**	**17**
NE2001	*0-20*	0	0	0	0	
	20-30	2,317	417	5,580	1,356	59
	30-50	1,779	1,149	2,452	336	19
	50-100	1,692	841	2,751	499	29
	Total	**5,789**	**3,383**	**8,884**	**1,461**	**25**
SW2003	*0-20*	249	83	434	95	38
	20-30	730	355	1,163	205	28
	30-50	1,335	737	2,107	351	26
	50-100	1,079	759	1,435	171	16
	Total	**3,394**	**2,564**	**4,396**	**455**	**13**
SW2004	*0-20*	351	93	645	141	40
	20-30	603	128	1,368	328	54
	30-50	1,965	720	4,217	981	50
	50-100	1,539	1,131	1,954	207	13
	Total	**4,459**	**2,801**	**6,805**	**1,078**	**24**

Appendix 12. Estimates of the stock biomass estimated of Chinese squid in the four surveys performed in the Gulf of Tonkin.

Surveys	***Strata*** *(m)*	***Biomasses (tones)***				
		Mean	**Percentiles**		**Std**	**CV (%)**
			2.5	**97.5**		
SW2001	*0-20*	3,197	1,675	5,201	900	28
	20-30	8,320	1,828	18,458	4,229	51
	30-50	3,783	2,357	5,732	862	23
	50-100	880	435	1,404	239	27

	Total	**16,181**	**9,257**	**26,056**	**4,378**	**27**
NE2001	*0-20*	130	0	325	121	93
	20-30	575	0	1,550	421	73
	30-50	2,516	1,496	3,833	603	24
	50-100	1,097	519	1,940	369	34
	Total	**4,318**	**2,809**	**6,184**	**830**	**19**
SW2003	*0-20*	262	0	643	169	64
	20-30	656	252	1,212	259	40
	30-50	851	617	1,077	114	13
	50-100	653	395	909	130	20
	Total	**2,422**	**1,761**	**3,163**	**352**	**15**
SW2004	*0-20*	464	34	1,251	327	70
	20-30	643	394	902	129	20
	30-50	1,180	788	1,663	217	18
	50-100	903	572	1,265	179	20
	Total	**3,190**	**2,406**	**4,166**	**451**	**14**

Appendix 13. Sample sizes of length frequency measured of the three indicator species sampled in the four surveys performed in the Gulf of Tonkin

Species	***Survey***	***Strata***				
		0-20m	20-30m	30-50m	50-100m	Total
Largehead hairtail	SW2001		65	206	441	712
	NE2001	128	140	63	554	885
	SW2003			508	268	776
	SW2004		56	4,958	442	5,456
Greater lizardfish	SW2001	464	44	1,330	901	2,739
	NE2001		1,098	1,507	1,130	3,735

	SW2003		82	357	183	622
	SW2004		218	68	180	466
Chinese squid	SW2001	1,526	3,247	1,888	1,035	7,696
	NE2001	63	152	826	417	1458
	SW2003			99		99
	SW2004			170	19	189

Appendix 14. Estimates of average length of the three indicator species sampled in the four surveys performed in the Gulf of Tonkin

Largehead hairtail

SW2001

```
                    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases              65         206         441         708
  Minimum               29.0        18.0        24.0        18.0
  Maximum               94.0        95.0       110.0       110.0
  Mean                  50.0        52.9        51.6        51.9
  Standard Dev          16.4        23.2        20.8        21.2
  C.V.                   0.3         0.4         0.4         0.4
  SW Statistic           0.9         0.9         0.8         0.9
  SW P-Value             0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                29.0        20.0        28.0        25.0
   97.5 %               91.9        94.3       103.0       101.6
```

NE2001

```
                    STRATUM1    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases              128         140          63         554         889
  Minimum                14.0        22.0        30.0        16.0        14.0
  Maximum                96.0        91.0        88.0        95.0        96.0
  Mean                   46.5        47.4        52.5        52.7        49.2
  Standard Dev           19.1        12.0        17.7        15.0        14.9
  C.V.                    0.4         0.3         0.3         0.3         0.3
  SW Statistic            0.8         1.0         0.9         0.9         0.9
  SW P-Value              0.0         0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                 21.0        26.0        30.0        30.0        26.0
   97.5 %                94.0        72.0        88.0        89.0        88.0
```

SW2003

```
                    STRATUM3    STRATUM4         SLD
  N of cases              508         268         806
  Minimum                30.0        32.0        32.0
  Maximum                83.0        77.0        95.0
  Mean                   47.0        51.7        50.6
  Standard Dev           13.6         7.7        14.6
  C.V.                    0.3         0.1         0.3
  SW Statistic            0.8         1.0         0.9
  SW P-Value              0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                 34.0        39.0        34.0
   97.5 %                71.0        66.8        91.0
```

SW2004

```
                    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases               56        4958         442        5431
  Minimum                39.0        34.0        30.0        30.0
  Maximum                61.0        71.0        83.0        83.0
  Mean                   52.5        48.8        46.2        48.6
  Standard Dev            4.7         4.6         5.6         4.8
  C.V.                    0.1         0.1         0.1         0.1
  SW Statistic            1.0         0.9         0.8           .
  SW P-Value              0.0         0.0         0.0           .
Method = CLEVELAND
   2.5 %                 39.9        40.0        37.0        40.0
   97.5 %                60.1        61.0        61.0        61.0
```

Greater lizardfish

SW2001

```
                    STRATUM1    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases              464          44        1330         901        2738
  Minimum                 8.0        10.0        11.0         8.0         8.0
  Maximum                26.0        22.0        27.0        26.0        27.0
  Mean                   15.1        16.6        16.6        17.0        16.4
  Standard Dev            5.1         3.7         4.9         4.3         4.8
  C.V.                    0.3         0.2         0.3         0.2         0.3
  SW Statistic            0.9         0.8         0.9         1.0         1.0
  SW P-Value              0.0         0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                  8.0        10.0        11.0         9.0         9.0
   97.5 %                25.0        20.8        26.0        25.0        25.0
```

NE2001

```
                    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases             1098        1507        1130        3735
  Minimum                 9.0         7.0         5.0         5.0
  Maximum                27.0        35.0        34.0        35.0
  Mean                   15.2        17.1        17.2        16.4
  Standard Dev            4.2         5.2         4.9         4.8
  C.V.                    0.3         0.3         0.3         0.3
  SW Statistic            0.8         1.0         0.9         1.0
  SW P-Value              0.0         0.0         0.0         0.0
```

```
Method = CLEVELAND
   2.5 %                10.0         9.0         5.0         8.0
   97.5 %               27.0        26.0        26.0        26.0
```

SW2003

```
                    STRATUM2    STRATUM3    STRATUM4        SLD
  N of cases              82         357         183         622
  Minimum                9.0        10.0        11.0         9.0
  Maximum               17.0        26.0        24.0        26.0
  Mean                  13.2        18.2        17.6        16.8
  Standard Dev           2.4         2.8         1.9         3.1
  C.V.                   0.2         0.2         0.1         0.2
  SW Statistic           0.9         1.0         1.0         1.0
  SW P-Value             0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                 9.0        12.0        14.0        10.0
   97.5 %               17.0        24.0        21.0        23.0
```

SW2004

```
                 STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases             218          68         180         470
  Minimum               10.0        14.0        16.0        11.0
  Maximum               29.0        23.0        22.0        24.0
  Mean                  16.5        18.7        18.0        18.1
  Standard Dev           4.5         2.1         1.4         2.3
  C.V.                   0.3         0.1         0.1         0.1
  SW Statistic           0.9         1.0         0.9         1.0
  SW P-Value             0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                11.0        15.0        16.0        13.0
   97.5 %               29.0        22.0        22.0        22.0
```

Chinese squid

SW2001

```
                      STRATUM1    STRATUM2    STRATUM3    STRATUM4          SLD
  N of cases            1526        3247        1888        1053        7713
  Minimum                3.0         6.0         2.0         2.0         2.0
  Maximum               22.0        16.0        30.0        28.0        30.0
  Mean                   7.8         9.1         9.1         6.5         8.7
  Standard Dev           2.0         1.5         3.7         3.2         2.5
  C.V.                   0.3         0.2         0.4         0.5         0.3
  SW Statistic           0.9         0.9         0.9         0.8           .
  SW P-Value             0.0         0.0         0.0         0.0           .
Method = CLEVELAND
   2.5 %                 4.0         6.0         3.0         2.0         4.0
   97.5 %               12.0        12.0        18.0        16.0        14.0
```

NE2001

```
                    STRATUM1    STRATUM2    STRATUM3    STRATUM4         SLD
  N of cases              63         152         826         417        1457
  Minimum                6.0         7.0         5.0         7.0         5.0
  Maximum               11.0        22.0        27.0        28.0        28.0
  Mean                   8.3        12.0        11.3        13.1        11.8
  Standard Dev           1.2         2.5         3.8         5.2         4.2
  C.V.                   0.1         0.2         0.3         0.4         0.4
  SW Statistic           0.9         0.9         0.9         0.9         0.9
  SW P-Value             0.0         0.0         0.0         0.0         0.0
Method = CLEVELAND
   2.5 %                 6.0         8.0         6.0         7.0         7.0
   97.5 %               11.0        18.7        20.0        25.0        23.0
```

SW2003

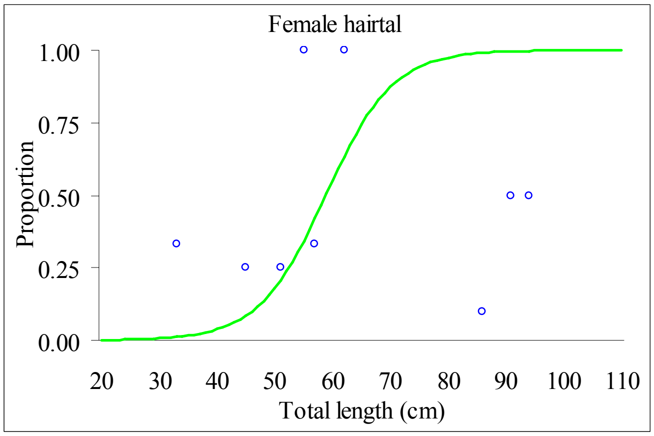
```
                     STRATUM3
```

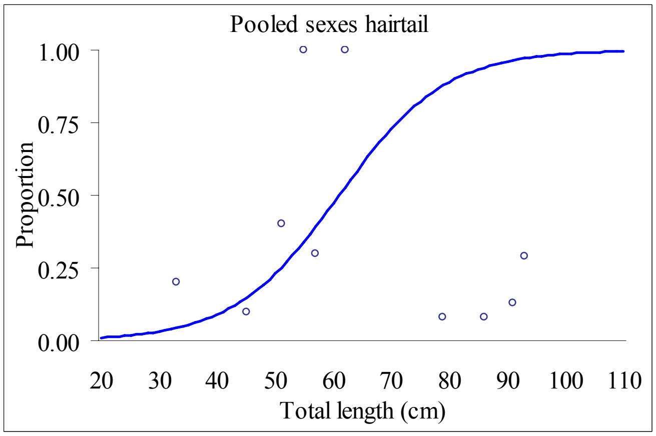
```
    N of cases                  99
    Minimum                    9.0
    Maximum                   28.0
    Mean                      15.5
    Standard Dev               3.3
    C.V.                       0.2
    SW Statistic               0.9
    SW P-Value                 0.0
Method = CLEVELAND
     2.5 %                    10.0
    97.5 %                    24.1
```

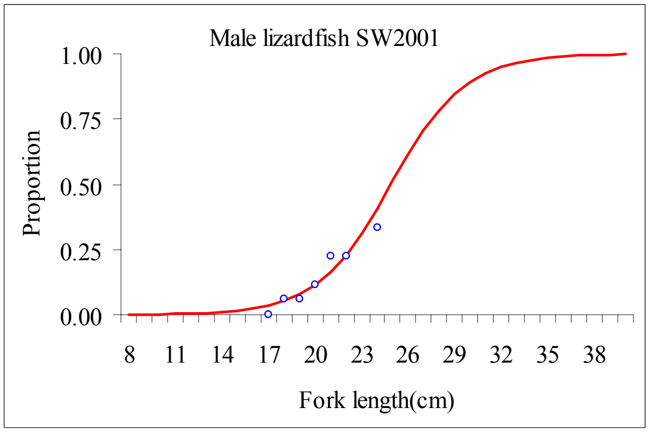
SW2004

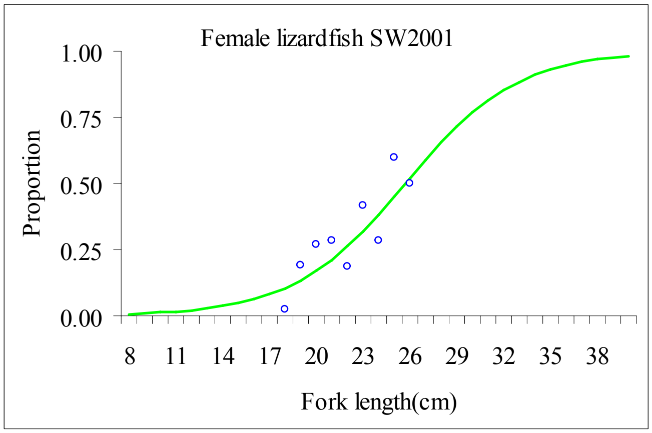
```
                        STRATUM3     STRATUM4         SLD
    N of cases                170           19         190
    Minimum                   5.0         10.0         5.0
    Maximum                  23.0         26.0        26.0
    Mean                     10.7         15.6        12.8
    Standard Dev              3.3          4.3         4.4
    C.V.                      0.3          0.3         0.3
    SW Statistic              1.0          0.9         1.0
    SW P-Value                0.0          0.3         0.0
Method = CLEVELAND
     2.5 %                    6.0         10.0         6.0
    97.5 %                   18.3         26.0        22.7
```

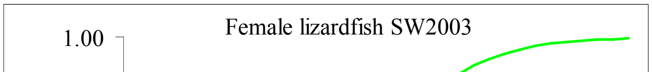
Appendix 15. Sigmoid curves fitted and mature observations of the three fished species in the Gulf of Tonkin sampled by bottom trawl surveys performed during 2001 to 2004.

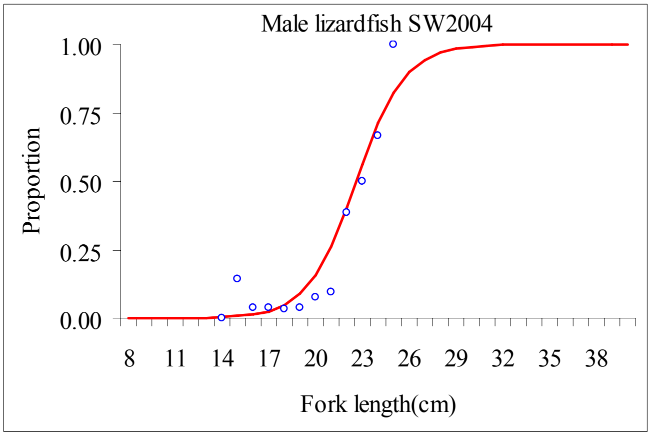


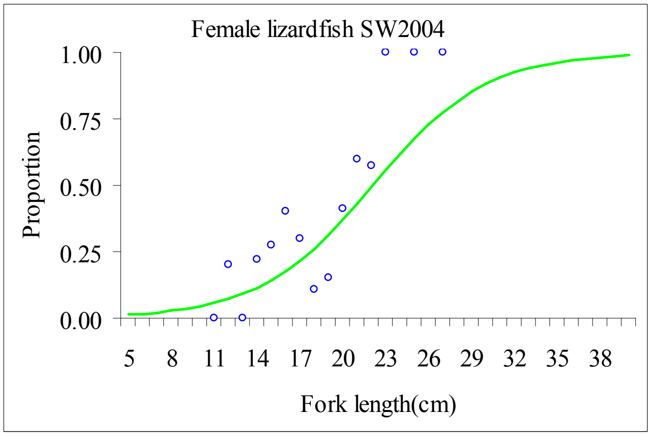


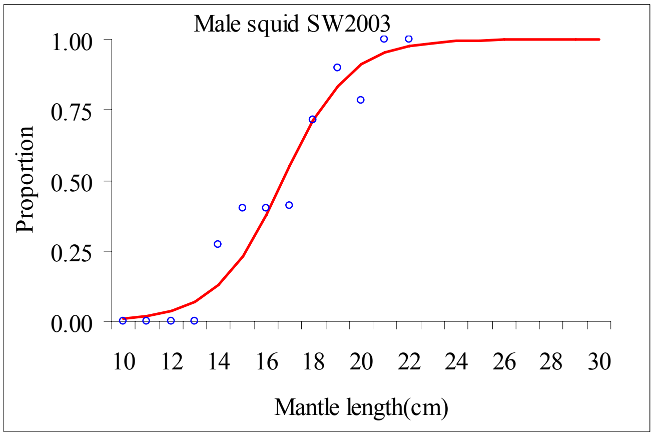


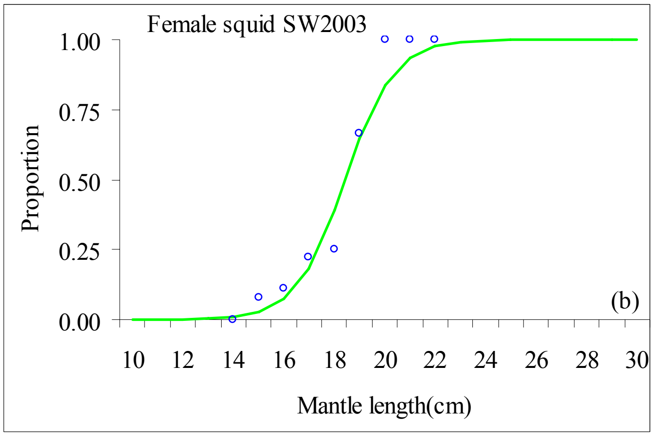





Male lizardfish SW2004


Female lizardfish SW2004


Male squid SW2003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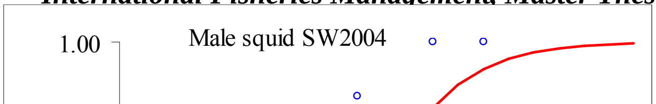
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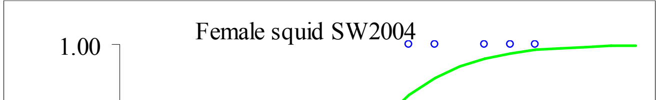
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