Study on Biology of Tuna in the South China Sea, Area IV; Vietnamese Waters

Chu Tien Vinh

Research Institute of Marine Products, 170 Lelai Str. Haiphong City, Vietnam

ABSTRACT

Tuna and tuna-like species are recognized as the most promising target species in off-shore waters of Vietnam. The first studies on biology of tuna were conducted in 1960. To ensure the sustainable exploitation of tuna resources in off-shore waters , studies on biology of tuna are being carried out by the Research Institute of Marine Products.

Materials on biology of tuna were collected on board of research and commercial vessels. Fishing gears were drift gillnets with different mesh-size and longline.

The results of study showed that tuna and tuna-like species are distributed widely in both neritic and oceanic waters of Vietnam. The percentage of Skipjack tuna caught by gillnet in total catch was highest (25.3 %) then followed by Frigate mackerel (8.9) and Bullet tuna (3.4). Yellowfin and Bigeye tunas were dominant in catch by longline.

Biological characteristics of four species of tuna like length frequency distribution, reproduction, feeding, growth and recruitment, mortality rate were described.

The author proposed that the further studies on tuna would be conducted in collaboration among countries bordering the South China Sea.

Key words: Tuna, gillnet, longline, off-shore

Introduction

The appropriate assessment and management of sustainable fisheries requires an understanding of the biological features and distribution of the species on which it is based.

Currently, due to overexploitation of the fisheries resources in coastal waters, problem of management of sustainable coastal fisheries and development of off-shore fisheries became urgent for fisheries sector of Vietnam.

Although the pelagic capture fisheries plays an important role in the development of off-shore fisheries and among pelagic species tuna and tuna-like species were recognized as the most important species in off-shore waters of Vietnam, little studies on their distribution and biology have been conducted.

The first studies on tuna in Vietnam were carried out jointly between Soviet Union and Vietnam in 1960-1961 on board of R/V ONDA and R/V ORLIK which were equipped with purse seine, drift gillnet and long-line. The study scope was mainly in the Tonkin Gulf and partly in the southern parts of the BIEN DONG (the South China Sea).

Some results of studies on distribution and biological characteristics of tuna in coastal waters of Vietnam were reported by [Drudzinhin (1964)], [Bui Dinh Chung (1965),[Tran Don and Nguyen Kiem Son (1978)],[Nguyen Phi Dinh et al. (1971, 1972)], [Chu Tien Vinh and Tran Dinh (1995)], [Vu Huy Thu at al. (1994)] ,[Bui Dinh Chung , Chu Tien Vinh and Nguyen Phi Dinh (1995)], [Nguyen Phi Dinh at al. (1996)].

Tuna species are presently being exploited by Vietnam and other countries in the South East Asian region both in coastal and offshore waters, forming the backbone of their respective pelagic fisheries.

To ensure the sustainable exploitation of these resources in offshore waters of Vietnam, studies on biology and capture fishery aspects of these stocks among other economically important species were carried out by the Research Institute of Marine Products under the Offshore Fishing Program (OFP) of the Ministry of Fisheries of Vietnam and under the technical assistance of JICA, DANIDA and SEAFDEC.

This paper presents results of study on biological features of four tuna and tuna-like species in off-shore waters of Vietnam as the basis for the sustainable exploitation and management of these resources.

Materials and Methods

The materials were collected mainly on board of several vessels operating under different research programs in offshore waters of Vietnam, namely:

· R/V BIEN DONG (1500 Hp) during the implementation of joint Vietnam-Japanese research project on " The marine resources study in Vietnam " which conducted in 1995 - 1997 in offshore parts of the Vietnamese EEZ in an area between Latitude $8^0$00' N to $18^0$00' N and from 40 m in depth to Longitude $112^0$00' E (Fig. 1). And during the implementation of the Collaborative Research Program with SEAFDEC on Marine Fishery Resources in the South China Sea from 01-20/05/1999 in area as shown in Fig. 2. Drift gillnet of 6 mesh-size including 73-mm, 95-mm, 100-mm,123-mm, 150-mm and 160 mm and additionally 48 -mm were used respectively.

· Commercial fishing vessels DONG NAM 01 (1800 Hp) and BV 7603TS (350 Hp). On these vessels , drift gillnet of 100-mm mesh-size was used and on commercial fishing vessel BR 7993 TS (120 Hp), long-line of 300 hooks was used. Those vessels were chartered from the state-owned and private fishing companies during the implementation of the governmental research project called " Survey on fisheries resources for development of offshore fisheries of Vietnam " in 1998- 1999. Study area is shown in [Fig 3].

· M/V SEAFDEC (2800 Hp) during the implementation of the Collaborative Research Program with Vietnam from 21/04-05/06/1999. Long-line and squid jigging were used. Study area is shown in [Fig.4].

In addition, some researchers have been on board of different commercial fishing vessels for collecting materials on tuna biology.

Catch of each haul was classified into species for analysis of catch composition, species composition and catch per unit of effort. The biological data of tuna species caught were obtained by:

Measurement of total and fork length in mm and body weight in g.

Identification of sex and maturity: 6 stages of maturity were recognized on the basis of visual assessed of the gonad and testis. Some matured gonads were collected for determination of fecundity in the laboratory.

Identification of degree of stomach fullness: 5 degrees of fullness were recognized by visual examination. Some stomach were collected for further analysis in the laboratory.

To estimate coefficients a, b of the Length -Weight relationship $W= a.L^{b}$ by least square regression method. Growth parameters of the von Bertalanffy growth equation $Lt=Lì.[1-exp(K.(t-t_0))]$ and mortality rate (Z, M, F) were estimated by FiSAT (FAO-ICLARM STOSK ASSESSMENT TOOLS) software.

Results

Species composition

98 species belonging to 22 families have been identified, of which 8 tuna and tuna-like species belonged to family *Scombridae*, namely:

- *Auxis rochei* (Risso) — Bullet tuna
- *A. thazard* (Lacepede) — Frigate mackerel
- *Euthynnus affinis* (Cantor) — Eastern little tuna
- *Katsuwonus pelamis* (Linnaeus) — Skipjack tuna
- *Thunnus albacares* (Bonnaterre) — Yellowfin tuna
- *T. obesus* (Lower) — Bigeye tuna
- *T. tonggol* (Bleeker) — Longtail tuna
- *Sarda orientalis* (Temm. et Sch.) — Striped bonito

However, target species of fishing gears used in study and in fishing practices are slightly different. For example, main target species of drift gillnet are Skipjack tuna, Frigate mackerel, Bullet tuna while of long- line are Yellowfin, Bigeye tuna, and Skipjack tuna. For purse seine and lift net Skipjack tuna, Eastern little tuna, Bullet tuna, Longtail tuna are main target species.

Biological characteristics of four species of tuna

Length frequency distribution

Skipjack tuna

Size (Lf) of captured skipjack by gillnet in the Southwest monsoon period (from April-September) ranged 26.4-55.0 cm with the mean length of 45.3 cm [Fig.5a] and in the Northeast monsoon (from October - March) ranged 25.9 - 65.8 cm with the mean length of 49.3 cm [Fig. 6a]. It shows that, in the Northeast monsoon size of caught Skipjack is larger than in the Southwest monsoon.

Due to gear selectivity of gillnet, length of Skipjack tuna being caught is different by mesh-size used. [Fig. 5 b-g] and [Fig. 6 b-f] show the length frequency distribution of Skipjack tuna in Southeast and Northeast monsoon periods respectively.

For the whole year, length of captured Skipjack tuna caught by gillnet of 6 different mesh-size ranged 23.5- 67.5 cm and weight 0.50-8.25 kg respectively, with the mean length of 47.8 cm. Three modes of length frequency distribution were found at 29 cm, 43cm and 55-57cm or at 0.5; 1.75 and 4.25 kg respectively.

Mean length of Skipjack caught by gillnet of 73 -mm mesh-size was 29.3 cm (fish of 1 year group) , of 95mm - 41.9 cm, of 123mm - 42.9 cm (fish of 2 year group) , of 150mm - 55.1 cm and of 160 mm- 56.5cm (fish of 5 year group).

It is noted that, even different mesh-sized gillnet was used, but Skipjack tuna of length group 30.5 -34.5 cm have not been found. It was assumed they might migrate off EEZ of Vietnam to the adjacent seawater of other countries in the region and then coming back to seawater of Vietnam for spawning when they reached 2 years old.

Total length and fork length relationship was :$Lf = 0.9496\ Lt - 1.9423$, $r^2 = 0.9936$ [Fig. 7].

Frigate mackerel

Size of Frigate mackerel caught in the Southwest monsoon period ranged 23.5-43.0 cm with the mean length of 34.5 cm, mode of 39.0 cm [Fig. 8a] and in the Northeast monsoon ranged 26.5-45.0 cm with the mean length of 36.7 cm [Fig.9a].It shows the size caught in Northeast monsoon was a little bit larger than in Northeast monsoon.

For the whole year, Frigate mackerels have length ranged from 23.5 - 45.0 cm and weight ranged 0.1 to 1.9 kg respectively. The mean length of Frigate mackerel captured by gillnet of mesh-size 73mm was 35.3 cm, of 95mm - 40.3 cm, of 123mm- 35.9 cm, of 150mm- 36.9 and of 160 mm- 37.3 cm.

Distribution of length frequency caught by different mesh-size gillnet in the Southwest and Northeast monsoon period is shown in [Fig.8 b-g] and [Fig.9 b-f].

Total length and fork length relationship was : Lf = 0.9372 Lt .+ 3.1655 and r^2 = 0.9856 [Fig. 12].

<u>Bullet tuna</u>

Size of Bullet tuna ranged 19.5 - 30.5 cm in the Southwest monsoon with the mean length of 26.1 cm [Fig.10a] and 14.5- 30.5 cm in the Northeast monsoon with the mean length of 25.6 cm [Fig.11a].

Distribution of length frequency of fish captured by different mesh-size gillnet in Southwest and Northwest monsoon are shown in [Fig.10 b-g] and [Fig. 11 b-f].

For whole year, mean length of Frigate mackerel was 26.1 cm and of those caught by mesh-size of 73 mm was 25.9 cm, 95mm - 26.1cm, 123mm- 25.3, 150mm- 25.2 and 160mm- 25.9.

The total length and fork length relationship was: Lf = 0.9064 Lt +14.017 and r^2 = 0.9192 [Fig. 13].

<u>Yellowfin tuna</u>

Length frequency distribution of Yellowfin tuna caught by gillnet of mesh-size 100mm [Fig. 14] and long-line [Fig. 15] showed that length of yellowfin tuna caught by gillnet ranged 49-90 cm with the mean length of 56.1 cm, and most of them belonging to size group of 49-55 cm while by long-line ranged 50-180 cm with mean length of 98.9 cm.

It showed that Yellowfin of larger size are distributed mainly at the deeper layer than the smaller ones.

Length-weight relationship

<u>Skipjack tuna</u>

Length-weight relationship of both sexes was: $W = 0.0058 \times L^{3..3471}$, $r^2 = 0.9926$ [Fig.16]. Length - weight relationship of Skipjack tuna caught by purse seine from Sarawak waters of Malaysia was $W = 1.494 \times 10^{-6} L^{3.4219}$ [Mansor (1997)] and from Philippines waters was $W = 0.00003267 L^{3.09569}$ [Ronquillo (1963)]

<u>Frigate mackerel</u>

Length-weight relationship of both sexes was: $W = 0.0113 \times L^{3.1547}$, $r^2 = 0.9298$ [Fig. 17]

<u>Bullet tuna</u>

Length-weight relationship of both sexes was: $W = 0.1248. L^{2.3530}$, $r^2 = 0.4058$ [Fig. 18]

<u>Yellowfin tuna</u>

Length-weight relationship of both sexes was: $W = 0.0208 L^{2.9793}$, $r^2 = 0.9860$ [Fig. 19]. In Malaysia waters $W = 8.885 \times 10^{-6} L^{3.1288}$ [Mansor (1997)], and in

Philippines waters $W = 0.00002352\ L^{2.84682}$ (for male).

Reproduction

Skipjack tuna

In the Southwest monsoon period , 38.4 % of females having gonads belonged to stage IV (developing stage) and V (spawning stage) and 22 % to stage VI-II, V-III (resting stage) [Fig.20]. The ratio of male and female in this period was 2.18 : 1 . It shown that the main spawning period of Skipjack was in the Southwest monsoon with the peak in April-May.

At the beginning of the Northeast monsoon period (in September-October) , 92.2 % of females of Skipjack were at maturity stage II and III, only 7.8 % still have gonads belonged to IV stage [Fig. 21]. The ratio of male and female in this period was 1: 1.94.

The absolute fecundity for female of 41 cm was about 2 million eggs. Size at first maturity was about 38-43 cm (2 years group).

In Philippines waters the length at first maturity of Skipjack tuna was 42 cm [Ronquillo (1963)].

Frigate mackerel

In the Southwest monsoon, 10.0 % and 16.7 % of females having gonads of IV and VI stage respectively, and 2.2 % of resting stage [Fig.22]. In this period, the ratio of male and female was 1.7: 1. It showed that the spawning season of Frigate mackerel is in this monsoon period with the peak in April-June.

In the Northeast monsoon, only 8.8 % of female having gonads belonged to IV stage, in this time the ratio of male and female was 1.5 : 1 [Fig. 23].

The absolute fecundity of females of 36.5-40.0 cm ranged 129,648- 357,006 eggs. Size at first maturity was about 34 cm.(2 years group).

In Thailand Gulf, the length of first maturity of Frigate mackerel was 31 cm, and fecundity of fish of length 31-39 cm ranged 78.000- 719.900 eggs. [Yesaki (1994)].

Bullet tuna

In the Southwest monsoon, about 30 % of female having gonads belonged to stage IV and V, around 15 % was at resting stage. The ratio of male and female was around 1 : 1 [Fig.24].

In the Northeast monsoon, most of female’s gonads were at stage of II and III. [Fig. 25]. The ratio of male and female was 2.7: 1.

The absolute fecundity of females with mean length ranged 25.0 - 26.9 cm varied from 515,010 to 989,066 egg. Size of first maturity was 20 cm (1 year group)

In Thailand Gulf, the length of first maturity of Bullet tuna was 17 cm and fecundity of length group 25-34 cm ranged 52.600-162.800 eggs. [Yesakj (1994)].

Yellowfin tuna

Yellowfin tuna females caught by gillnet in the Southwest monsoon were immature fish with 100 % of maturity stage II, caught in the Northeast monsoon were 100 % of stage III.

On the contrary , Yellowfin tuna caught by long-line in the Southwest monsoon were mature with 16 % of maturity stage IV and 50 % of resting stage. It indicated that spawning season of Yellowfin tuna was in the Southwest monsoon.

According to [Ronqillo (1963)], in Philippines waters the length of first maturity of Yellowfin tuna was 55-67 cm.

Feeding

Skipjack tuna

Degree of fullness of stomach in the Southwest and Northeast monsoon is shown in [Table 1].

In the Northeast monsoon, degree of fullness 3 and 4 comprised 30.3 %, while in the Southeast monsoon only 22.1 %. It indicated that in the spawning period, feeding activity of Skipjack was less than in the post spawning period when fishes had to feed actively in order to recover energy spent during spawning season.

Major species of preys found in stomach of Skipjack were Anchovies, *Caranx spp.* , Indian mackerel *(Rastrelliger kanagurta),* Scad *(Decapterus spp.),* Squids and Shrimp.

Frigate mackerel

In the Southwest monsoon, stomach fullness of 3 and 4 degree accounted only for 4.88 % while in the Northeast monsoon 18.44 % [Table 2].

Squid and Shrimp were often found in their stomach.

Bullet tuna

Degree of stomach fullness of Bullet tuna is shown in the [Table 3].

Shrimps were most frequently found in stomach of bullet tuna, then followed by Euphausia and Squids.

Yellowfin tuna

Table 4 shows the degree of stomach fullness of Yellowfin tuna by gillnet comparing with tuna caught by long-line in the Southeast monsoon.

It showed that larger Yellowfin tuna caught by long-line were more active in feeding than tuna caught by gillnet.

Unicom leatherjacket (*Aluterus monoceros*), Flying fish, snake mackerel and squid , etc. were found in stomach of Yellowfin tuna.

Growth and recruitment

Skipjack tuna

Parameters of the von Bertalanffy growth equation was estimated as follows:

L_8 = 77.67 cm , K = 0.299 ; t_0 = - 0.510

Standard error (S.E) and Coefficient of Variation (CV) of estimated parameters are shown in [Fig. 26].

Mean fork length of fish of 1 year was 28 cm, 2 years - 42 cm, 3 years- 50cm, 4 years- 58cm and 5 years- 63 cm. It showed that Skipjack grew very fast in the first 2 years before becoming matured and taking part in spawning population.

Skipjack tuna have highest recruitment in November (22.48 %), then followed in December (20.96 %) and January (16.12 %) (Fig. 27).

Growth parameters and length at age of Skipjack tuna in various areas estimated by different Authors are shown in the [Table 5].

Frigate mackerel

Parameters of the von Bertalanffy growth equation was estimated as follows:

L_8 = 49.02 cm, K = 0.426 , t^0 = - 0.867

S.E and CV are shown in [Fig. 28].

Mean length of fish of 1 year was 27 cm, 2 years- 35 cm, 3 years- 39 and 4 years- 43 cm.
The highest percent of recruitment was found in November (20.25 %), then in October (19.26 %) [Fig. 29].

The growth parameter and length at age of Frigate mackerel in various areas were shown in the [Table 6].

Bullet tuna

Estimated mean length of fish of 1 year was 20 cm, 2 year- 27 cm. According to Le Trong Phan (1996), in coastal waters of Central Vietnam, Bullet tuna reached 20.5 cm at 1 year, 27.5 cm at 2 years.

Yellowfin tuna

According to [Wild (1960)] , length at age of Yellowfin in the Eastern Pacific Ocean was as follows: 1 year- 46 cm, 2 years- 84cm, 3 years- 111 cm, 4 years- 131 cm and 5 years- 146 cm.

Mortality rate

Skipjack tuna

Total mortality rate (Z) was estimated to be 0.87, natural mortality M = 0.62 , fishing mortality F = 0.25 and exploitation rate E = 0.29 [Fig.30]. It indicated that , production of Skipjack tuna still can be increased in offshore waters of Vietnam in the future.

Frigate mackerel

Total mortality Z = 1.44 ,natural mortality M = 0.67, fishing mortality F = 0.77 and exploitation rate E = 0.53 [Fig.31].

Discussion

Tuna and tuna-like species are distributed widely in both neritic and oceanic waters of Vietnam. Among them, Skipjack, Yellowfin and Bigeye tunas are highly migratory species and being caught by different fishing gears in offshore waters of Vietnam.

Small size Yellowfin , Bigeye tunas and Skipjack tuna, Frigate mackerel and Bullet tuna were being caught by drift gillnet, purse seine, while larger Yellowfin and Bigeye are captured mainly by long-line.

In catches by gillnet, the percentage of Skipjack tuna was dominant (25.3 %), then followed by Frigate mackerel (8.9 %) and Bullet tuna (3.4 %). On the contrary in catches of long-line Yellowfin and Bigyeye tunas were dominant. Some larger Skipjack were also captured by long-line at depth about 30-40m from surface.

Theoretically, distribution of the oceanic tuna mainly depended on water layer, whereby smaller fish ten to distribute at the upper layer as compared to the larger fish at the deeper layer [Monintja (1998)].

The absence of length group of 30.5-34.5 cm of Skipjack in both neritic and offshore waters of Vietnam indicated on whether their migration from EEZ of Vietnam to adjacent waters or to deeper layer. Fish of this length group was captured by purse seine (80m deep & 10 cm mesh-size) in Sarawak waters of Malaysia [Mansor (1997)]. Therefore determination of movement of Skipjack tuna would be very useful if the tagging method is to be used.

The length frequency distribution of Yellowfin tuna caught by gillnet in offshore waters of Vietnam showed the similarity with the length frequency distribution of Yellowfin caught by purse seine in Sarawak waters of Malaysia. [Kikawa (1973)] suggested that there are two separable migratory groups of Yellofin tuna, one in the western Indian Ocean and other in the Banda-Flores Seas of Indonesia.

The Frigate mackerel are very widely distributed in the continental shelf waters and around the islands in the Southeast Asian waters. They are the seasonal visitors to the coastal waters and usually caught in coastal waters by different fishing gears.

Analysis of maturity stage and fish larvae collected during surveys showed that the Southwest monsoon being a spawning season of most of tuna and tuna-like in offshore waters of Vietnam and April-June were the peak of spawning. [Yamanaka (1990)] reported that the spawning period of Yellowfin off the north Celebes Sea was from April to June and Skipjack are known to breed during the greater part of the year in Philippines waters. [Ronquillo, (1963)].

The coefficients of the length-weight relationship, parameters of the von Bertalanffy growth equation and mortality rates were found different from coastal and offshore populations of tuna studies in Vietnam.The differences were also found between populations inhabiting in offshore waters of Vietnam and other areas.

Skipjack tuna and frigate mackerel in offshore waters of Vietnam have very low natural morality rate.

Tuna and tuna-like species are promising target species for offshore fisheries development in Vietnam. Preliminary findings suggest that offshore waters of Vietnam is an important migratory route for oceanic tuna and they may originate from groups outside the area as indicated by appearance of different size groups during seasons of the year. Therefore further studies on tunas would be conducted in collaboration between countries bordering the South China Sea.

Table 1. Degree of stomach fullness of Skipjack tuna.

Degree of fullness	Fish caught by gillnet (%)	Fish caught by long-line (%)
0	42.86	47.06
1	28.57	0
2	7.14	17.65
3	7.14	11.76
4	7.14	23.53

Table 2. Degree of stomach fullness of Frigate mackerel.

Degree of fullness	Southwest monsoon (%)	Northeast monsoon (%)
0	25.61	64.54
1	61.38	5.67
2	8.13	11.35
3	4.88	17.02
4	0	1.42

Table 3. Degree of stomach fullness of Bullet tuna.

Degree of fullness	Southwest monsoon (%)	Northeast monsoon (%)
0	41.16	40.0
1	41.57	40.0
2	10.61	20.0
3	4.80	0
4	1.77	0

Table 4. Degree of stomach fullness of Yellowfin tuna.

Degree of fullness	Fish caught by gillnet (%)	Fish caught by long-line (%)
0	42.86	47.06
1	28.57	0
2	7.14	17.65
3	7.14	11.76
4	7.14	23.53

Table 5. Growth parameters and length at age of Skipjack tuna.

Areas	Growth parameters			Length at age (cm-year)				Authors
	K	L_8	t_0	1	2	3	4	
North of Japan				26	34	43	54	Aikiwara,1937
Japan				15	45	63	73	Kawasaki,1965
Taiwan	0.302	103.6	-0.016	27	47	62	73	Chi & Yang,1973
Central Pacific	0.550	102.0	-0.02	44	68	83	91	Uchiyama&Struhsaker,1981
Guine Gulf	0.307	86.7	-0.317	29	44	55	64	Chur& Zharov,1983
Coastal waters of Vietnam	0.700	65.0		33	49	57	61	Nguyen Phi Dinh at al.,1996

Table 6. Growth parameters and length at age of Frigate mackerel.

Areas	Growth parameters			Length at age			Authors
	K	L8	t_0	1	2	3	
West of Java	0.70	47.5		24	36	42	Dwiponggo et al.,1986
West coast of Thailand	0.80	47.2		26	37	43	Yesaki, 1994
Sri Lanca	0.54	58.0		25	39	47	Joseph et al.,1986
India	0.49	63.0	-0.270	29	42	50	Silas et al,1985

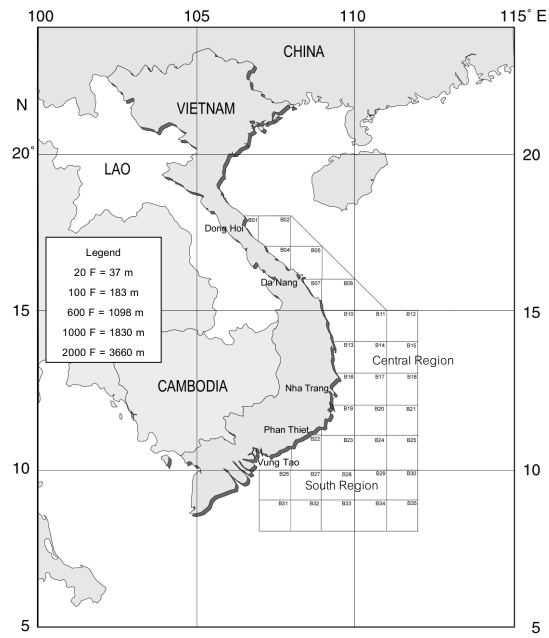


Fig. 1. Study area of R/V BIEN DONG under JICA Project in 1995-1997.

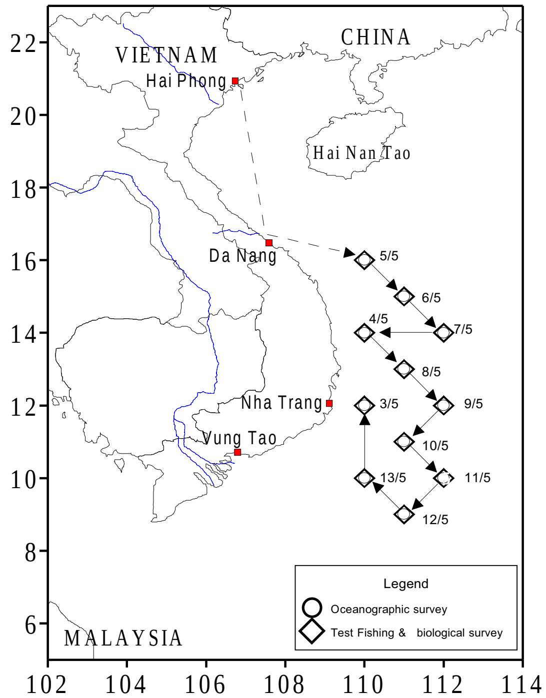


Fig. 2. Study area of R/V BIEN DONG under the collaborative research program with SEAFDEC in May 1999.

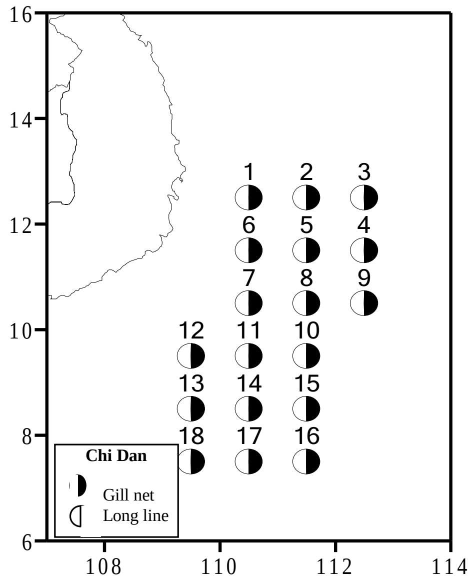


Fig. 3. Study area of F/V DONG NAM, BV 7603 TS and 7993 TS in 1998-1999.

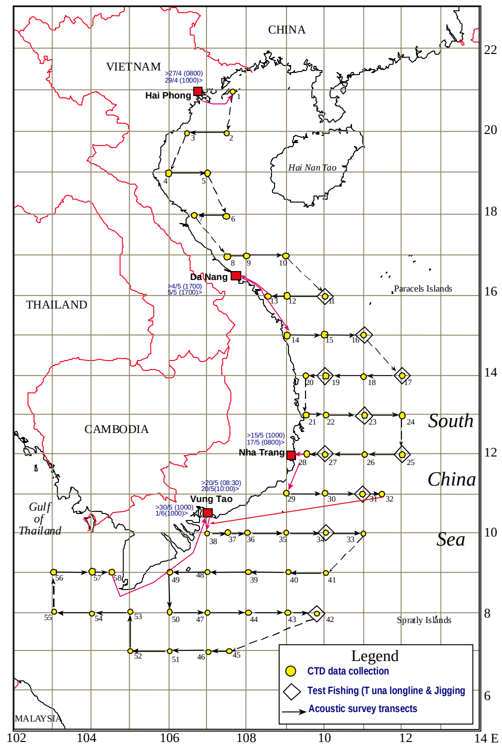


Fig. 4. Study area of M/V SEAFDEC in April-May/1999.

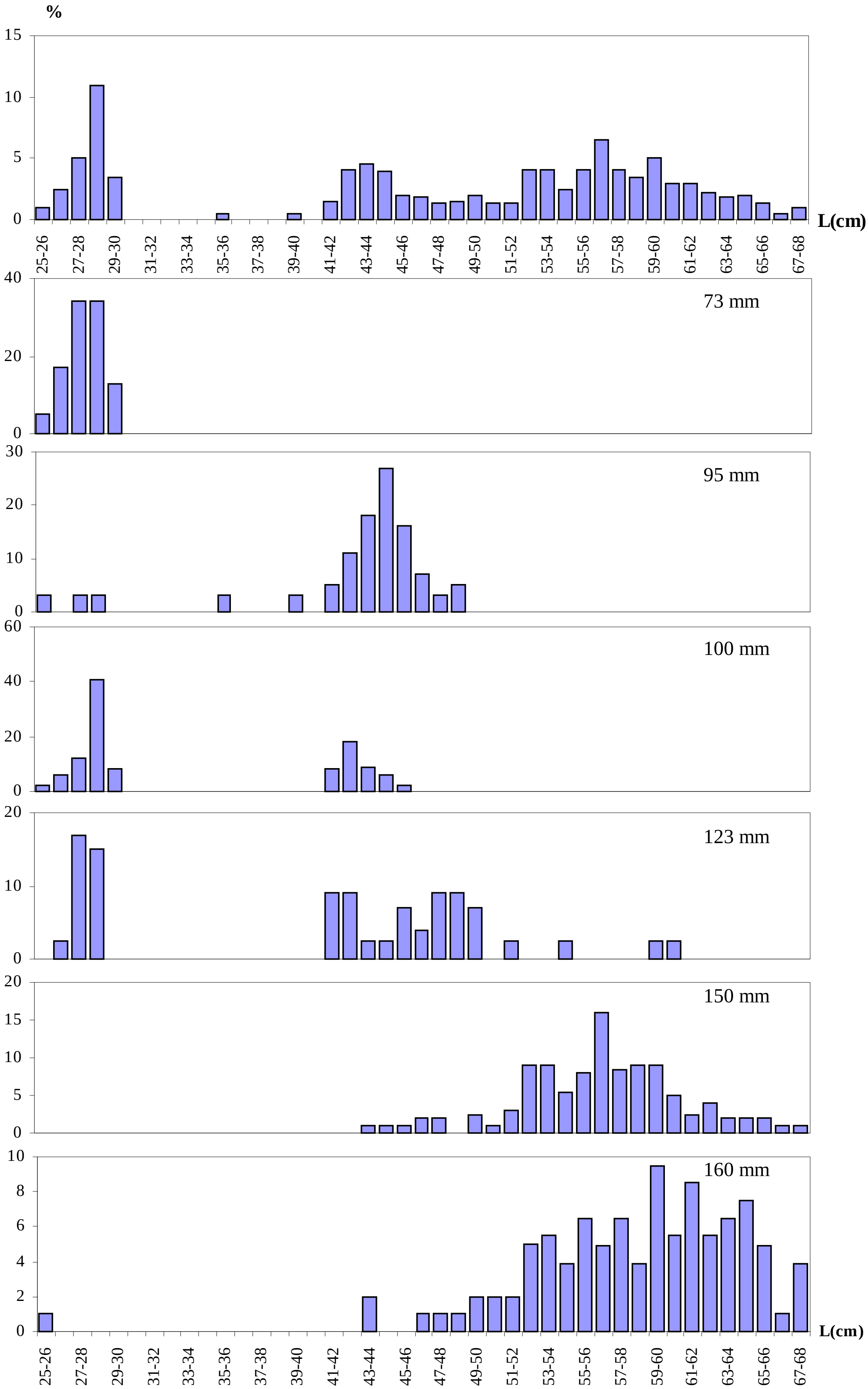


Fig. 5. Length frequency distribution of Skipjack tuna in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

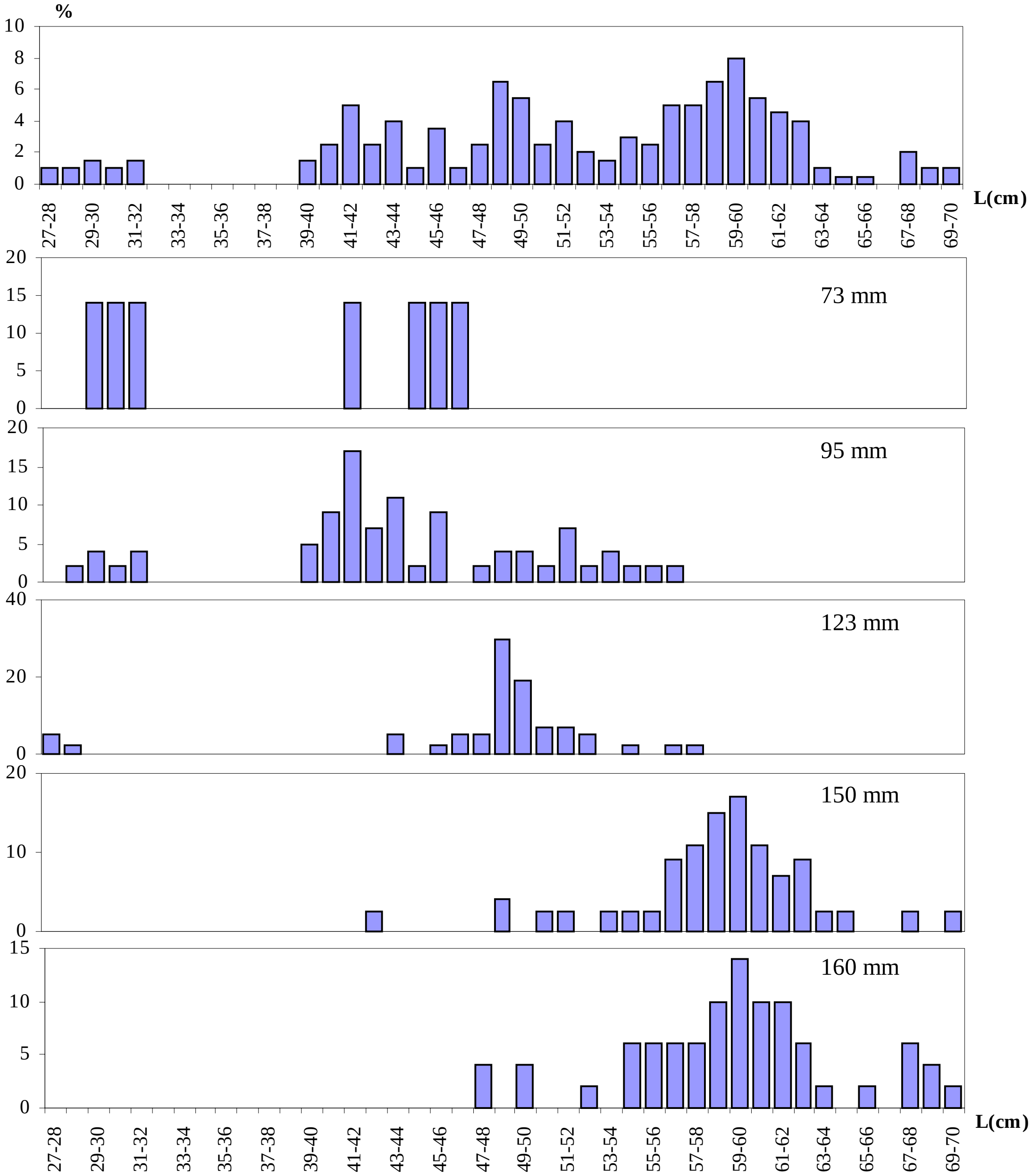


Fig. 6. Length frequency distribution of Skipjack tuna in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150, f-150 and g-160 mm).

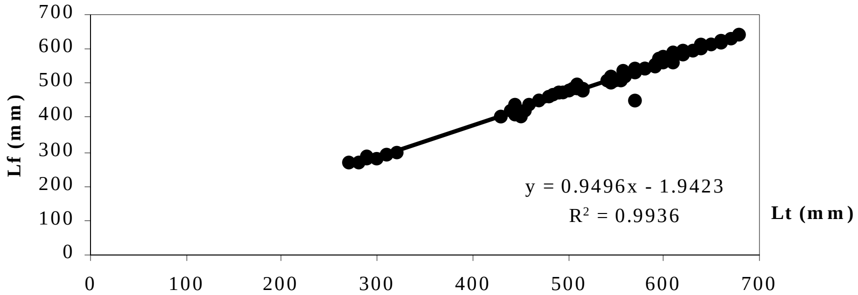


Fig. 7. Relationship between total and fork length of Skipjack tuna.

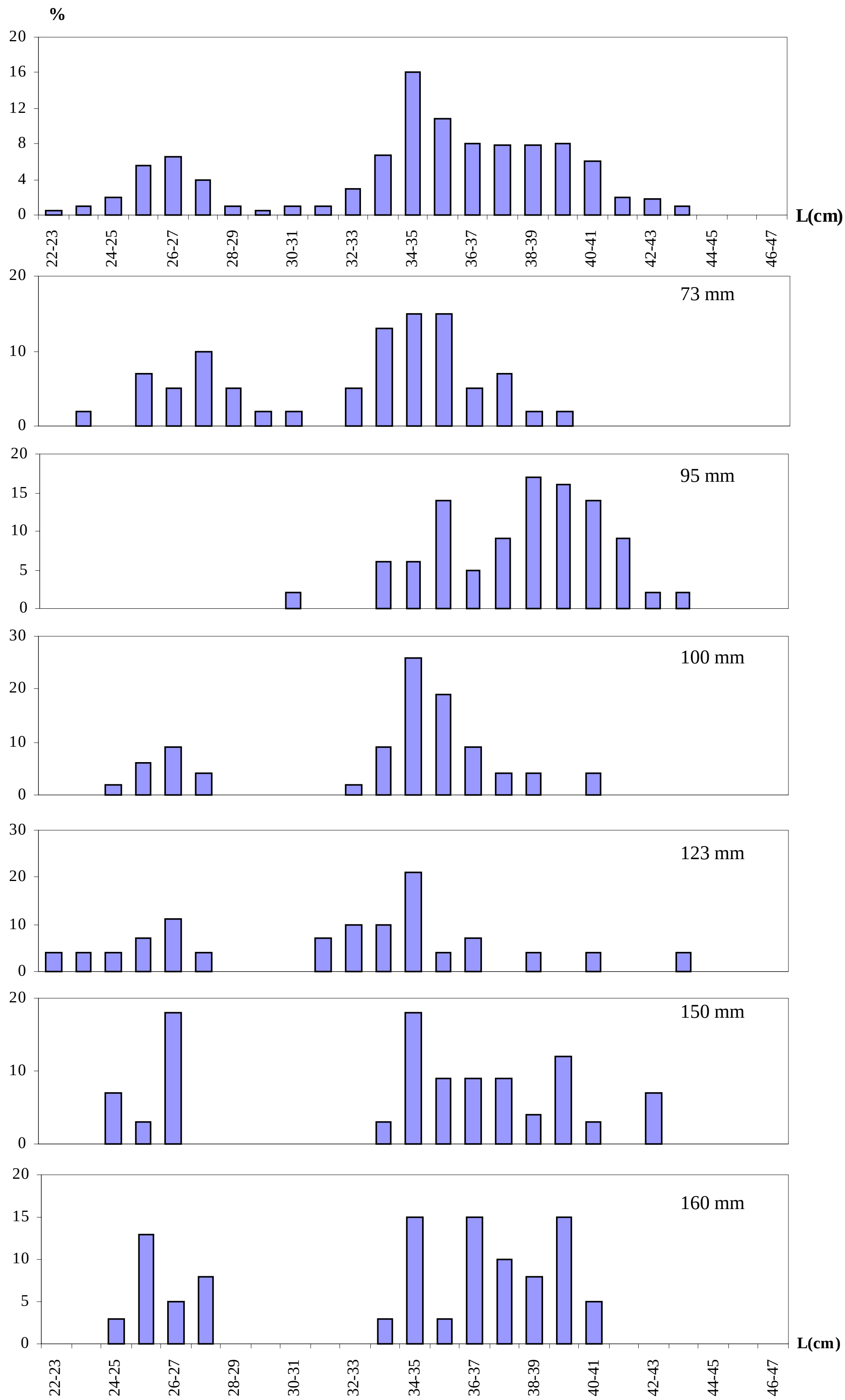


Fig. 8. Length frequency distribution of Frigate mackerel in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

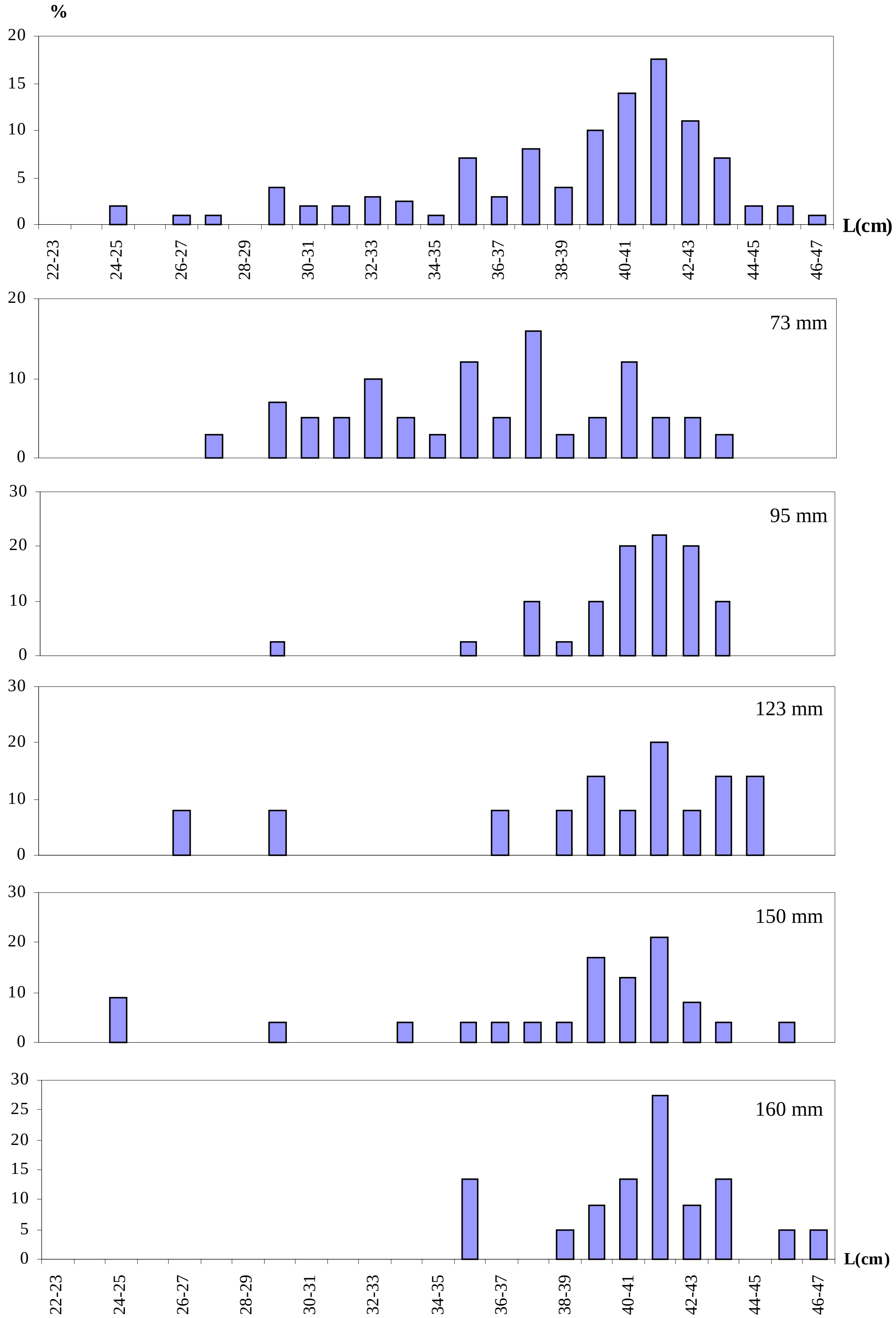


Fig. 9. Length frequency distribution of Frigate mackerel in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150, f-160 mm).

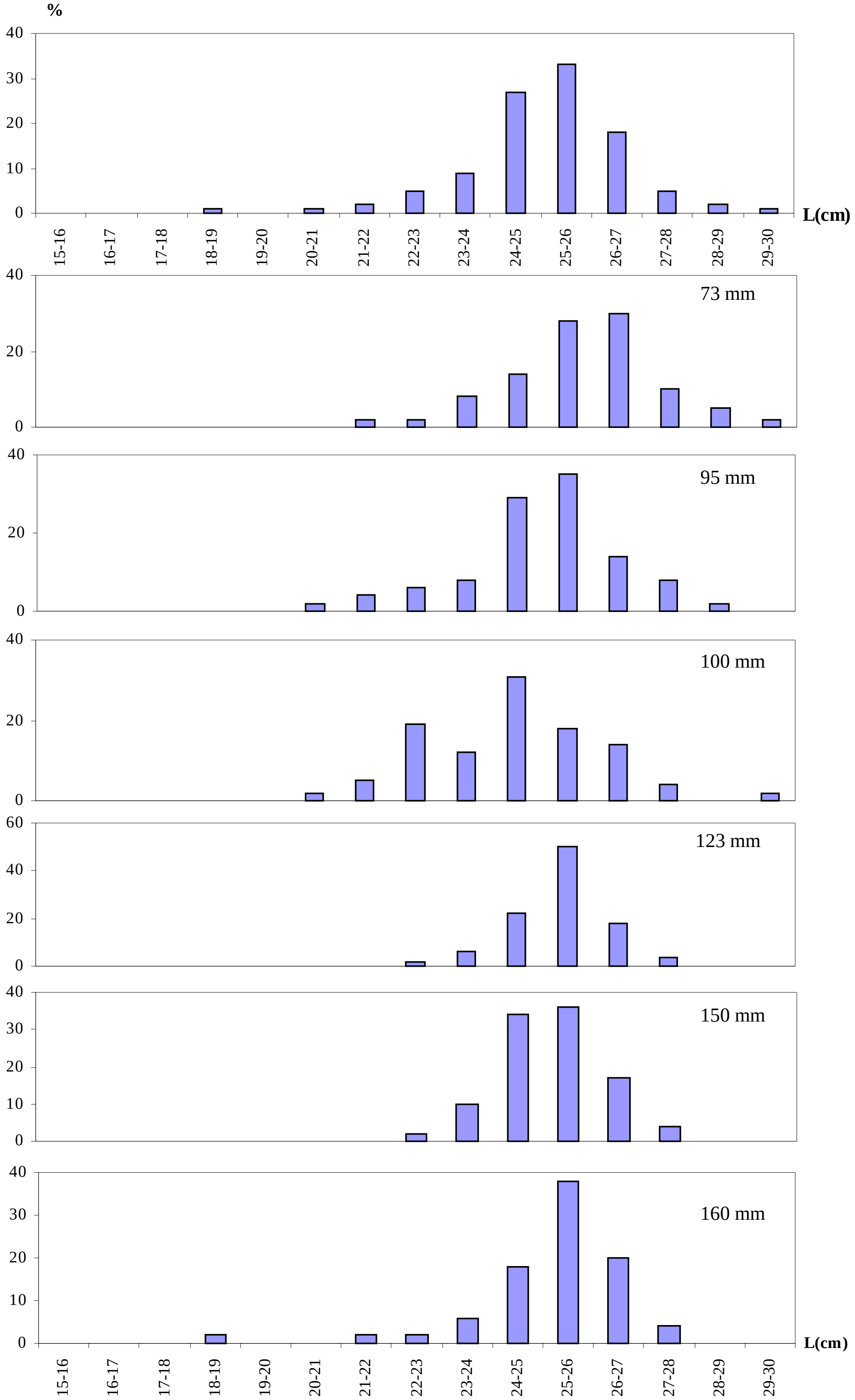


Fig. 10. Length frequency distribution of Bullet tuna in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

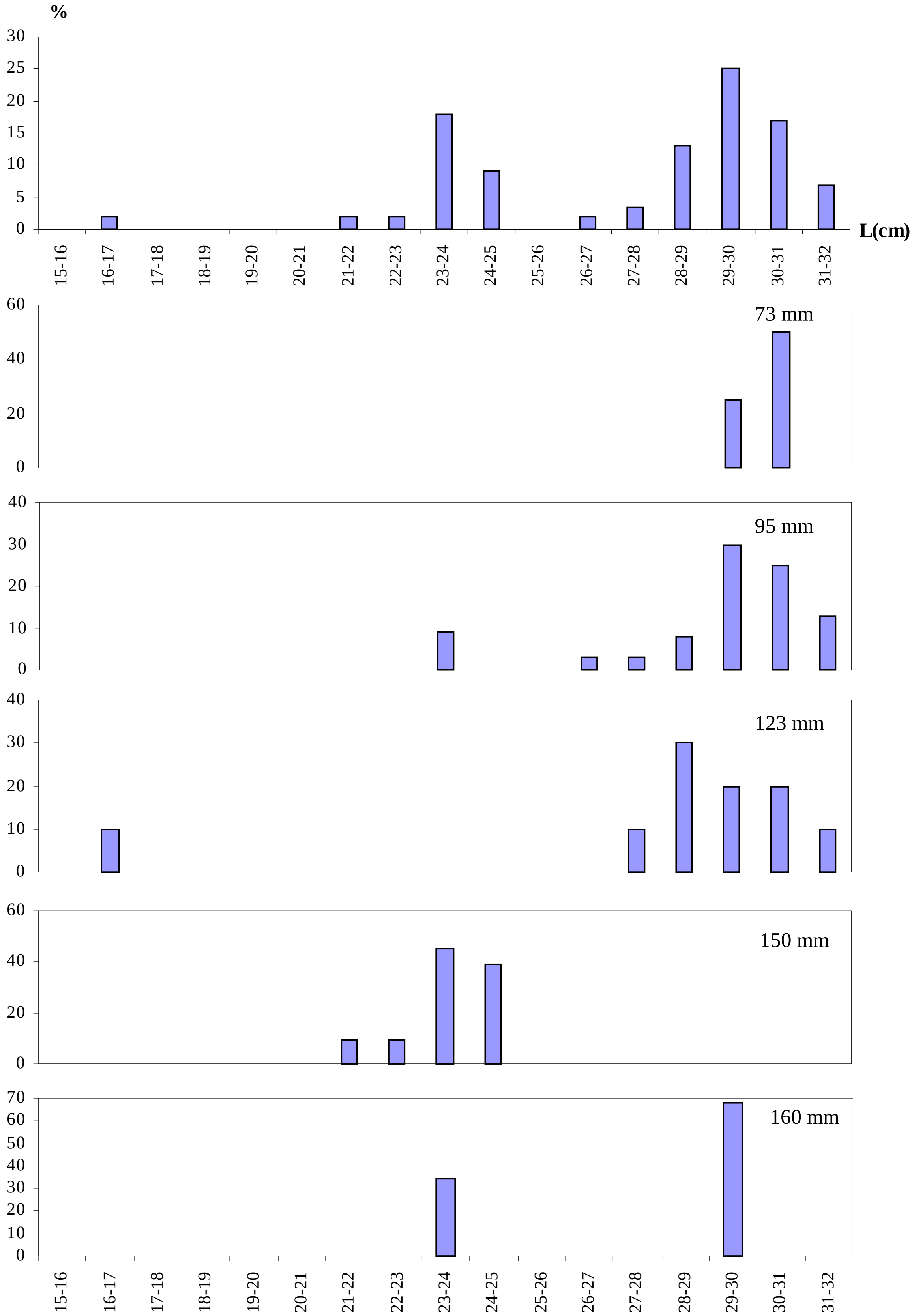


Fig. 11. Length frequency distribution of Bullet tuna in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150 and f-160 mm).

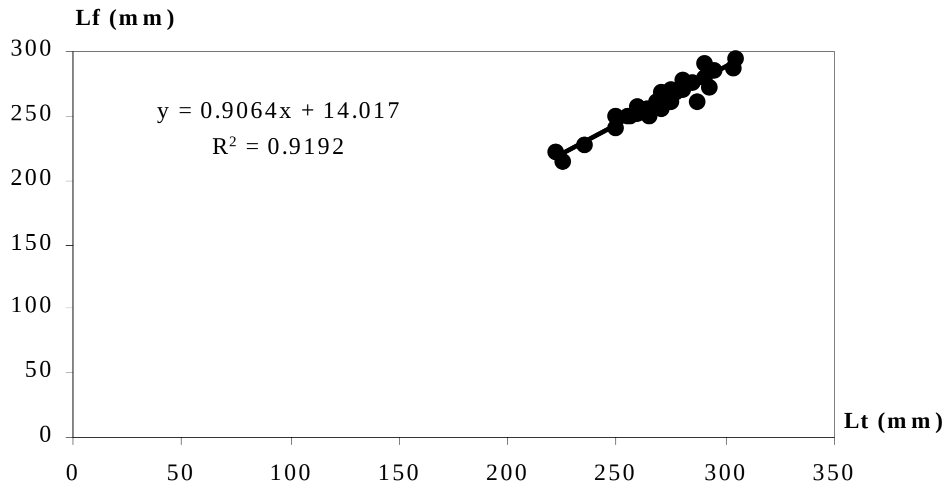


Fig. 12. Relationship between total and fork length of Frigate mackerel.

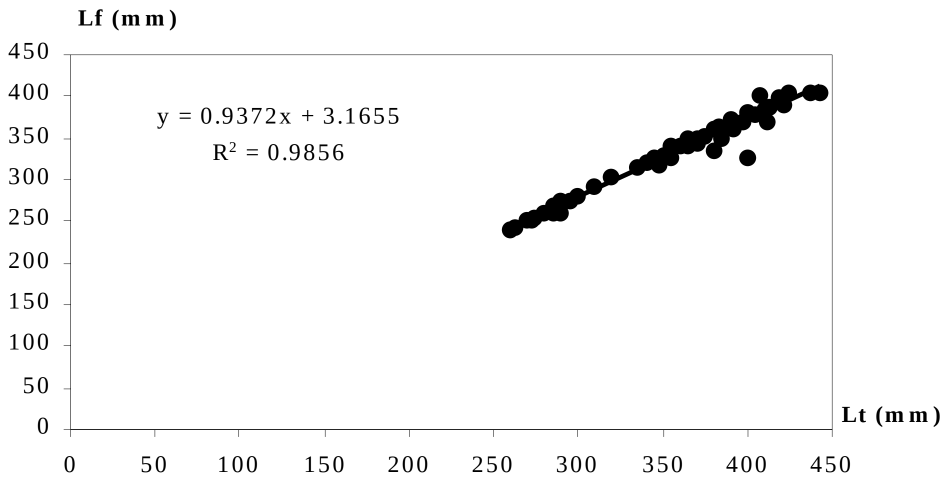


Fig. 13. Relationship between total and fork length of Bullet tuna.

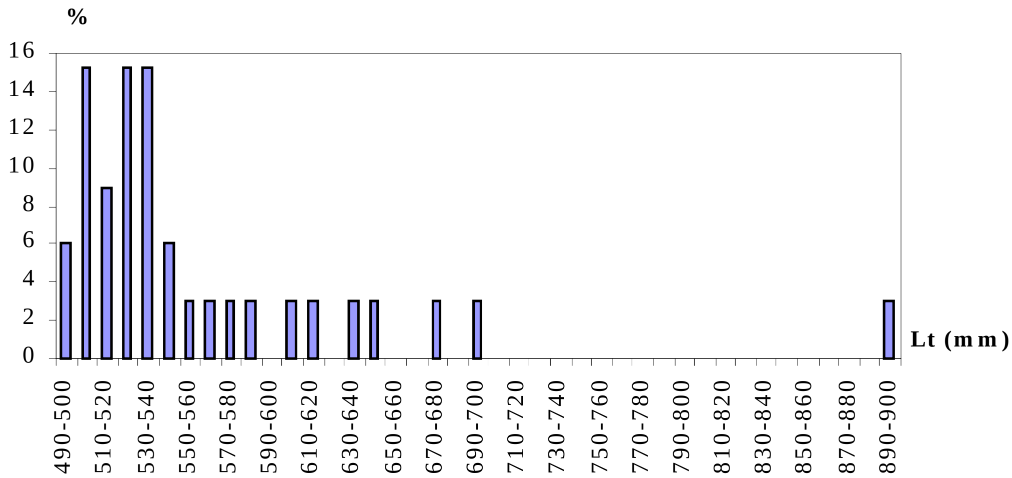


Fig. 14. Length frequency distribution of Yellowfin tuna caught by gillnet.

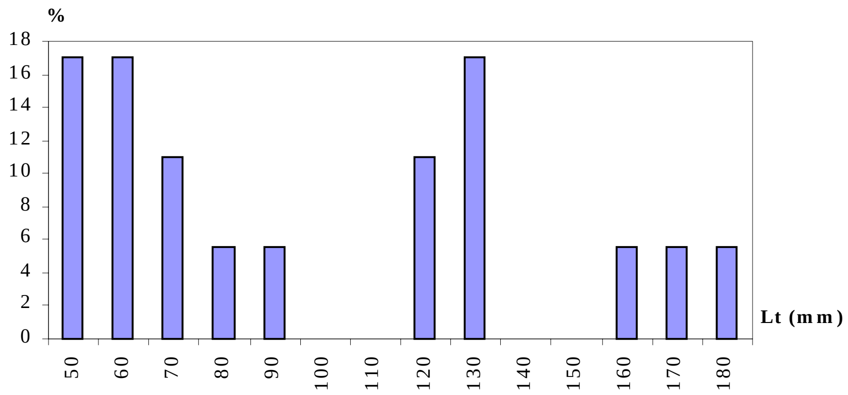


Fig. 15. Length frequency distribution of Yellowfin tuna caught by longline.

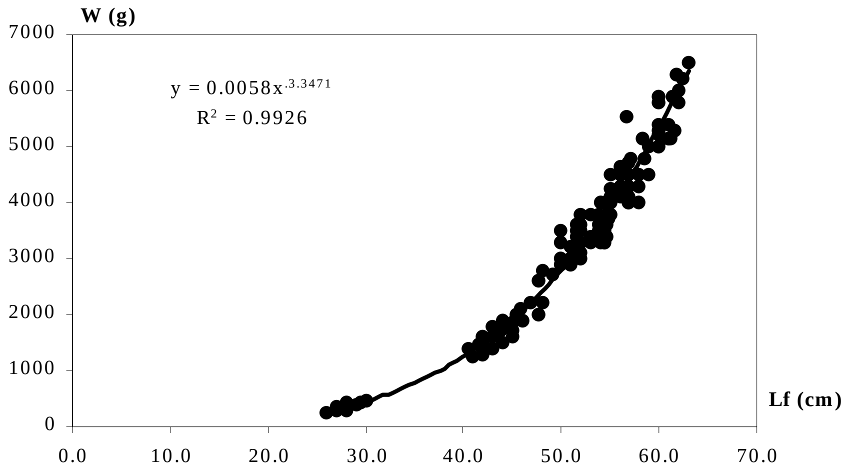


Fig. 16. Length-weight relationship of Skipjack tuna.

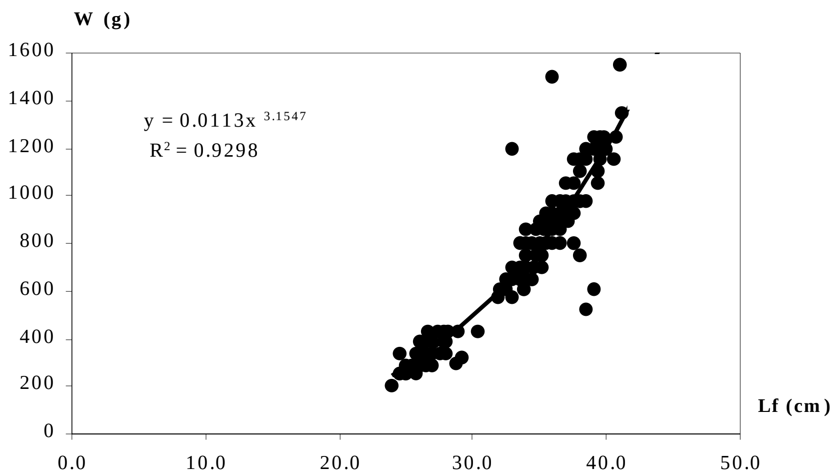


Fig. 17. Length-weight relationship of Frigate mackerel.

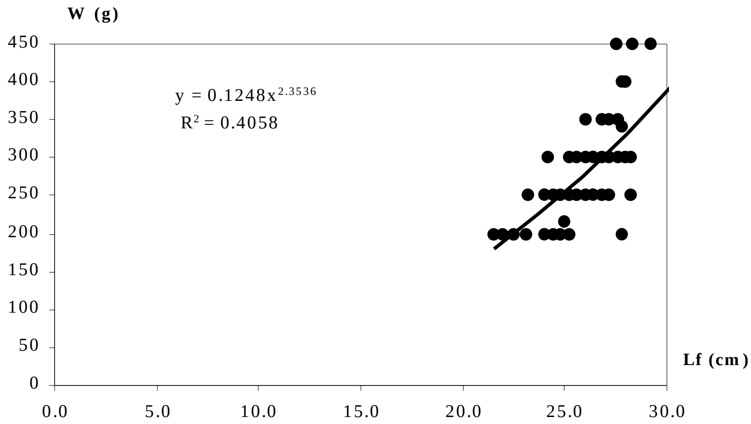


Fig. 18. Length-weight relationship of Bullet tuna.

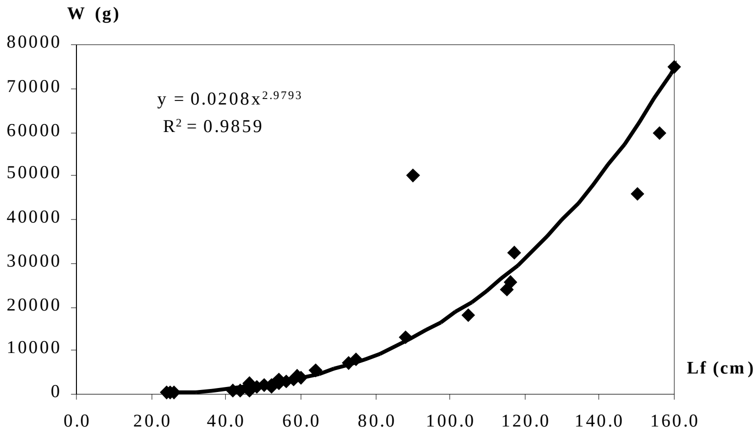


Fig. 19. Length-weight relationship of Yellowfin tuna.

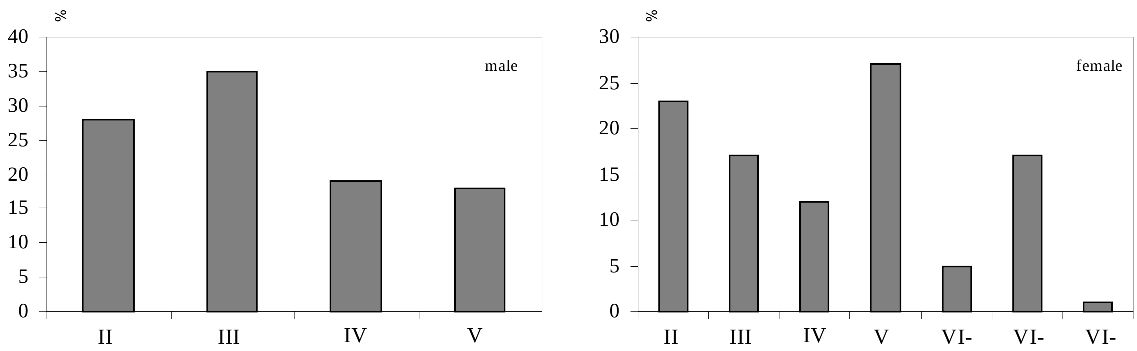


Fig. 20. Maturity stage of Skipjack tuna in Southwest monsoon.

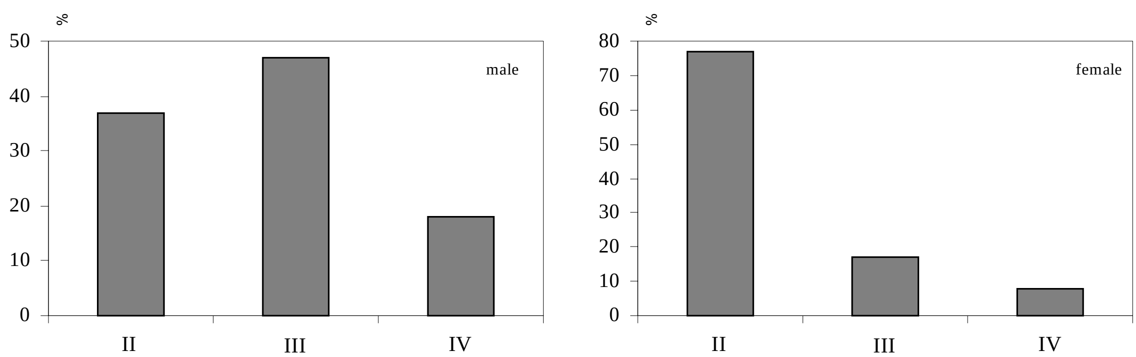


Fig. 21. Maturity stage of Skipjack tuna in Northeast monsoon.

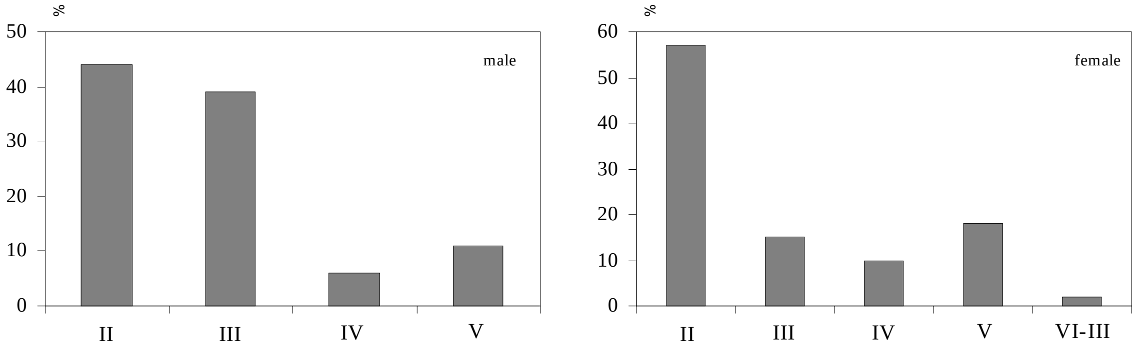


Fig. 22. Maturity stage of Frigate mackerel in Southwest monsoon.

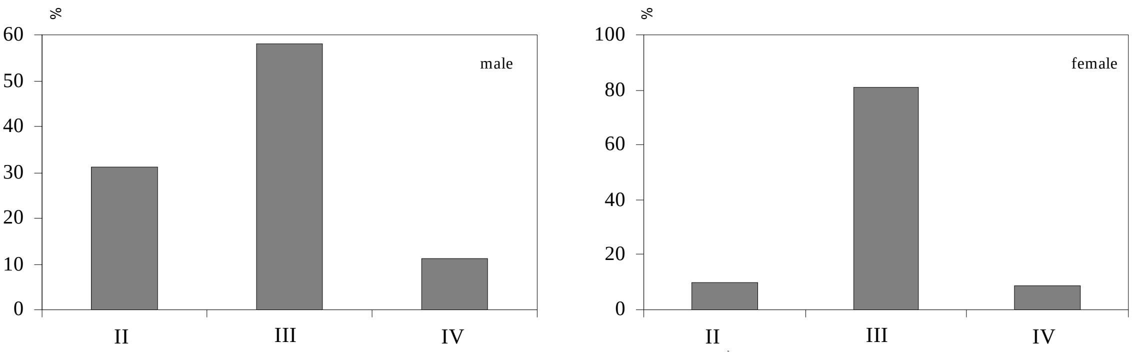


Fig. 23. Maturity stage of Frigate mackerel in Northeast monsoon.

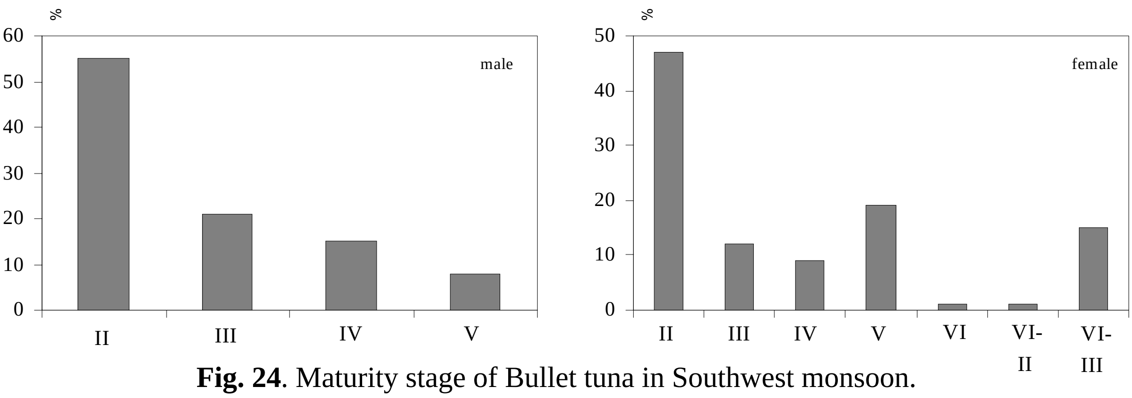


Fig. 24. Maturity stage of Bullet tuna in Southwest monsoon.

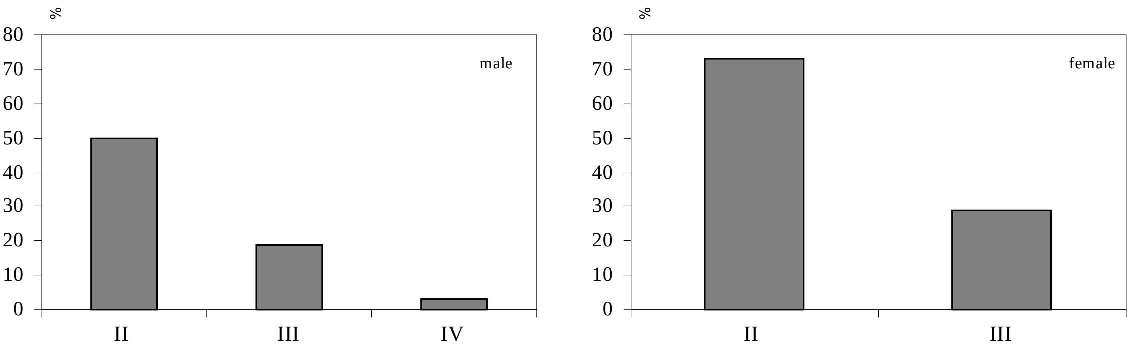
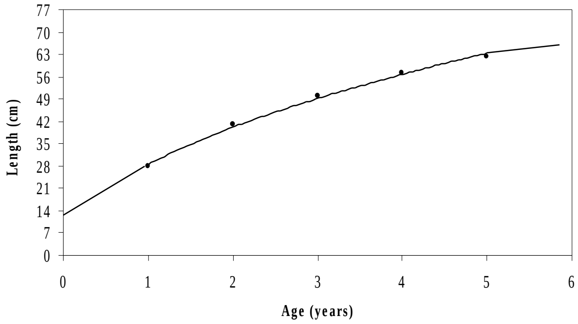


Fig. 25. Maturity stage of Bullet tuna in Northeast monsoon.

Species : *Katsuwonus pelamis*
Model : von Bertalanffy Growth Function (non-seasonalized)
Remarks : Data points were not weighted



PARAMETER ESTIMATES

L∞	:	77.665
K	:	0.299
t0	:	-0.510
φ'	:	3.256

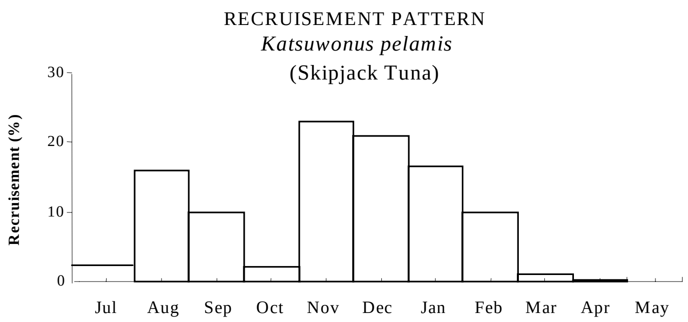
s.e. OF ESTIMATES

L∞	:	4.322
K	:	0.045
t0	:	0.153
φ'	:	0.481

CV OF ESTIMATES

L∞	:	0.0556
K	:	0.1498
t0	:	-0.3000

Fig. 26. Growth parameters of Skipjack tuna.



Loo = 77.66 , K = 0.299 , C = 0 , WP = 0 , t0

FILE : ST

Absolute Time	Percentage Recruisement
1 Jul	2.35
2 Aug	15.78
3 Sep	9.82
4 Oct	1.75
5 Nov	22.48
6 Dec	20.96
7 Jan	16.12
8 Feb	9.45
9 Mar	0.61
10 Apr	0.52
11 May	0.14
12 Jun	0.00

Select option in the right box. The Hasselblad' s NORMSEP may be used to estimate normal distribution (s).

Species name
Katsuwonus pelamis
Skipjack tuna

Fig. 27. Recruitment pattern of Skiplack tuna.

Species : *Auxis thazard*
Model : von Bertalanffy Growth Function (non-seasonalized)
Remarks : Data points were not weighted

PARAMETER ESTIMATES

L∞	:	49.018
K	:	0.426
t0	:	-0.867
φ'	:	3.010

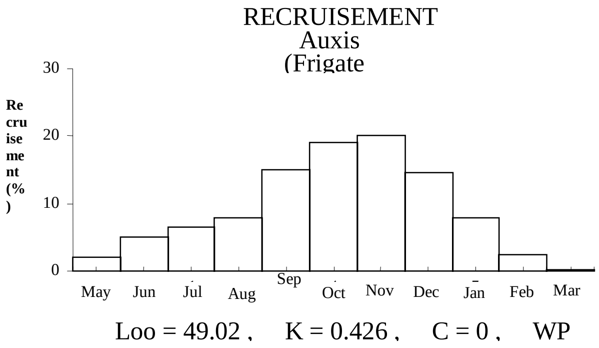
s.e. OF ESTIMATES

L∞	:	4.802
K	:	0.164
t0	:	0.492
φ'	:	0.187

CV OF ESTIMATES

L∞	:	0.0980
K	:	0.3846
t0	:	-0.5679
φ'	:	0.0623

Fig. 28. Growth parameters of Frigate mackerel.



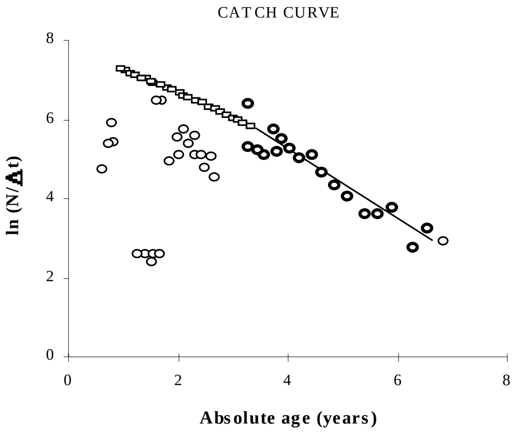
FILE : FRIMAC

Absolute Time	Percentage Recruisement
1 May	1.55
2 Jun	5.11
3 Jul	6.48
4 Aug	8.05
5 Sep	14.51
6 Oct	19.26
7 Nov	20.25
8 Dec	14.23
9 Jan	7.81
10 Feb	2.34
11 Mar	0.40
12 Apr	0.00

Select option in the right box. The Hasselblad's NORMSEP may be used to estimate normal distribution (s).

Species name
Auxis thazard
Frigate mackeral

Fig. 29. Recruitment pattern of Frigate mackerel.



Filename : ST

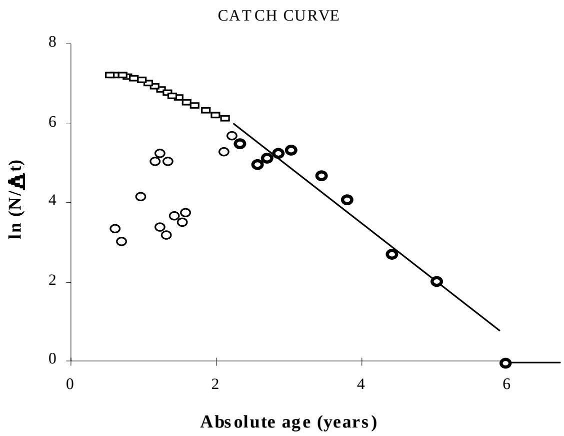
Growth Parameters
Loo : 77.66 cm K : 0.30
C : 0.00 WP : 0.00
t0 : -0.51

Cutoff length (L') = 53.000
Mean length (from L') = 58.856
Z from catch curve = 0.87
Z entered = 0.87
Natural mortality
(M, for T=28°C) = 0.62
M value used = 0.62
Fishing mortality (F=Z-M)
(Z & M as entered) = 0.25
exploit. Rate (E=F/Z) = 0.29

Species name :
Kasuwonus pelamis
Other file identifiers :
Skipjack tuna

Range of length observations :
27 – 71 cm
Class size :
1 cm

Fig. 30. Total, natural and fishing mortality of Skipjack tuna.



Filename : FRIMAC

Growth Parameters
Loo : 49.02 cm K : 0.43
C : 0.00 WP : 0.00
t0 : -0.867

Cutoff length (L') = 37.000
Mean length (from L') = 40.488
Z from catch curve = 1.44
Z entered = 1.44
Natural mortality
(M, for T=28°C) = 0.89
M value used = 0.67
Fishing mortality (F=Z-M)
(Z & M as entered) = 0.77
exploit. Rate (E=F/Z) = 0.53

Species name :
Auxis thazard
Other file identifiers :
Frigate mackerel

Range of length observations :
24 - 47 cm
Class size :
1 cm

Fig. 31. Total, natural and fishing mortality of Frigate mackerel.

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