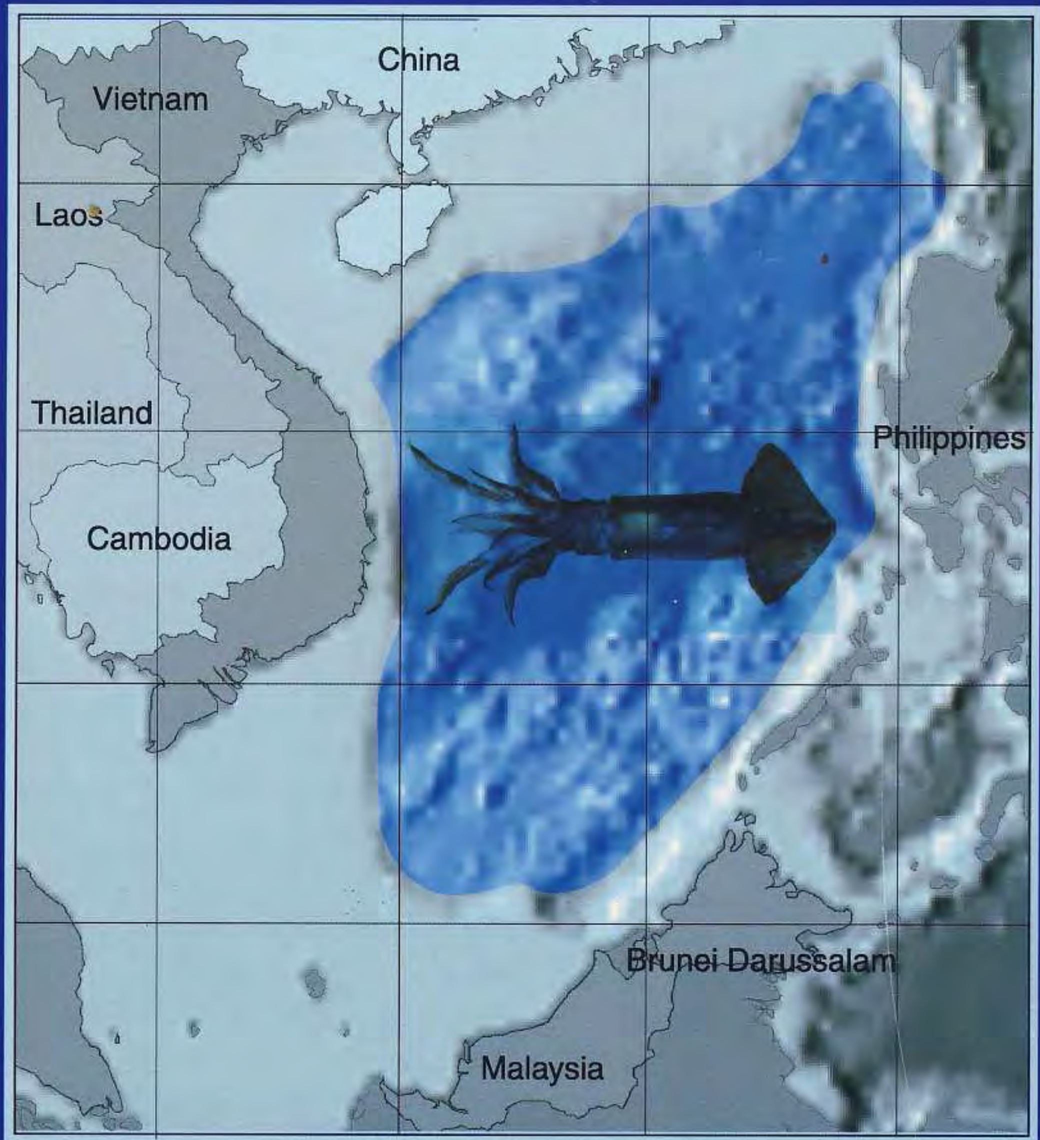
Exploration of Purpleback Flying Squid, *Sthenoteuthis oualaniensis* Resources in the South China Sea



Southeast Asian Fisheries Development Center
Training Department

TD/RES/48

JUNE 2001

FOREWORD

In the SEAFDEC drive towards the achievement of sustainable fisheries one significant ray of hope is the possibility of locating and harvesting under utilized species. This paper recognizes and postulates a resource known as the oceanic squid, which is a possible contender for use as a protein and food source, which is still bountiful in volume.

The exploration of this resource has been recognized in Japan, but only recently has research, development and effort been put into its exploitation in the Southeast Asian Region. In review, this paper explores the squid fisheries in the region, the types of fishing gear used and the potential for a more concerted effort on the catch of oceanographic squid species.

Not only are the technological aspects investigated, but also the potential for the future. Thus, this in-depth analysis breaks new ground in the true sense of regional fisheries development. The methods postulated for harvesting these ocean species are not highly sophisticated but represent a highly selective, cost efficient and responsible fishing technology. The research is both thorough and profound in its depth and completeness, adding a new dimension to deep-sea fisheries and can relieve, to some extent, the fishing pressure on the already declined economic species of the deep seas.

Panu Tavarutmaneegul

Panu Tavarutmaneegul
Secretary-General

Exploration of Purpleback Flying Squid, *Sthenoteuthis oualaniensis* Resources in the South China Sea

Somboon Siriraksophon[1], Yoshihiko Nakamura[2]

and Natinee Sukramongkol[1]

[1] *Southeast Asian Fisheries Development Center, Training Department*
P.O.Box 97 Phrasamutchedi, Samut Prakan, Thailand 10290, E-mail : somboon@seafdec.org

[2] *Tokyo University of Fisheries, 4-5-7 Konan, Minato-ku, Tokyo 108 Japan*

ABSTRACT

In an attempt to come up with initial jigging fishery on the purpleback flying squid, *Sthenoteuthis oualaniensis* in the Southeast Asia region, SEAFDEC has conducted the survey on resources and fishing ground conditions of the squid in the South China Sea. The survey objectives are to determine distribution and abundance of the purpleback flying squid in relation to oceanographical conditions and to examine the feasibility of harvesting squid with jig gear. In addition, the author reviews cephalopod fisheries in Southeast Asian countries as a whole against total landings of marine products by SEAFDEC statistical areas. Where possible landing are given separately by group of species, i.e., squids, cuttlefishes and octopus. Details are provided on species caught, statistic data by species, by groups and by countries, fishing gear types and perspective of fishing from the viewpoint of technological aspect.

Based on statistical data from 1976 to 1994 the amount of cephalopods caught in the region steadily increased from 83,692 tons in 1976 to 184,409 tons in 1994. Thai fishermen caught about 50% of this total catch in 1994, the rest 20% and 18% being the Philippines and Malaysia, respectively. More than 50% of the catch is generally composed of squid. 9 groups of fishing gears: surrounding net, seine net, trawl, gill net, lift net/cast net, trap/stake, hook and line, push/scoop net and miscellaneous gears are employed for catching the cephalopods. Trawl fisheries in Malaysia, Thailand and the Philippines caught about 88%, 70% and 44% of the total catch for 1994, respectively.

Exploration of the *S. oualaniensis* resources and its fishing ground were

Exploration of Purpleback Flying Squid, *Sthenoteuthis oualaniensis* Resources in the South China Sea

Somboon Siriraksophon[1], Yoshihiko Nakamura[2]

and Natinee Sukramongkol[1]

[1] *Southeast Asian Fisheries Development Center, Training Department*
P.O.Box 97 Phrasamutchedi, Samut Prakan, Thailand 10290, E-mail : somboon@seafdec.org

[2] *Tokyo University of Fisheries, 4-5-7 Konan, Minato-ku, Tokyo 108 Japan*

ABSTRACT

In an attempt to come up with initial jigging fishery on the purpleback flying squid, *Sthenoteuthis oualaniensis* in the Southeast Asia region, SEAFDEC has conducted the survey on resources and fishing ground conditions of the squid in the South China Sea. The survey objectives are to determine distribution and abundance of the purpleback flying squid in relation to oceanographical conditions and to examine the feasibility of harvesting squid with jig gear. In addition, the author reviews cephalopod fisheries in Southeast Asian countries as a whole against total landings of marine products by SEAFDEC statistical areas. Where possible landing are given separately by group of species, i.e., squids, cuttlefishes and octopus. Details are provided on species caught, statistic data by species, by groups and by countries, fishing gear types and perspective of fishing from the viewpoint of technological aspect.

Based on statistical data from 1976 to 1994 the amount of cephalopods caught in the region steadily increased from 83,692 tons in 1976 to 184,409 tons in 1994. Thai fishermen caught about 50% of this total catch in 1994, the rest 20% and 18% being the Philippines and Malaysia, respectively. More than 50% of the catch is generally composed of squid. 9 groups of fishing gears: surrounding net, seine net, trawl, gill net, lift net/cast net, trap/stake, hook and line, push/scoop net and miscellaneous gears are employed for catching the cephalopods. Trawl fisheries in Malaysia, Thailand and the Philippines caught about 88%, 70% and 44% of the total catch for 1994, respectively.

Exploration of the *S. oualaniensis* resources and its fishing ground were

conducted by using MV SEAFDEC of the Southeast Asia Fisheries Development Center. The survey area in the South China Sea was divided into three areas, namely Area I: Western Philippines Waters, Area II: Vietnamese Waters, and Area III: Sabah Sarawak (Malaysia) and Brunei Darussalam Waters, of which the surveys were in the exclusive economic zones of each country, respectively. Four automatic squid jigging gears with luring light system were employed for catching the squid. Catch per Unit Effort (CPUE: the number of squids per line-hour) is used an index of abundance for a fishing ground. 30 squid samplings and 117 oceanographic stations were carried out during March-May of 1998-2000. Water temperature, salinity, dissolved oxygen, chlorophyll and other parameters were measured at all stations to elucidated oceanographic features of the research area. At each station, squid larvae surveys were also conducted.

A total of 4,257 *S. oualaniensis* specimens, captured were consisted of 2,592 specimens from the Western Philippines, 1,412 specimens from theVietnamese waters, and 253 specimens from the Sabah, Sarawak (Malaysia) and Brunei Darussalam waters. Mantle length range of the *S. oualaniensis* captured within each survey area was 90-250mm, 90-240mm and 58-230mm, respectively. Female dominated the catch, accounting for about 81% of the total squid. Males were generally smaller than females of which their mantle lenght range was 90-180mm. CPUEs of the *S. oualaniensis* were 0.15-18.47 ind./line-hour in April-May. High CPUEs were located in the EEZ of the Philippines off Currimao and San Fernando (17°-18°N and 117°-119°E) and in the EEZ of Vietnam off Danang (15°N and 111°E). Drop-off rates for jigs fished by the jigging machines ranged from 0 to 0.33 squid/line-hour. Angling depth where the squid were abundant ranged from 50 m to 100m.

S. oualaniensis distributed in the warm water mass whereas the sea temperature ranged from 14°c to 31°c within the depth from 150m upto the sea surface at night. Good fishing grounds of the squid were at the area of 17°N, 117°E and 18°N, 119°E, of which seasonal upwelling was found at the later. Dissolved oxygen at abundant area was 3.27 to 4.4ml/l. Downwelling was found at 16°N, 118°E where less potential of squid, the water transparency depth was obeserved to be 44m. Another upwelling was also observed within the EEZ of Vietnam at 14°N, 111°E during May. Cephalopod paralarvae were collected at most stations on the shelf and shelf edge of the South China Sea basin where the bottom topographical depth are deeper than 150m.

Table of Contents

	Page
1) Introduction	1
2) Review of Squid Fisheries in Region	2
2.1 Catch Composition	2
2.2 Statistic Data by Species/ by Group/ by Countries	2
2.3 Fishing Gear Types	5
2.4 Perspective of Fishing from the View Point of Technological Aspects	8
3) Exploratory Method	10
3.1 Survey Areas	10
3.2 Research Vessel	13
3.3 Fishing Gear	17
3.4 Light System	17
3.5 Data Collection	17
3.5.1 Catch and Effort	17
3.5.2 Biological Features	20
3.5.3 Specimens for Systematic Study	20
3.5.4 Cephalopod Paralarvae	20
3.5.5 Oceanographic Measurement and Data Analysis	22

	Page
4) Results	24
4.1 Systematic of *Sthenoteuthis oualaniensis*	24
4.1.1 Material Examined	26
4.1.2 Description	26
4.1.3 Remarks	29
4.2 Distribution, Abundance and Biological Features	30
4.2.1 Western Philippines Waters	30
4.2.1.1 CPUEs Distribution and Sex Compositions	31
4.2.1.2 Length Frequency Distribution	33
4.2.1.3 Length-Weight Relationship	34
4.2.1.4 Cephalopod Paralarvae Abundance and Distribution	34
4.2.2 Vietnamese Waters	36
4.2.2.1 CPUEs Distribution and Sex Compositions	36
4.2.2.2 Length Frequency Distribution	37
4.2.2.3 Length-Weight Relationship	39
4.2.2.4 Cephalopod Paralarvae Abundance and Distribution	40
4.2.3 Sabah, Sarawak (Malaysia) and Brunei Darussalam Waters	42
4.2.3.1 CPUEs Distribution and Sex Compositions	42

Page

4.2.3.2 Length Frequency Distribution 42

4.2.3.3 Length-Weight Relationship 43

4.2.3.4 Cephalopod Paralarvae Abundance and Distribution 43

4.3 Diet and Feedings 45

4.4 Oceanographic Characteristics 46

4.4.1 Western Philippines Waters 46

4.4.1.1 Horizontal Distribution of the Temperature, Salinity and Fluorescence 46

4.4.1.2 Horizontal Distribution of the Water Transparency 48

4.4.1.3 Vertical Profiles of the Temperature, Salinity and Dissolved Oxygen 48

4.4.1.4 Vertical Distribution of the Temperature 50

4.4.2 Vietnamese Waters 50

4.4.2.1 Horizontal Distribution of the Temperature, Salinity and Fluorescence 50

4.4.2.2 Horizontal Distribution of the Transparency and Sea Color 57

4.4.2.3 Vertical Profiles of the Temperature and Salinity 57

4.4.2.4 Vertical Distribution of the Temperature and Salinity 57

4.4.3 Sabah, Sarawak (Malaysia) and Brunei Darussalam waters 58

		Page
4.4.3.1	Horizontal Distribution of the Temperature, Salinity and Fluorescence	58
4.4.3.2	Horizontal Distribution of the Transparency and Sea Color	58
4.4.3.3	Vertical Profiles of the Temperature, Salinity and Fluorescence	58
4.4.3.4	Vertical Distribution of the Temperature	67
4.5	Angling Depth	68
4.6	Lunar Effects	69
5)	**Discussion**	70
6)	**Acknowledgements**	71
7)	**References**	72
8)	**Appendix**	78

List of Figures

Page

Fig. 1. Commercially important squid and cuttlefish found in the Southeast Asian Countries: a) *Loligo chinensis, b) L. duvaucelli, c) L. edulis, d) L. singhalensis, e) Sepia aculeata, f) S. Lycidas, g) S. pharaonis, h) Sepiella inermis,* and *i) Sepioteuthis lessonniana* . 3

Fig. 2. Annual cephalopod production of Southeast Asian countries from 1976 to 1994. 4

Fig. 3. Percent of catch of cephalopods in the Southeast Asian countries in 1976 and 1994. 4

Fig. 4. Percent of catch by groups of cephalopod in Southeast Asian countries in 1994. 5

Fig. 5. Percent of catch by types of fishing gear in 1978. 7

Fig. 6. Percent of catch by types of fishing gear in 1994. 7

Fig. 7. Annual catch and number of registered fishing boats for squid cast net in Thailand, 1978-82. 9

Fig. 8. Illustration of the squid cast net in Thailand. 9

Fig. 9. Survey areas in the South China Sea during 1998-2000. 10

Fig. 9-1. Oceanographic and squid samplings stations of the survey areas I: Western Philippines in the South China Sea during 19 April - 10 May, 1998. 11

Fig. 9-2. Oceanographic and squid samplings stations of the survey areas II: Vietnamese waters in the South China Sea during 29 April - 30 May 1999. 12

Fig. 9-3. Oceanographic and squid samplings stations of the survey areas III: waters of Sabah, Sarawak (Malaysia) and Brunei Darussalam in the South China Sea during 21 March - 7April, 2000. 13

Fig. 10. Illustration of jig line used with the automatic squid jigging machine for this survey. 18

Fig. 11. Automatic squid jigging gear used to collect the oceanic squid: a) The automatic squid jigging machine installed at port side of MV SEAFDEC, b) 1,250g cast-iron sinker, c) a reel of the jigging machine consisted of main line and jigs, d) type of jig cases with 5 different colors. 19

		Page
Fig. 12.	Luring lamps of 500 W bulb each setting above the machine inside the vessel.	19
Fig.13.	Diagrammatic illustrations of the measurements of squids. Dorsal view, AL= Arm Length, ClL=Club Length, FL=Fin Length, FW=Fin Width, HL=Head Length, HW=Head Width, ML=Mantle Length, MW=Mantle Width, I=dorsal arm, II=dorso-lateral arm, III=ventro-lateral arm, IV=ventral arm, TtL=Tentacular Length	21
Fig. 14.	Bongo net (a) and its operation at the sea surface (b) used for collecting the cephalopod paralarvae in this survey	23
Fig. 15.	Specimens of the purpleback flying squid, *Sthenoteuthis oualaniensis* collected from the Vietnamese waters in the South China Sea	24
Fig. 16A.	*Sthenoteuthis oualaniensis:* a) dorsal view and b) ventral view.	27
Fig. 16B.	*Sthenoteuthis oualaniensis:* a) head, b) foveola and side pockets, c) funnel and mantle locking cartilages, d) arm sucker e) radula.	27
Fig. 16C.	*Sthenoteuthis oualaniensis:* a) hectocotylised arm, b) lateral view of hectocotylised arm showing a series of pits, c) tentacular club, d) club sucker, e) gladius.	28
Fig. 16D.	*Sthenoteuthis oualaniensis:* a) upper beak, b) lower beak, c) spermatophore, d) enlargement of oral cap, e) enlargement of cement body.	28
Fig. 17.	Sex composition and CPUEs distribution of the purpleback flying squid in the South China Sea, Western Philippineswaters during April-May 1998.	31
Fig. 18A.	Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea, Western Philippines waters during April-May 1998.	32
Fig. 18B.	Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea, Western Philippines waters during April-May 1998.	33
Fig. 19.	Length-weight relationships of the male and female purpleback flying squid from the South China Sea, Western Philippines waters during April-May 1998.	33
Fig. 20.	Abundance and distribution of the purpleback flying squid paralarvae in the South China Sea, Western Philippineswaters during April-May 1998.	34

		Page
Fig. 21.	Sex composition and CPUEs distribution of the purpleback flying squid in the South China Sea, Vietnamese waters during May 1999.	37
Fig. 22A.	Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea, Vietnamese waters during May 1999.	38
Fig. 22B.	Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea, Vietnamese waters in May 1999.	39
Fig. 23.	Length-weight relationships of the male and female purpleback flying squid from the South China Sea, Vietnamese waters in May 1999.	39
Fig. 24.	Abundance and distribution of the purpleback flying squid paralarvae in the South China Sea, Vietnamese waters in May 1999.	40
Fig. 25.	CPUEs distribution and sex composition of the purpleback flying squid in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.	43
Fig. 26A.	Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-Apr. 2000.	44
Fig. 26B.	Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.	45
Fig. 27.	Length-weight relationships of the female purpleback flying squid from the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.	45
Fig. 28.	23 days synoptic chart of the sea surface temperature (a) and 100m deep (b) in the Western Philippines during 17 April - 9 May 1998.	47
Fig. 29.	23 days synoptic chart of the salinity (a) and chlorophyll a fluorescence value (b) at the surface layer in the Western Philippines during 17 April - 9 May 1998.	47
Fig. 30.	23 days synoptic chart of the water transparency depth in the Western Philippines during 17 April - 9 May 1998.	48
Fig. 31.	Vertical profiles of temperature, salinity and dissolved oxygen at each squid samplings station in the Western Philippinesduring 17 April - 9	49

		Page
Fig. 32.	Vertical distribution of temperature (3°c interval) at the cross section of LINE A, LINE B, LINE C, and LINE D in the Western Philippines during 17 April - 9 May 1998.	51
Fig. 33-1.	Vertical distribution of temperature (3°c interval) at the cross section of LINE 1, LINE 2, LINE 3, and LINE 4 in the Western Philippinesduring 17 April - 9 May 1998.	52
Fig. 33-2.	Vertical distribution of temperature (3°c interval) at the cross section of LINE 5, LINE 6, LINE 7, and LINE 8 in the Western Philippinesduring 17 April - 9 May 1998.	53
Fig. 34.	30 days synoptic chart of the sea surface temperature (a) and 100m deep (b) of the South China Sea: Vietnamese waters during 30 April-29 May 1999.	54
Fig. 35.	30 days synoptic chart of the salinity (a) chlorophyll a fluorescence value (b) at the sea surface in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	54
Fig. 36.	30 days synoptic chart of the sea color (a) transparency depth (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	55
Fig. 37.	Vertical profiles of the salinity and temperature of each squid samplings station in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	56
Fig. 38.	Vertical distribution of the temperature at the cross section of LINE 1 (a) and LINE 2 (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	59
Fig. 39.	Vertical distribution of the salinity at the cross section of LINE 1 (a) and LINE 2 (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	59
Fig. 40.	Vertical distribution of the temperature (3°c interval) at the cross section of LINE A (a), LINE B (b), LINE C (c) and LINE D (d) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.	60
Fig. 41.	20 days synoptic chart of the sea surface temperature (a) and 100m deep (b) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	61
Fig. 42.	20 days synoptic chart of the salinity (a) and chlorophyll a fluorescence value (b) at the surface layer of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	62

		Page
Fig. 43.	20 days synoptic chart of the water transparency depth (a) and sea color value (forel scale index) at the surface layer of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	63
Fig. 44.	Vertical profiles of the salinity and temperature and chlorophyll a fluorescence value at squid samplings station of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	64
Fig. 45.	Vertical distribution of the temperature (3°c interval) at the cross section of LINE A (a), LINE B (b), LINE C (c) and LINE D (d) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	65
Fig. 46.	Vertical distribution of the temperature (3°c interval) at the cross section of LINE 1 (a), LINE 2 (b), and LINE 3 (c) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.	66
Fig. 47	Echo traces of the purpleback flying squid and sinker observed from the dual frequencies of colour echo sounder at 200 Hz.	68
Fig. 48	Relationship between the result of catch in CPUE and phase of the moon referred to the percent of illumination from the moon in different survey area in the South China Sea.	69
Fig. 49	Distribution of the *Sthenoteuthis oualaniensis* in the South China Sea	71

List of Tables

		Page
Table 1	Types of fishing gear on cephalopod fisheries in Southeast Asian Countries.	6
Table 2	Detailed information of the number of station, date and position of each squid sampling, oceanographic collection and squid larvae sampling stations in survey area1: Western Philippines, Area 2: Vietnamese waters and Area 3: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters.	14-16
Table 3	Definition of counts, measurements and indices.	21
Table 4A.	Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis* . in the Area 1, Station no. 12. Lat. 16° 59.8N, Long. 117° 04.7E. Auto squid jigging, angling depth 100 m, time 1915-0130 hrs, surface temperature 27.8°C, M.V. SEAFDEC 25 April 1998, total catch in weight 100.299 kg and in number 739 pcs.	25
Table 4B.	Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis* . in the Area 2, Station no. 16. Lat. 15° 02.5N, Long. 110° 58.8E. Auto squid jigging, angling depth 100 m, time 2015-0230 hrs, surface temperature 28.3°C, M.V. SEAFDEC, 7 May 1999, total catch in weight 52.59 kg and in number 492 pcs.	25
Table 5	Sampling stations and catch results of the purpleback flying squid in the South China Sea: Western Philippines waters	30
Table 6	The number of cephalopod paralarvae per 1000 m^3 at 31 stations in the western Philippines waters, during 7 April- 19 May 1998.	35
Table 7.	Sampling stations and catch results of the purpleback flying squid in the South China Sea: Vietnamese waters during May 1999.	36
Table 8.	Number of cephalopod paralarvae per 1000 m^3 at 58 stations in the Vietnamese waters, during 30 April- 29 May 1999.	41
Table 9.	Sampling stations and catch results of the purpleback flying squid in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.	42

1. Introduction

In the Southeast Asian Region many coastal resources are being fished close to, or even beyond, the level of effort yielding the maximum sustainable yield resulting in the extreme over-exploitation of both demersal and pelagic resources. In the search for new resources that can locally support a high level of exploitation in the near future, oceanic species must occupy a leading place, both because of their abundance and their undeniable nutritional qualities. Oceanic flying squid like the purpleback flying squid could be new resources that might even take the place of coastal resources because of their wider distribution covering all seas in the Region particularly, the South China Sea, Sulu Sea, Andaman Sea, Western Pacific Ocean and Eastern Indian Ocean.

The flying squids (Roper *et al.* 1984) of the family Ommastrephidae (Suborder Oegopsida) account for about 65% percent of the world's commercial cephalopods (Brunetti 1990), which totaled about 2.6 million tons in 1991 (FAO 1983). The purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson) and flying squid, *Ommastrephes bartramii* are oceanic squid species of this family and their geographical distribution is to be found from the Indo-Pacific to the Indian Ocean. Voss (1973) speculates that the potential of the purpleback flying squid is at least 100,000 metric tons in the central eastern Pacific. It is on record that purpleback flying squid are caught commercially by hook and line with luring lights at night in the eastern and southern East China Sea, from Taiwan to Okinawa (Tung 1981, Yoshikawa 1978, Okutani and Tung 1978, Okutani 1980). In addition the most promising evidence for the exploitation of this squid in the eastern Arabian Sea and in the western Pacific Ocean to the eastward of the Philippines and Indonesia (JAMARC 1977).

It is premature to say much about the feasibility of commercial fishing for these flying squid at this stage except for the existing fisheries in the region tht are to be found in the Philippines and Vietnam. The availability of these species in terms of likely catch rates for local fisheries is still unknown even though the potential yield is believed to be large. Oceanographic and environmental conditions need to be examined in connection with the ecological/biological requirements of the squid. In an attempt to evaluate the exploration of new resources and the initial jigging fishery on oceanic squid, SEAFDEC has conducted a comparative study on oceanic squid in the South China Seas between 1998-2000 under the SEAFDEC Collaborative Research Program on Fisheries Resources Surveys in the South China Sea. The purpose of these surveys was to determine their distribution and abundance, particularly the purpleback flying squid in relationship to the oceanographic conditions and to examine the feasibility of harvesting squid with the automatic squid jig gear. Studies have been reviewed of the situation of cephalopod fisheries in the region.

In this paper the author reviews squid fisheries in the Southeast Asian countries as a whole against total landings of marine products by SEAFDEC statistical areas. In addition, the results from the surveys both on squid sampling and oceanographic observation in the South China Sea covering the Western Philippines waters, Vietnamese waters and Sabah, Sarawak (Malaysia) and Brunei Darussalam waters are reported.

2. Review of Squid Fisheries in Region

In this part, the author reviews squid fisheries in Southeast Asian countries as a whole against total landings of marine products by SEAFDEC statistical areas. Where possible landings are given separately by group of species, i.e., squids, cuttlefish and octopus, details are provided on species caught, statistic data by species, by groups and by countries. Also included are fishing gear types and perspectives of fishing from the technological aspect based upon statistical data from 1976 to 1994.

2.1 Catch Composition

The cephalopods mainly consist of cuttlefish, squid, octopus and chambered nautilus, which is easily distinguished by external characteristics and is mainly caught in the Southeast Asian Countries. Thirty-one species of cephalopods were found in the Gulf of Thailand throughout the seas from the coast of Peninsular Malaysia and Andaman sea. Commercially important squid and cuttlefish in the Region include: *Loligo chinensis, L. duvaucelli, L. edulis, L. singhalensis, Loliolus sumatrensis, L. affinis, Sepioteuthis lessonniana, Sipia aculeata, S. pharaonis, S. Lycidas, S. brevimana,* and *Sepiella inermis* as shown in **Fig. 1**. In the Philippines and Vietnam, another three species commonly found in the market are as follows: *Sthenoteuthis oualaniensis, Thysanoteuthis rhombus* and nautilus.

2.2 Statistic Data by Species/ by Group/ by Countries

Fig. 2 Shows the annual cephalopod catch in the Southeast Asian countries; Indonesia, Malaysia, the Philippines, Singapore and Thailand based upon the SEAFDEC statistical data from 1976 to 1994. The total catches increased year by year in each country and steadily increased for Thailand because of the development of Thailand's trawl and squid cast net fisheries. In Thailand, cephalopod production reached 70,000 tons in 1994, which was 50% of the total production in Southeast Asian countries as shown in **Fig. 3**.

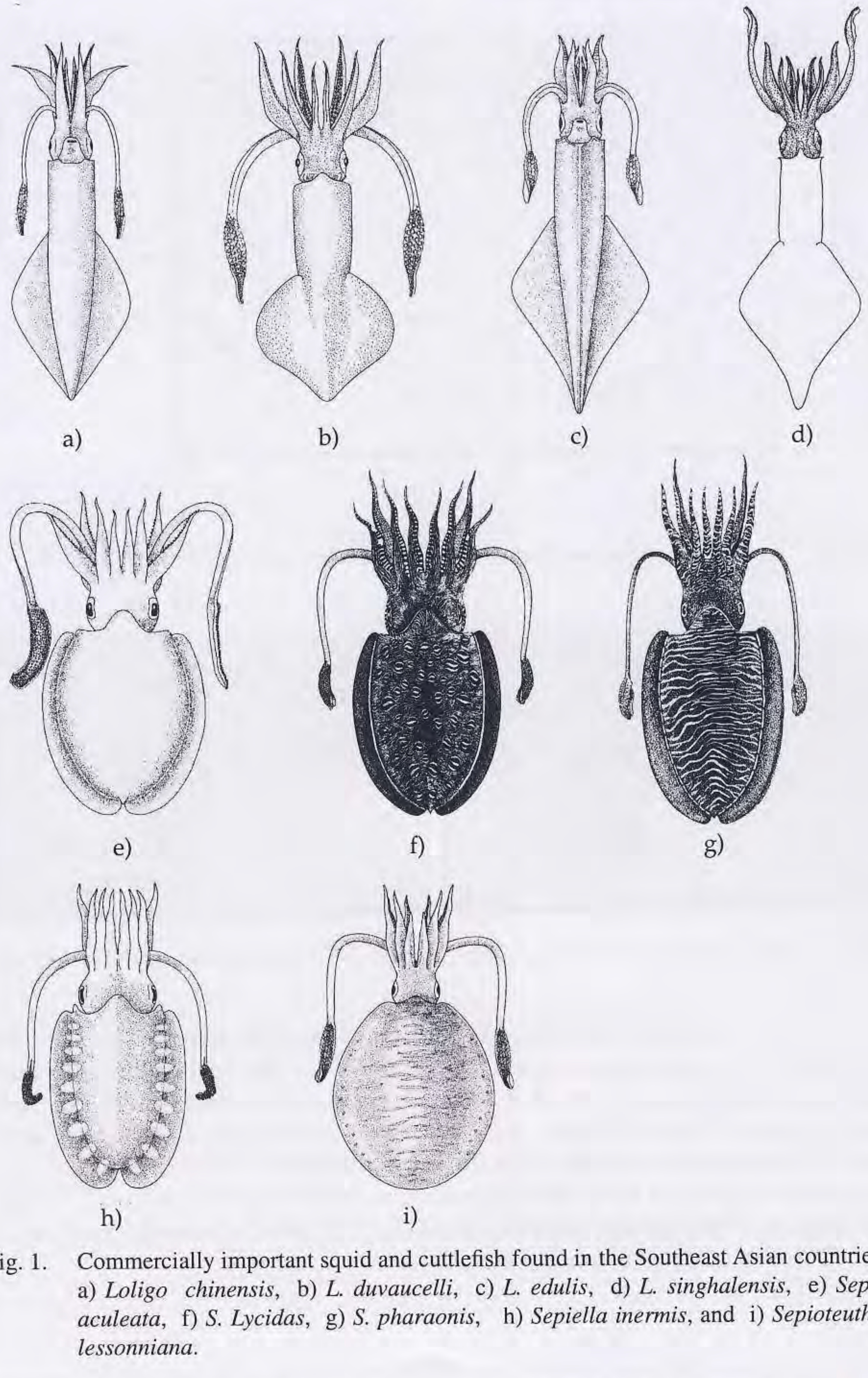


Fig. 1. Commercially important squid and cuttlefish found in the Southeast Asian countries: a) *Loligo chinensis*, b) *L. duvaucelli*, c) *L. edulis*, d) *L. singhalensis*, e) *Sepia aculeata*, f) *S. Lycidas*, g) *S. pharaonis*, h) *Sepiella inermis*, and i) *Sepioteuthis lessonniana*.

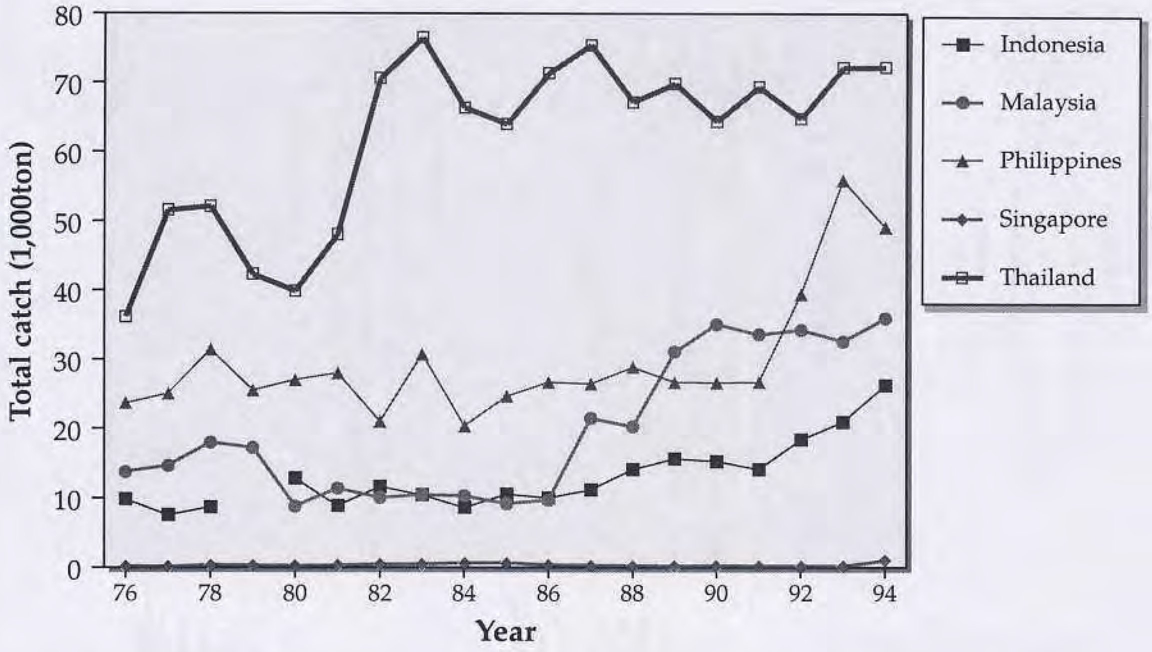


Fig. 2. Annual cephalopod production of Southeast Asian countries from 1976 to 1994.

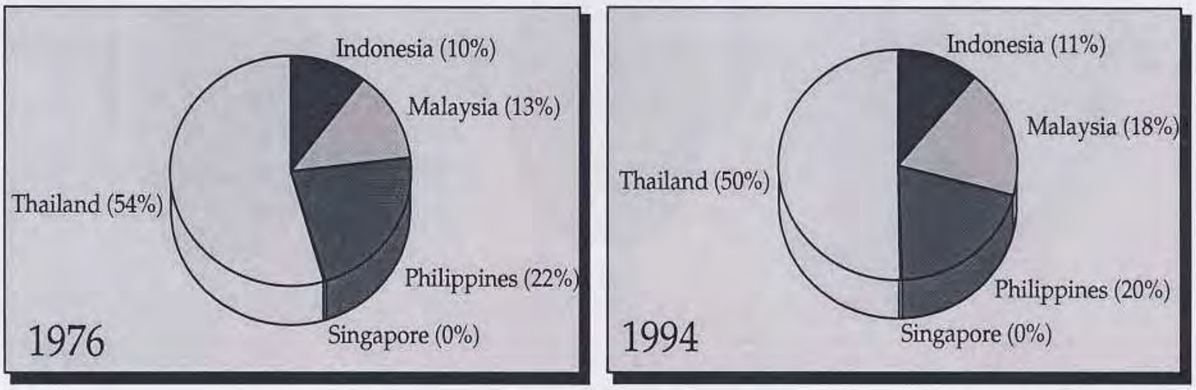


Fig. 3. Percent of catch of cephalopods in the Southeast Asian countries in 1976 and 1994.

Fig. 4 shows the percentage of cephalopod groups caught based upon the 1994 data. The results show that in Malaysia 70% of the total cephalopod catch was squid; the remaining 29% and 1% were represented by cuttlefish and octopus, respectively. For the Philippines, 84% of the total cephalopod catch was squid, 4% and 12% represented cuttlefish and octopus, respectively. In Thailand, 50% of the total cephalopod catch was squid, 39% represented cuttlefish and the remaining 11% was for octopus. These indicate that more than 50% of the catch is generally composed of squid, the rest being cuttlefish and octopus.

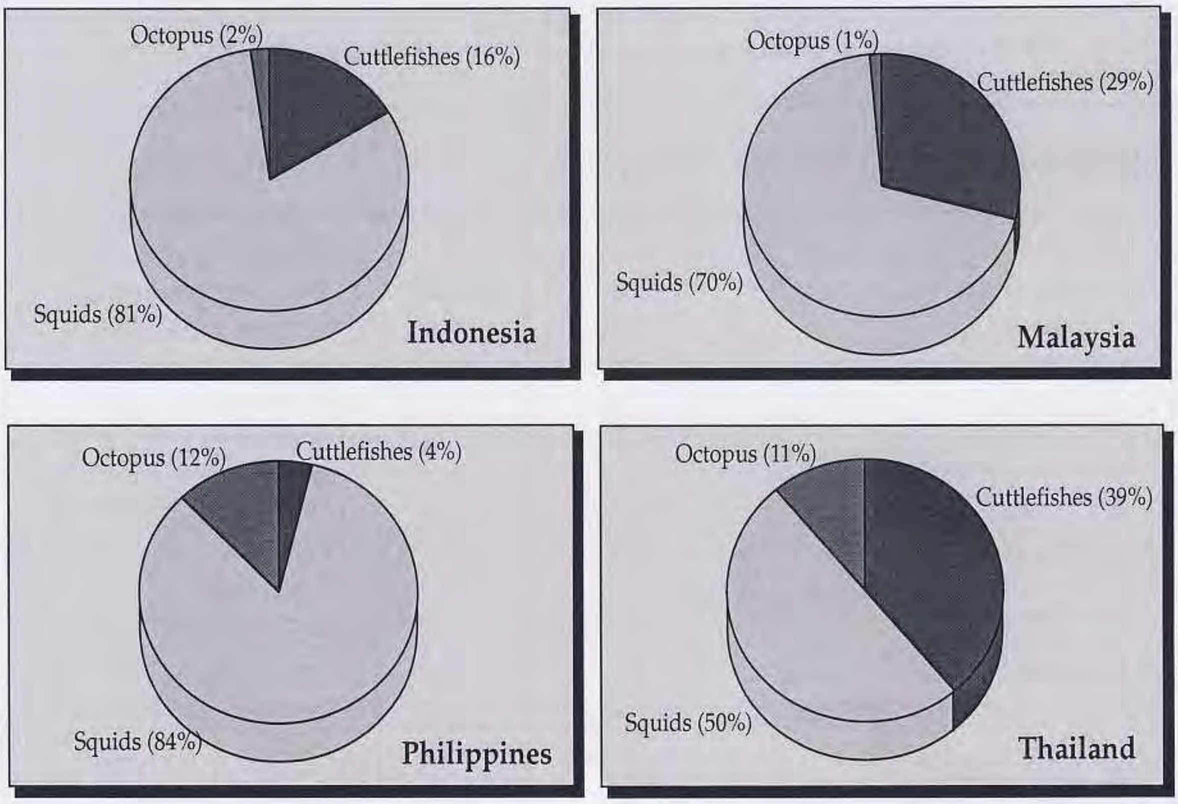


Fig. 4. Percent of catch by groups of cephalopod in Southeast Asian countries in 1994.

2.3 Fishing Gear Types

Fishing gear groups used in cephalopod fishing for both large and small scale in the Southeast Asia can be classified into 9 groups: surrounding net, seine net, trawl, gill/drift net, lift net/cast net, trap/stakes, hook and line, push/scoop net and miscellaneous gear. **Table 1** gives the types of cephalopod fishing gear found in Malaysia, Philippines and Thailand.

Fig. 5 shows the proportion of catch by types of gear used for catching cephalopods in Malaysia, the Philippines and Thailand in 1978. Trawl fisheries in Malaysia and Thailand caught about 95% of the total catch of cephalopods. Only 2% of the catch were caught by hook and line methods in Malaysia and squid cast net in Thailand.

In the Philippines most of the cephalopods were caught by various types of gear including trawls, lift nets, hook and line, seine nets, gill net and others. The statistical catch data shows that 44%, 21%, 17% and 12% of the total cephalopod were caught by trawls, lift nets, hook and line and seine nets, respectively.

Fig. 6 shows the proportion of catch by type of gear used for catching

Table 1 Types of fishing gear on cephalopod fisheries in Southeast Asian Countries.

Major Groups	Malaysia	Philippines	Thailand	Types of Gear
1) Surrounding Net	a,b	a	a,b,c	a) One boat purse seine b) Two boat purse seine c) Without purse line
2) Seine Net	a,b	a,b	b	a) Beach seine b) Boat seine
3) Trawl	a	a	a,b,c	a) Otter board trawl b) Pair trawl c) Beam trawl
4) Gill/ Drift	a	a	a	a) Other gillnet
5) Lift Net / Cast Net	a,b	a,b	a,b,c	a) Stationary lift net b) Portable lift net c) Squid cast net
6) Traps/ Stakes	b	b	a,b	a) Bamboo stake trap b) Squid Trap
7) Hook and Line	a	a	a	a) Handline with jig or bait
8) Push / Scoop Net	a,b	a	a	a) Push net b) Scoop net
9) Others	a,b	a,b,c,d,e,	b	a) Drive in b) Luring device c) Spear gun d) Miracle hole e) Gaff hook

cephalopods in 1994. The figure indicates that the percentage of the catch by trawl was still high in Malaysia, which reached 88% compared with others gear and hook and line caught about 8%. In Thailand 70% of the total catch was caught by trawl and about 20% was caught by cast net gear.

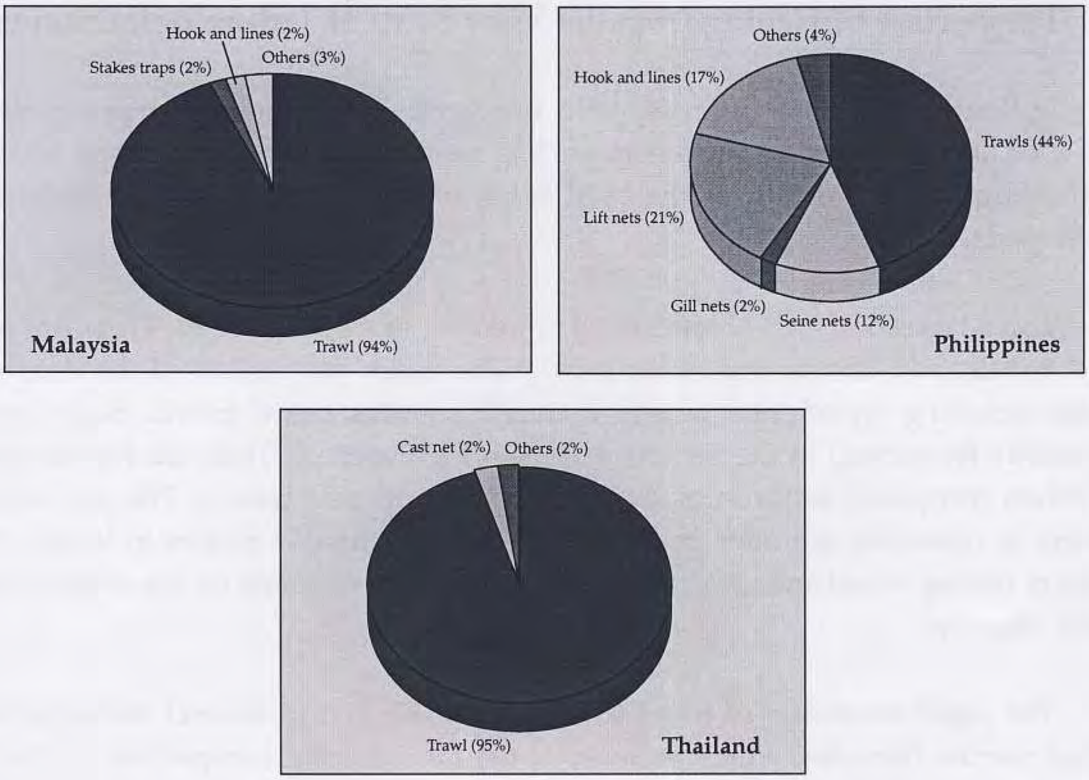


Fig. 5. Percent of catch by types of fishing gear in 1978.

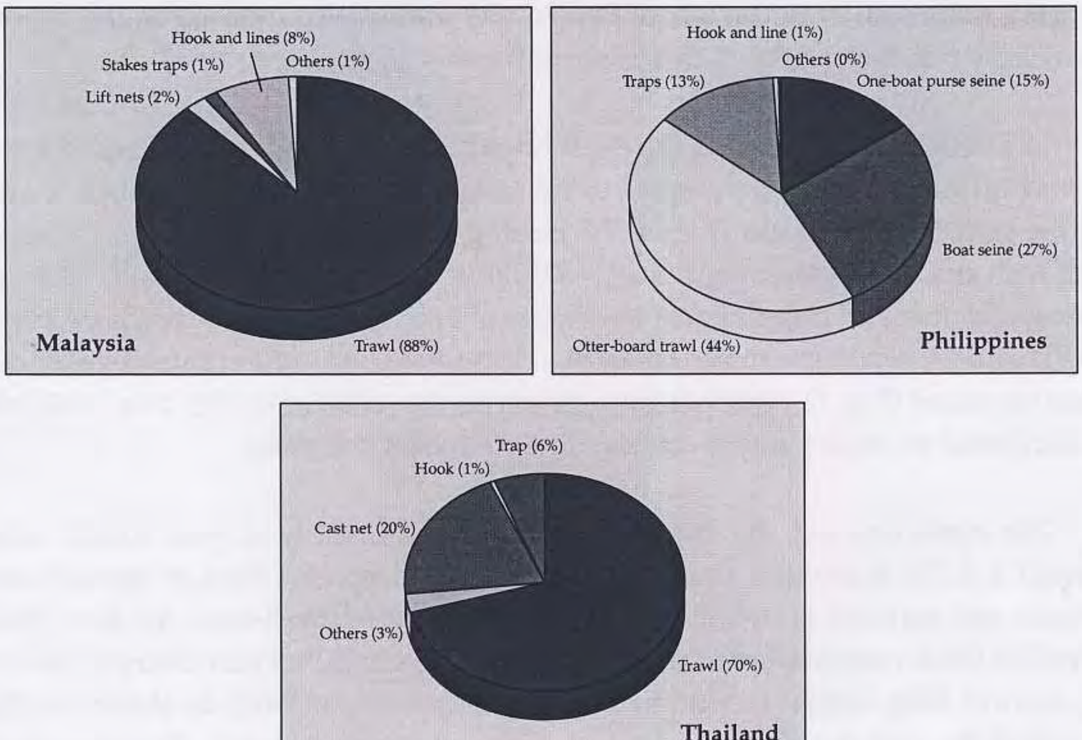


Fig. 6. Percent of catch by types of fishing gear in 1994.

2.4 Perspective of Fishing from the View Point of Technological Aspects

In Southeast Asian countries, with the rapid development of trawl fisheries since 1960, inshore gear like push nets, set bag nets and bamboo stake traps, account for a negligible proportion of the total catch of the demersal species including cephalopods.

Three types of trawls are presently employed in trawl fisheries. These are otter board trawls, pair trawls and beam trawls. The major proportion of the demersal species including cephalopod groups is caught by otter board trawls. Beam trawls fish mainly for shrimp in the inshore waters along the coast. Their catches are quite low when compared to those of the otter board and pair trawls. The majority of trawlers in operation are otter board trawlers of less than 14 meters in length. The design of fishing vessel and the dimensions of trawl gear depends on the development in each country.

The rapid extension of trawl fisheries has resulted in several developments in Thai marine fisheries, which include: 1) the keen fishing competition in fishing grounds in the Gulf of Thailand and in the Andaman Sea; 2) the development of medium and large-sized trawlers (18 meters or longer) and the formation of a distant water fishing fleet of trawlers operating off the coast of Cambodia, Vietnam, Malaysia, Indonesia, and recently in the Bay of Bengal and India; 3) an increase in the export of some fishery products, notably frozen shrimp and squid.

In Thailand and Malaysia the most important gear used to catch squid are cast nets and lift nets. Luring techniques using lamps by night was developed together with the gear to catch squid from 1978. Fishing vessels generally are 8-25 meters in length with an electric generator size of 3-30 kilowatt. Recently, this method has become the most effective and popular gear to catch squid compared to pair trawls. According to the Thai fishery statistical records from 1978 to 1982, the annual catch by squid cast net has increased (**Fig.** 7). A particularly sharp rise was evident in 1981 and 1982, which was attributed to improvements in gear, like stick-held cast nets.

The squid cast net, the largest of the traditional cast nets, were found suitable for squid fishing. A modern squid cast net is 6-8 m deep and 35 m in circumference. The main net material is nylon of 210 d/4-6, 25-30 mm mesh-size. An iron chain is attached to the lowest meshes of the net. An iron (Fe)-chain, 6.5 mm diameter and 36m long, around 35kg weight is used to block the escape of the catch as shown in **Fig. 8.** The size of the cast net differs according to the operational areas. The operation of the cast net requires skill, but can be carried out by one man on a small boat, usually on a dark night, using a kerosene or electric luring light. Apart from squid, the catch consists of cuttlefish and some fishes.

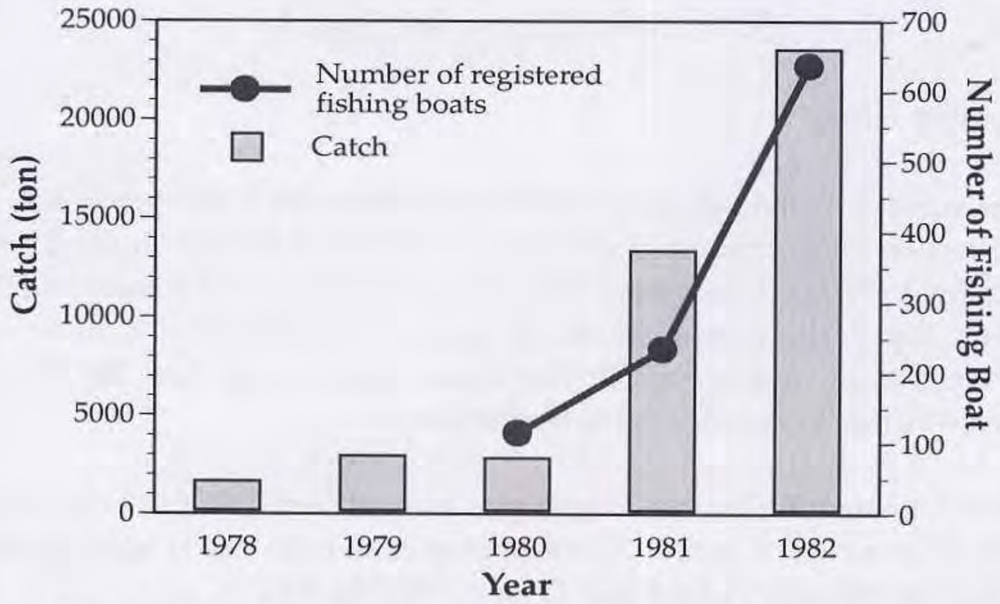


Fig. 7. Annual catch and number of registered fishing boats for squid cast net in Thailand, 1978-82.

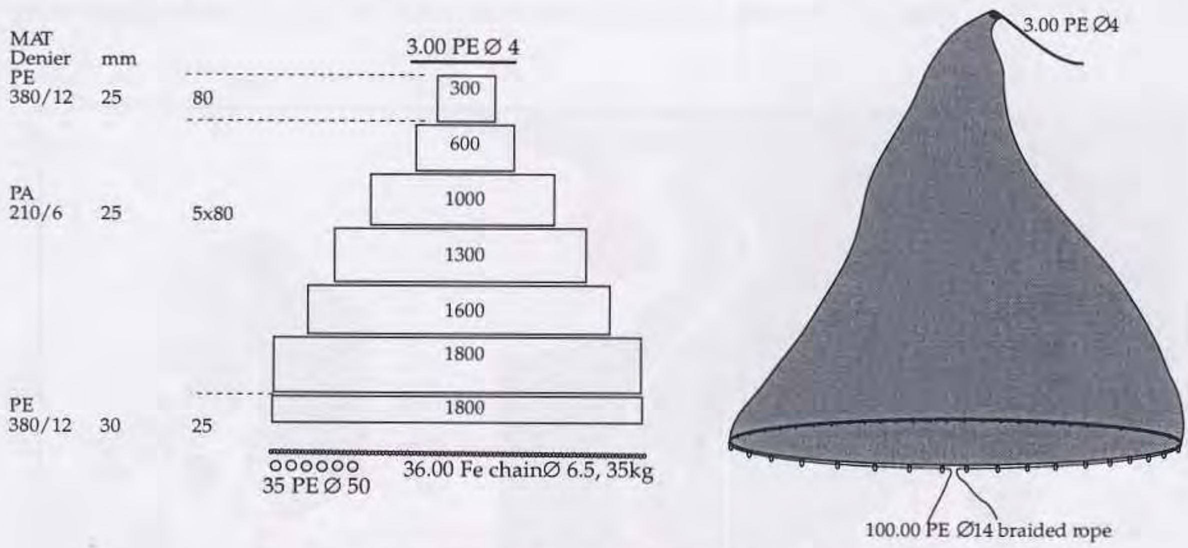


Fig. 8. Illustration of the squid cast net in Thailand.

The Philippines is an archipelago composed of more than 7,000 islands bounded in the east by the Pacific Ocean and on the west by South China Sea, in the south by the Celebes Sea and Borneo waters and in the north by Taiwanese waters. Various types of fishing gear were developed to catch cephalopods, not only trawl fishing but also purse seine fishing, seine net fishing and traps. Filipino fishermen generally use a hand-line with artificial bait for catching big fin reef squid but this operation is limited, as the distribution of the squid is not very great, then they developed bamboo pots instead to catch this squid. Trap fishing was employed to catch not only cuttlefish and big fin reef squid but was also developed for catching nautilus in some areas of Zambales and Palawan Islands.

3. Exploratory Method

3.1 Survey Areas

The surveys including squid sampling, oceanographic surveying and squid larvae collection were conducted covering the South China Sea in the Exclusive Economic Zones (EEZs) of the Western Philippines, Vietnam, East Malaysia and Brunei Darussalam. **Fig. 9** shows how the survey areas were divided into 4 areas; Area I: Western Philippines waters, Area II: Vietnamese waters, and Area III: Waters off Sabah, Sarawak (Malaysia) and Brunei Darussalam.

Area I, Western Philippines waters was covered from 11° to 20°N latitude and 117° to 121°E longitude. A total of 31 oceanographic stations and 11 squid samplings were carried out between 19 April and 10 May 1998 (**Fig. 9-1**).

Area II, Vietnamese waters was covered from latitude 7° to 21°N and longitudes 103° to 112°E. A total of 58 oceanographic stations and 10 squid samplings were

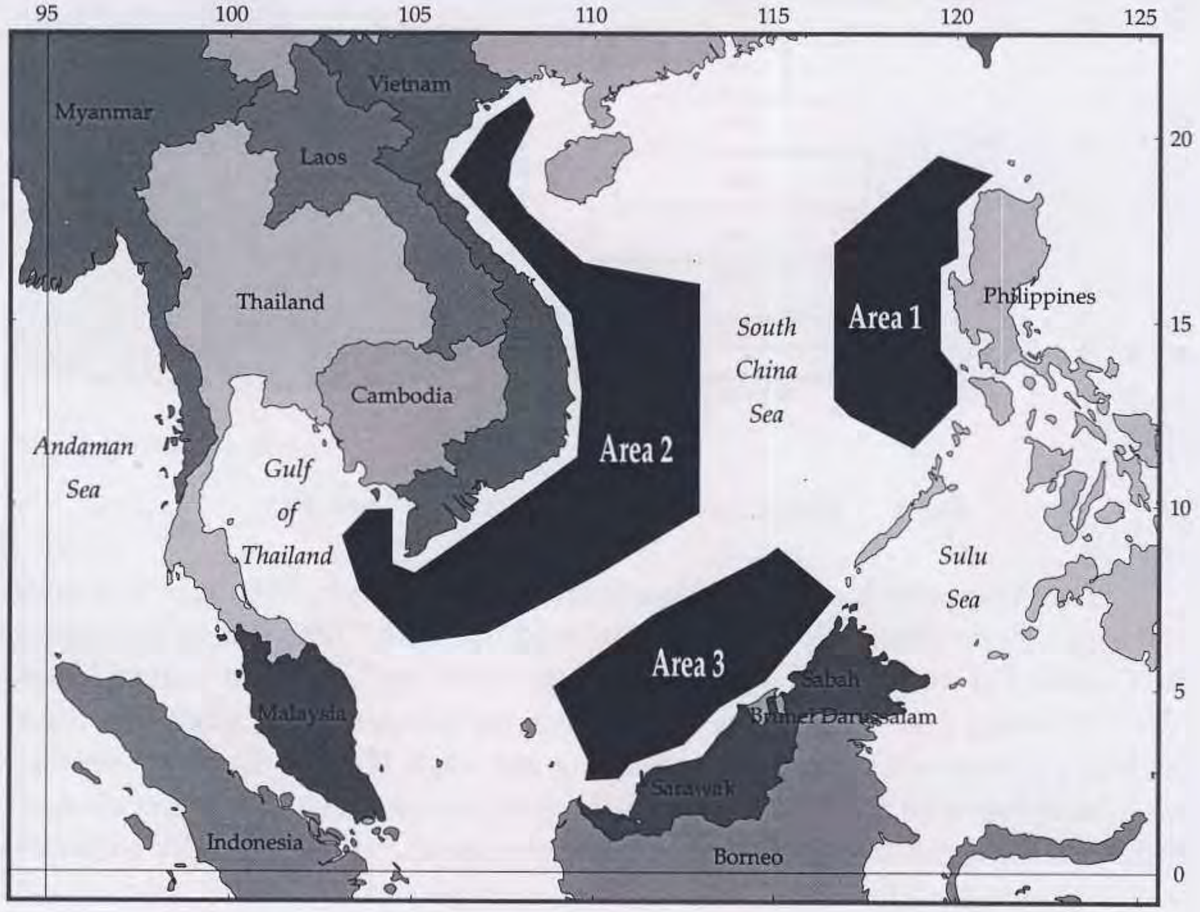


Fig. 9. Survey areas in the South China Sea during 1998-2000.

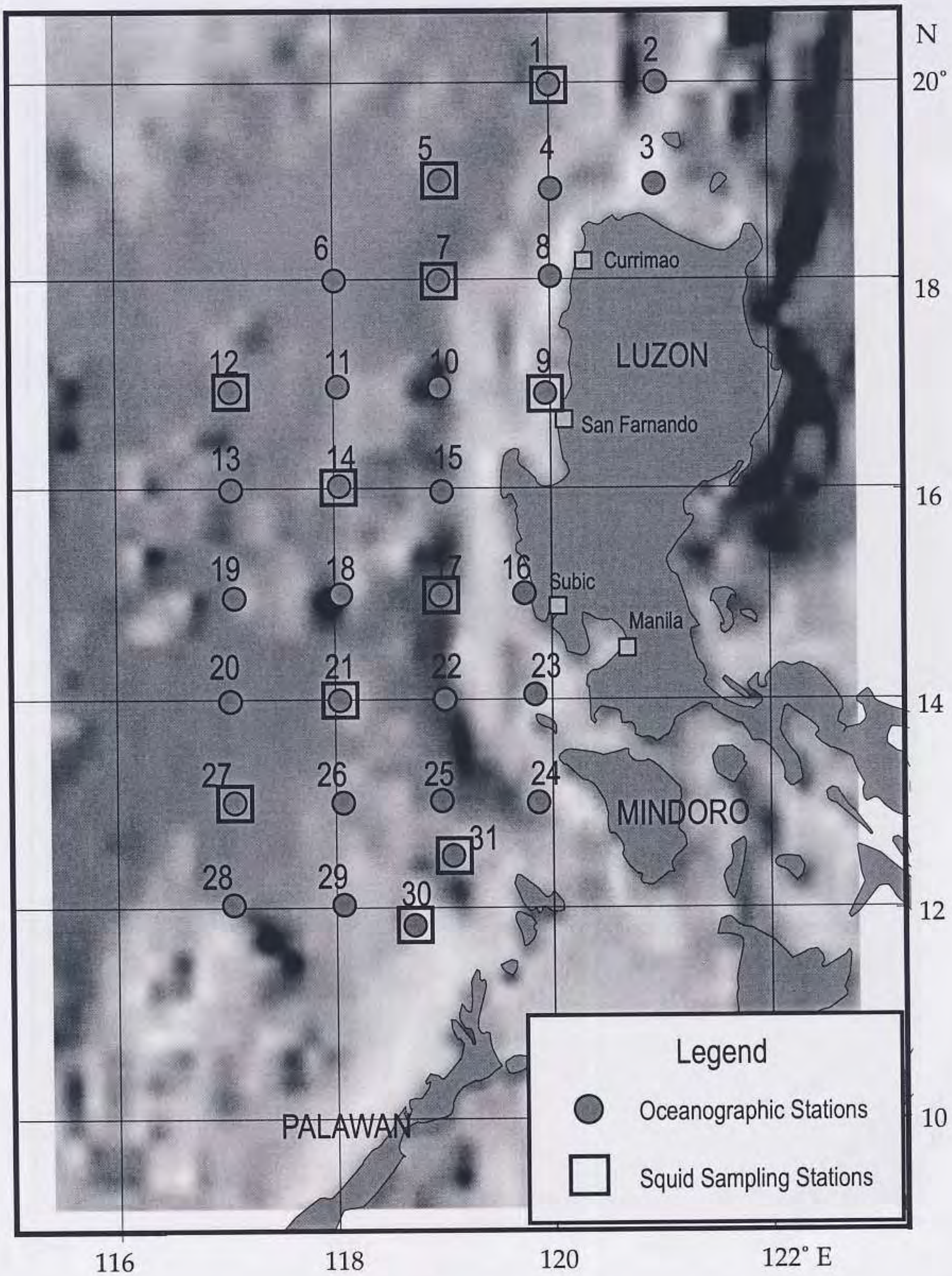


Fig. 9-1. Oceanographic and squid samplings stations of the survey areas I: Western Philippines in the South China Sea during 19 April - 10 May, 1998.

carried out between 29 April and 30 May 1999. All the squid sampling stations are located in the central part of Vietnam where the depth of water ranged from 600 to 3000 m (**Fig. 9-2**).

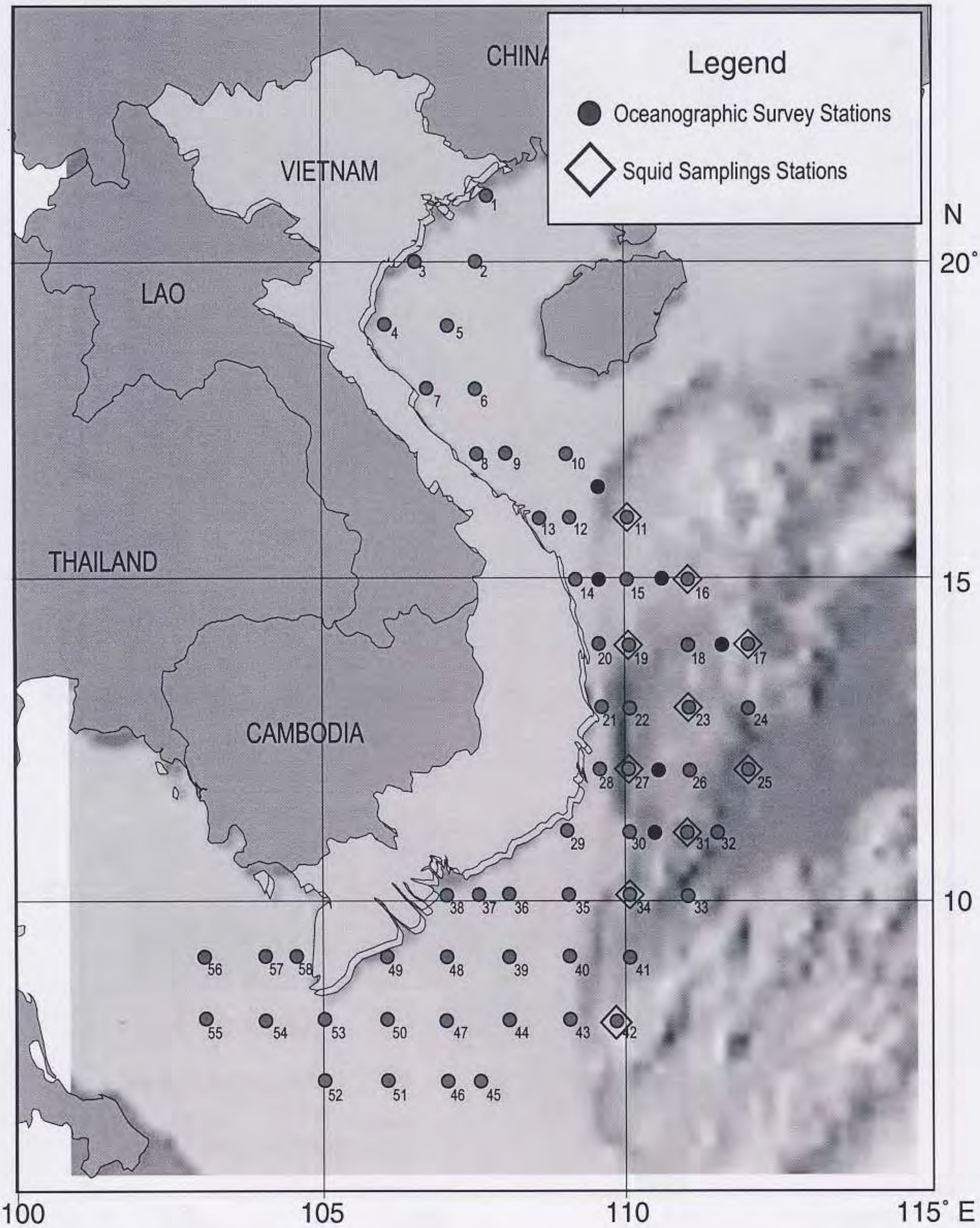


Fig. 9-2. Oceanographic and squid samplings stations of the survey areas II: Vietnamese waters in the South China Sea during 29 April - 30 May 1999.

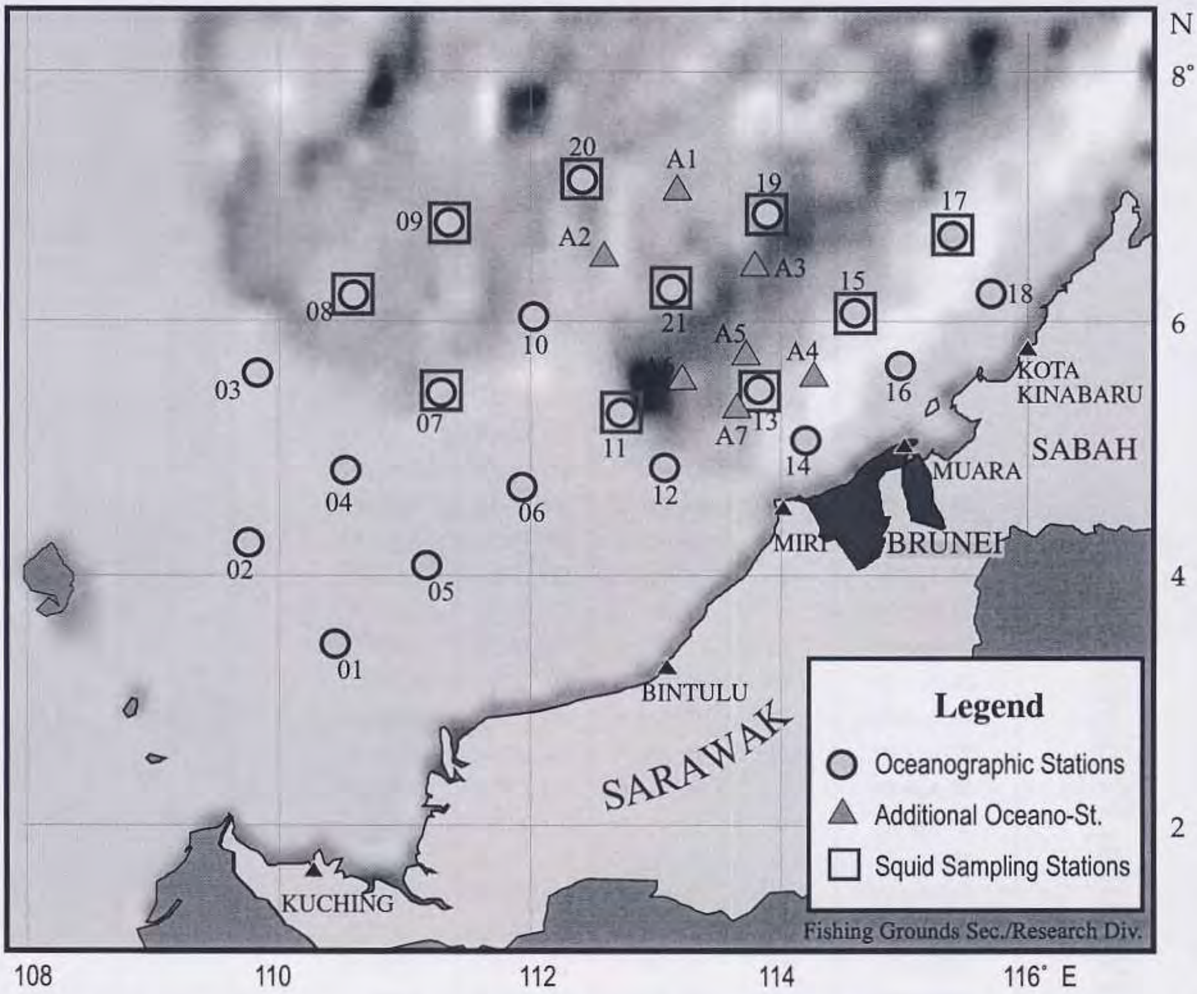


Fig. 9-2. Oceanographic and squid samplings stations of the survey areas II: Vietnamese waters in the South China Sea during 29 April - 30 May 1999.

Area 3, waters of Sabah, Sarawak (Malaysia) and Brunei Darussalam was covered from latitudes 3° to 7°N and longitudes 110° to 116°E. A total of 28 oceanographic stations and 10 squid samplings were carried out between 21 March and 2 April 2000 (**Fig. 9-3**).

Table 2 shows the number of squid samplings, oceanographic surveys and squid larvae collecting stations for each survey area in the South China Sea.

3.2 Research Vessel

The Training and Research Vessel, MV SEAFDEC was employed in this survey. Appendix 1 shows the detailed information of the MV SEAFDEC.

Table 2 Detailed information of the number of station, date and position of each squid sampling, oceanographic collection and squid larvae sampling stations in survey area1: Western Philippines, Area 2: Vietnamese waters and Area 3: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters.

Survey Area	Survey Date	Station No.	Position		Depth (m)	Activities		
			Lat. (N)	Long. (E)		Squid Jigging	Oceano-graphic	Squid lavae
Area 1: Western Philippines	19-Apr-98	1	19_59.2 N	119_58.7 E	3,620.0	√	√	√
	19-Apr-98	2	20_00.0 N	121_00.2 E	1,434.0		√	√
	20-Apr-98	3	19_01.5 N	121_00.4 E	2,565.0		√	√
	20-Apr-98	4	19_00.2 N	120_00.4 E	1,100.0		√	√
	21-Apr-98	5	19_00.2 N	120_04.0 E	3,820.0	√	√	√
	22-Apr-98	6	18_00.0 N	118_00.0 E	1,830.0		√	√
	22-Apr-98	7	18_00.3 N	119_00.2 E	1,180.0	√	√	√
	23-Apr-98	8	18_00.0 N	120_00.0 E	2,932.0		√	√
	23-Apr-98	9	17_00.0 N	120_00.0 E	1,505.0	√	√	√
	26-Apr-98	10	17_00.0 N	119_00.0 E	1,851.0		√	√
	26-Apr-98	11	17_00.0 N	118_00.0 E	3,967.0		√	√
	26-Apr-98	12	17_00.0 N	117_00.0 E	4,031.0	√	√	√
	27-Apr-98	13	16_00.3 N	117_00.6 E	4,113.0		√	√
	28-Apr-98	14	16_00.4 N	118_00.7 E	4,041.0	√	√	√
	29-Apr-98	15	16_01.3 N	119_00.35 E	3,646.0		√	√
	29-Apr-98	16	15_01.3 N	120_00.4 E	59.0		√	√
	30-Apr-98	17	15_00.4 N	118_57.4 E	4,559.0	√	√	√
	30-Apr-98	18	15_00.0 N	117_59.9 E	937.0		√	√
	1-May-98	19	14_59.6 N	116_59.3 E	1,206.0		√	√
	1-May-98	20	14_00.2 N	116_59.5 E	1,674.0		√	√
	2-May-98	21	14_04.2 N	117_57.7 E	1,777.0	√	√	√
	2-May-98	22	14_00.3 N	118_59.9 E	1,800.0		√	√
	3-May-98	23	14_01.6 N	119_59.9 E	2,185.0		√	√
	5-May-98	24	13_00.7 N	119_58.6 E	710.0		√	√
	6-May-98	25	12_59.8 N	118_59.0 E	440.0		√	√
	6-May-98	26	13_00.2 N	117_58.9 E	822.0		√	√
	6-May-98	27	13_01.3 N	116_59.1 E	1,672.0	√	√	√
	7-May-98	28	12_00.34 N	116_59.6 E	3,810.0		√	√
	8-May-98	29	12_01.6 N	118_00.0 E	1,143.0		√	√
	9-May-98	30	11_59.9 N	118_45.6 E	1,922.0	√	√	√
	10-May-98	31	11_13.5 N	118_03.1 E	544.0	√	√	√
Area 2: Vietnamese Waters	30-Apr-99	1	21_00.0 N	107_55.0 E	34.0		√	√
	30-Apr-99	2	20_00.0 N	107_29.9 E	29.0		√	√
	30-Apr-99	3	19_59.9 N	106_29.3 E	28.0		√	√
	1-May-99	4	19_00.2 N	105_59.5 E	26.5		√	√
	1-May-99	5	19_00.0 N	107_00.7 E	58.0		√	√
	1-May-99	6	17_59.8 N	107_29.7 E	80.0		√	√
	1-May-99	7	17_59.8 N	106_39.9 E	40.0		√	√
	2-May-99	8	17_00.0 N	107_29.9 E	45.0		√	√
	2-May-99	9	16_35.0 N	108_00.7 E	75.0		√	√

Table 2 Detailed information (continued)

Survey Area	Survey Date	Station No.	Position		Depth (m)	Activities		
			Lat. (N)	Long. (E)		Squid Jigging	Oceano-graphic	Squid lavae
	2-May-99	10	17_00.3 N	109_00.1 E	107.0		√	√
	3-May-99	11	16_01.4 N	109_58.0 E	847.0	√	√	√
	3-May-99	12	16_00.4 N	108_59.9 E	105.0		√	√
	4-May-99	13	16_00.6 N	108_30.6 E	42.0		√	√
Continue	6-May-99	14	14_59.7 N	109.00.6 E	36.0		√	√
	6-May-99	15	15_00.4 N	110_00.3 E	426.0		√	√
Area 2	7-May-99	16	15_02.5 E	110_58.8 E	1,230.0	√	√	√
	8-May-99	17	14.06.5 N	111_56.5 E	2,100.0	√	√	√
	8-May-99	18	14_00.1 N	111_00.0 E	2,200.0		√	√
	9-May-99	19	14_10.7 N	109_58.9 E	653.0	√	√	√
	10-May-99	20	13_59.9 N	109_29.1 E	143.0		√	√
	10-May-99	21	13_00.2 N	109_30.0 E	134.0		√	√
	10-May-99	22	12_59.7 N	109_59.2 E	1,910.0		√	√
	11-May-99	23	12_55.3 N	111_00.3 E	2,703.0	√	√	√
	12-May-99	24	13_00.0 N	111_59.5 E	3,332.0		√	√
	12-May-99	25	12_00.1 N	111_59.5 E	4,117.0	√	√	√
	13-May-99	26	12_00.2 N	111_00.0 E	2,889.0		√	√
	14-May-99	27	11_46.2 N	109_56.1 E	1,734.0	√	√	√
Vietnamese Waters	14-May-99	28	11_59.0 N	109_25.1 E	110.0		√	√
	17-May-99	29	11_00.2 N	108_59.9 E	72.0		√	√
	18-May-99	30	11_00.0 N	110_00.7 E	648.0		√	√
	18-May-99	31	10_59.7 N	111_01.0 E	2,940.0	√	√	√
	19-May-99	32	10_59.7 N	111_30.3 E	3,897.0		√	√
	22-May-99	33	09_59.9 N	111_00.1 E	3,385.0		√	√
	21-May-99	34	09_59.9 N	110_00.3 E	1,614.0	√	√	√
	21-May-99	35	09_59.7 N	109_10.7 E	156.0		√	√
	20-May-99	36	10_00.2 N	108_00.7 E	45.5		√	√
	20-May-99	37	09_59.6 N	107_29.6 E	32.0		√	√
	20-May-99	38	10_00.4 N	106_59.2 E	22.0		√	√
	23-May-99	39	08_59.8 N	107_59.9 E	62.0		√	√
	23-May-99	40	09_00.2 N	108_59.5 E	129.0		√	√
	22-May-99	41	09_00.7 N	110_00.0 E	1,967.0		√	√
	26-May-99	42	08_01.2 N	109_49.9 E	628.0	√	√	√
	25-May-99	43	08_00.1 N	109_00.4 E	147.0		√	√
	25-May-99	44	07_59.7 N	108_00.6 E	79.0		√	√
	26-May-99	45	06_59.7 N	107_30.5 E	61.0		√	√
	27-May-99	46	06_59.9 N	107_00.4 E	51.0		√	√
	24-May-99	47	07_59.6 N	107_00.4 E	42.0		√	√
	23-May-99	48	08_59.9 N	106_59.6 E	33.0		√	√
	24-May-99	49	09_00.3 N	106_00.5 E	20.0		√	√
	24-May-99	50	08_00.0 N	106_00.0 E	33.0		√	√

Table 2 Detailed information (continued)

Survey Area	Survey Date	Station No.	Position		Depth (m)	Activities		
			Lat. (N)	Long. (E)		Squid Jigging	Oceano-graphic	Squid lavae
	27-May-99	51	06_59.9	105_59.9 E	44.0		√	√
	27-May-99	52	06_59.4 N	104_59.6 E	51.0		√	√
	27-May-99	53	07_59.7 N	105_00.7 E	34.0		√	√
	28-May-99	54	07_59.7 N	104_00.2 E	26.0		√	√
	28-May-99	55	07_59.6 N	103_00.3 E	70.0		√	√
	28-May-99	56	08_59.6 N	102_59.7 E	57.0		√	√
	29-May-99	57	09_00.4 N	104_00.0 E	34.0		√	√
	29-May-99	58	09_00.1 N	104_30.5 E	23.5		√	√
Area 3 Waters off Sabah, Sarawak (Malaysia) and Brunei Darussalam	21-Mar-00	01	03_44.18 N	110_42.45 E	65.0		√	√
	21-Mar-00	02	04_13.12 N	109_46.98 E	100.0		√	√
	21-Mar-00	03	05_56.72 N	109_56.80 E	145.0		√	√
	22-Mar-00	04	04_47.08 N	110_51.20 E	117.0		√	√
	22-Mar-00	05	04_02.58 N	111_17.90 E	71.0		√	√
	23-Mar-00	06	04_59.53 N	111_56.60 E	88.0		√	√
	23-Mar-00	07	05_45.27 N	111_29.45 E	452.0	√	√	√
	24-Mar-00	08	06_21.73 N	110_53.33 E	1,237.0	√	√	√
	25-Mar-00	09	06_55.02 N	111_37.63 E	1,880.0	√	√	√
	26-Mar-00	10	06_02.77 N	111_02.12 E	1,560.0		√	√
	26-Mar-00	11	05_25.17 N	113_01.25 E	1,257.0	√	√	√
	27-Mar-00	12	05_07.95 N	113_04.12 E	130.0		√	√
	27-Mar-00	13	05_32.65 N	113_48.57 E	2,150.0	√	√	√
	28-Mar-00	14	05_26.60 N	114_17.07 E	150.0		√	√
	28-Mar-00	15	06_16.94 N	114_32.80 E	1,975.0	√	√	√
	29-Mar-00	16	05_56.20 N	114_52.00 E	177.0		√	√
	29-Mar-00	17	06_56.51 N	115_17.87 E	1,516.0	√	√	√
	30-Mar-00	18	06_49.45 N	115_42.27 E	228.0		√	√
	30-Mar-00	19	07_03.25 N	113_52.17 E	1,836.0	√	√	√
	31-Mar-00	A1	07_08.98N	113_07.27E	1,436.0		√	√
	01-Apr-00	20	07_06.74 N	112_24.15 E	2,003.0	√	√	√
	1-Apr-00	A2	06_28.72N	112_28.12E	1,338.0		√	√
	02-Apr-00	21	06_19.83 N	113_06.10 E	1,592.0	√	√	√
	02-Apr-00	A3	06_28.45N	113_47.04E	1,202.0		√	√
	05-Apr-00	A4	05_37.57 N	114_15.91 E	810.0		√	√
	06-Apr-00	A5	05_41.23 N	113_47.85 E	2,188.0		√	√
	06-Apr-00	A6	05_37.55 N	113_07.26 E	800.0		√	√
	07-Apr-00	A7	05_19.38N	113_39.48E	1,639.0		√	√

3.3 Fishing Gear

Squid samples were collected by the automatic squid jigging machine: SE-88, Sanmei, Co. Ltd. A total of 4 automatic squid jigging machines consisting of eight main lines were installed on the port side. Each machine was set 3-4 m apart from each other. The main line of stainless wire #39 (7x7), was attached to a series of 25 typical Japanese squid jigs spaced approximately 1m apart by nylon monofilament leaders (30, 40 and 50 lb test) as shown in **Fig. 10** and **11**.

The squid jigs used in this study were of 5 colours of CR15-New Kaio hook including fluorescent purple, green, blue, light green and pink. At the end of the jig line a cast iron sinker of 1,250g was attached by 8m of nylon monofilament leader. Jigs and main line were lowered to the desired depth ranging from 50 to 200m and the line moved up and down at a speed of about 1.0 m/s in a slow jigging motion until a squid was hooked and brought to the deck.

The squid samplings were generally started after sunset until the around 03:00 am in the morning of the next day depending upon the sea condition.

No sea anchor was used during the fishing operation. Angling depth layers where squid were caught were also recorded.

3.4 Light System

500 W attracting lights were suspended around 1.0m inboard and 5.0m above the machine and were spaced 70-80 cm apart down the length of the port side of the vessel where the machines were installed. 54 bulbs or a total of 27kW were used (**Fig. 12**).

3.5 Data Collection

3.5.1 Catch and Effort

Catch and effort data were collected at each fishing station. Target species caught were counted and if not all weighted, a sub-sample was weighed and counted to extrapolate the total catch weight at each station. Effort was recorded in line hours, calculated by multiplying the number of lines actively fishing by the length of time in use.

Catch per Unit Effort (CPUE: the number of squids per line-hour) is used as an index of abundance for a fishing ground. The number of squid lost for a given period

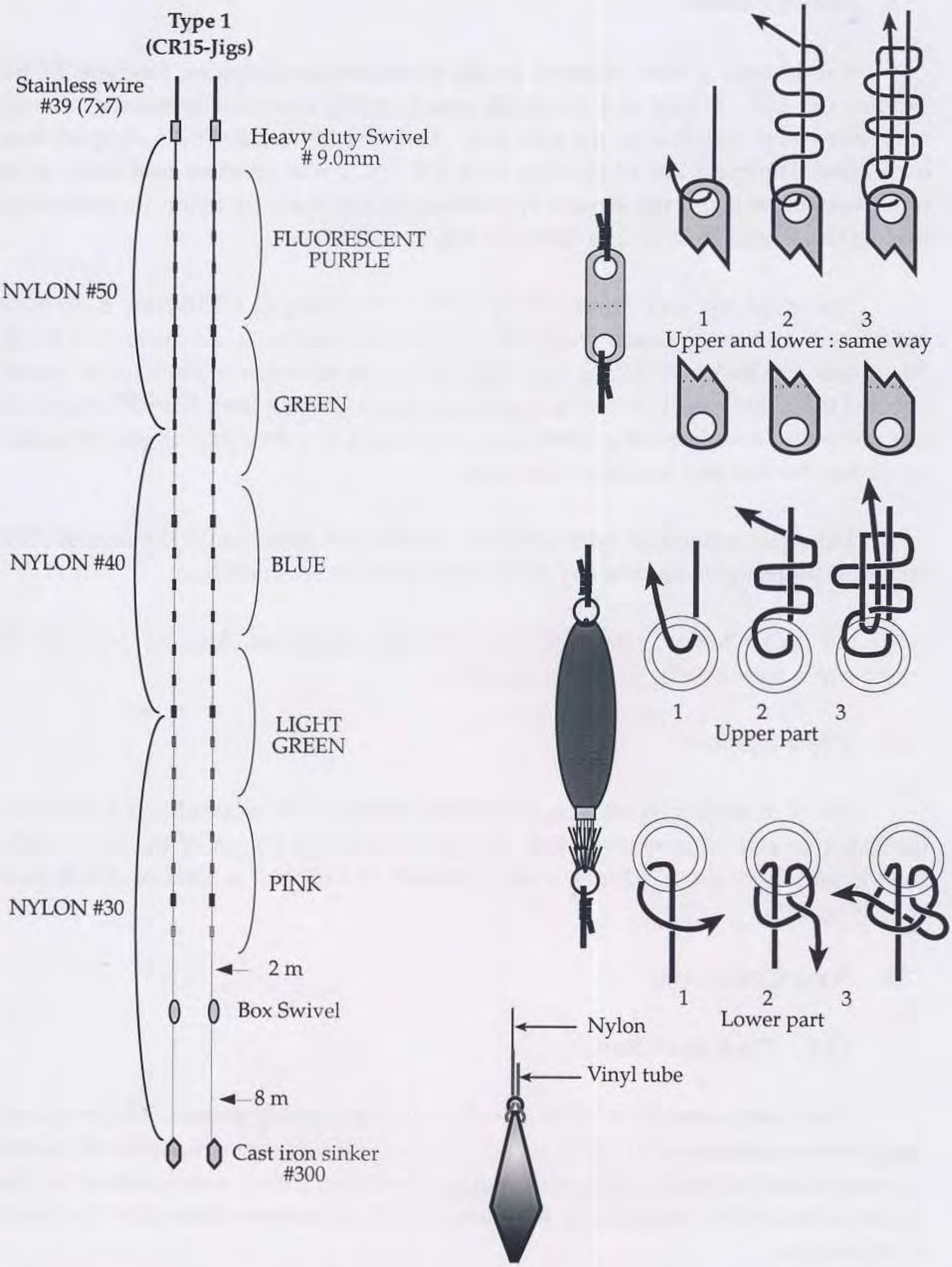
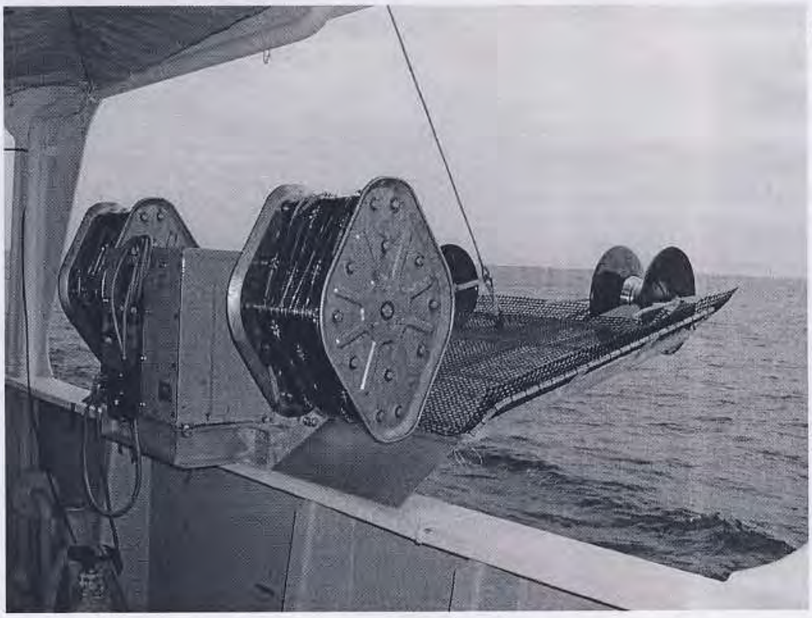


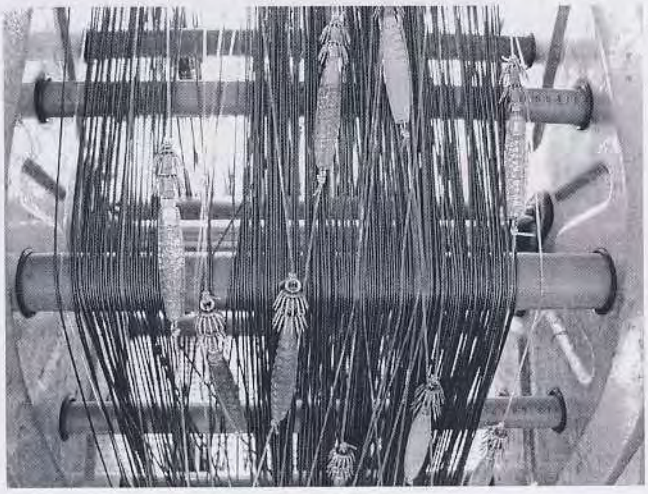
Fig. 10. Illustration of jig line used with the automatic squid jigging machine for this survey.

a)



b)

c)



d)

Fig. 11. Automatic squid jigging gear used to collect the oceanic squid: a) The automatic squid jigging machine installed at port side of MV SEAFDEC, b) 1,250g cast-iron sinker, c) a reel of the jigging machine consisted of main line and jigs, d) type of jig cases with 5 different colors.

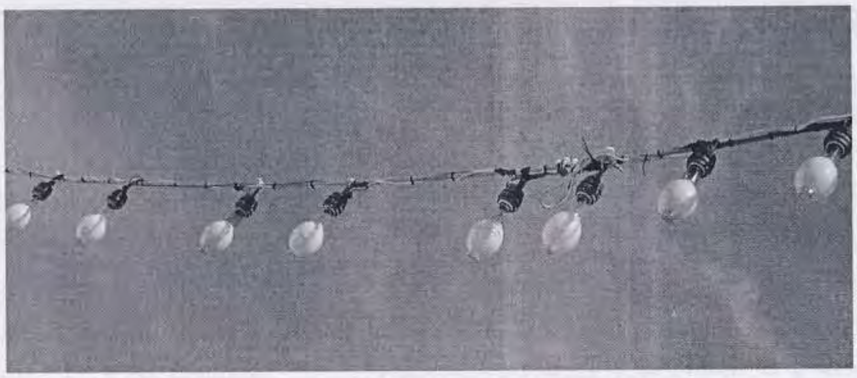


Fig. 12. Luring lamps of 500 W bulb each setting above the machine inside the vessel.

because of drop-off was also observed.

3.5.2 Biological Features

The biological features of the squid were measured. Length frequencies (mantle length) were recorded in millimeters and weight in grams, Length and weight data were transformed with a log transformation and length-weight relationships calculated using a least square regression method.

The sex of squid was identified by the characteristics of the 4th arm of the squid.

3.5.3 Specimens for Systematic Study

In order to accomplish the systematics of the purpleback flying squid, some collected squid were preserved in 10% neutralized formalin. Not all squid were relaxed or killed prior to preservation as they were dead after capture. The fixed-specimens were later transferred to 75% ethyl alcohol for permanent storage. All specimens were examined, and measurements, body proportions, counts and indices were obtained from the whole body as described by Roper & Voss (1983). Measurements are in millimeters (mm). Indices are expressed as percentages of dorsal mantle length and are denoted by the final initial I, e.g. HWI = HW/ML x 100. The diagram and summary of the measurements, counts and indices are shown in **Fig. 13** and **Table 3.** The buccal mass was removed from some specimens and the beaks and radulae extracted, cleaned, and illustrated. The beaks, radulae and spermatophores were drawn with the aid of a camera lucida. The enlargement section of the spermatophores and most of the radulae were stained with methylene blue to get higher contrast during examination and illustration in the compound microscope.

3.5.4 Cephalopod Paralarvae

Cephalopod paralarvae were collected using 0.33 mm mesh net attached to 60 cm diameter bongo frames (Fig. 14). A flowmeter, attached within the aperture of the net, measured the amount of water filtered. At each station, a 30 minute oblique tow of the bongo net was made with a ship's speed of about 2 knots. The depth of the haul was 60 meters below the sea surface. Samples were preserved in 10 % buffered formalin-seawater immediately. In the laboratory, cephalopod paralarvae were sorted and identified to genus level. The classification of cephalopod paralarvae was based on Kubodera and Okutani (1981), Okutani (1966 and 1968), Okutani and Mc Gowan (1969), Sweeney *et al* (1992), Tsuchiya *et al.* (1991), Yamamoto and Okutani (1975) and Young and Harman (1985).

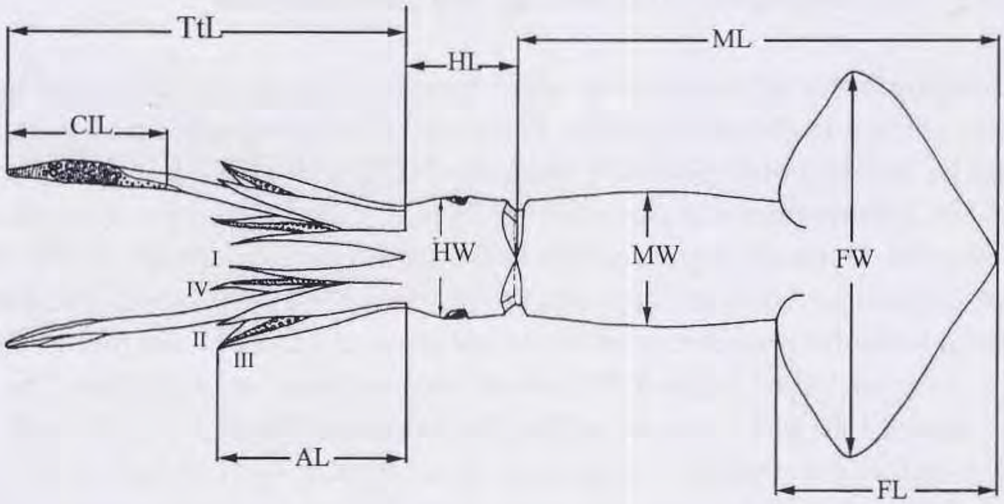


Fig. 13. Diagrammatic illustrations of the measurements of squids. Dorsal view, AL= Arm Length, ClL=Club Length, FL=Fin Length, FW=Fin Width, HL=Head Length, HW=Head Width, ML=Mantle Length, MW=Mantle Width, I=dorsal arm, II=dorso-lateral arm, III=ventro-lateral arm, IV=ventral arm, TtL=Tentacular Length

Table 3 Definition of counts, measurements and indices.

ML	Mantle Length	Dorsal mantle length measured from the anterior most point of the mantle to the posterior tip.
MWI	Mantle Width Index	Greatest straight-line (dorsal width of mantle as a percentage of mantle length).
FLI	Fin Length Index	Greatest length of fins as a percentage of mantle length.
FWI	Fin Width Index	Greatest width (dorsally) across both fins as a percentage of mantle length.
HWI	Head Width Index	Greatest width of head at level of eyes as a % of mantle length.
HLI	Head Length Index	Dorsal length of head measured from point of fusion of dorsal arms to anterior tip of nuchal locking-cartilage as a percentage of mantle length.
ALI	Arm Length Index	Length of each designated arm (I, II, III, IV) measured from first basal (proximal most) sucker to the tip of arm as a percentage of mantle length.
TtLI	Tentacle Length Index	Total length of tentacular stalk and club as a percentage of mantle length.
ClLI	Club Length Index	Length of designated club as a percentage of mantle length.

3.5.5 Oceanographic Measurement and Data Analysis

Oceanographic characteristics were measured to clarify the oceanographic features in relation to the catch results. The physical oceanographic parameters were measured by the Falmouth Scientific Integrated CTD unit [ICTD], using a sampling rate of 25 Hz. Temperature was corrected to ITS 90 standard. Salinity was calculated by the PSS 78 scale. Dynamic depth relative to the surface was computed by the EG & G CTD Post-acquisitive Analysis Software at every dbar pressure interval. The dissolved carbonate in seawater was calculated from total alkalinity and pH was measured using the in situ sensor attached to the ICTD [It was later measured onboard using the Fisher Scientific model 1002 pH meter, when the pH sensor malfunctioned]. Total alkalinity was measured as the capacity of seawater to neutralize hydrochloric acid and the saturation level of seawater was calculated from the ratio between actual carbonate concentration and its concentration at equilibrium. Continuous oxygen profiles at each station were obtained using the Beckman Polarographic electrode connected to the ICTD unit and the raw data was averaged at every dbar pressure level (The data was calibrated at some stations by the Winkler titration method).

Water transparency and sea color were measured by Sechi disc in units of a meter and the Forel scale at daytime stations, respectively.

The horizontal distribution of the temperature, salinity, chlorophyll and fluorescence value at the sea surface were plotted in relation to the catch results. Horizontal distribution of each oceanographic parameter are based on the measurements at the 10m depth layer, not the values at the sea surface to avoid meteorological disturbance.

The vertical distribution and profile of the temperature were plotted along the longitude for north-south direction and along the latitude for the west-east direction. In each survey area, the vertical distribution of temperature was prepared as shown in the Appendix 3.

All of the vertical distributions and profiles and the horizontal distributions of each oceanographic parameter were analyzed and plotted by a data processing application "Transform" version 3.4 (Fortner Software).

Light intensity in the water column was measured by Quantum Light Sensor for both in-water and in-air at the daytime stations. These data were recorded by Data Logger IL1000. The intensity of light at the sea surface (I_0) was used to estimate light intensity at a desired depth (I_z), from the following equation (Jerlov 1976):

a)

b)

Fig. 14. Bongo net (a) and its operation at the sea surface (b) used for collecting the cephalopod paralarvae in this survey

$$I_z = I_0 \exp(-kz)$$

where k is the attenuation coefficient (m^{-1})

From this equation the ambient light at angling depth where squid living can be solved in order to recalculate to the depth whereas the squid exist during the day time. Regarding this knowledge, if it is true, the squid jigging operation can be modified and made during the day time the same as the Japanese common squid fisheries in Japan, which are operated both in day and at night.

Environmental factors such as wind, current, and other navigational data were observed.

In spite of sufficient depth with virtually the same sea conditions, the number of catch differed according to date. This is believed to be because of the lunar effects. The phases of the Moon during the fish sampling date were recorded to examine how the relationship between the catch and the percentage of illumination from the moon. The percentage of moon illumination depended upon the phase of the moon and can be calculated from a Freeware "Moon Tool" version 1.01 developed by Richard Knuckey, 1994 without consideration of the sea condition and effect from cloud.

4. Results

4.1 Systematics of *Sthenoteuthis oualaniensis*

Sthenoteuthis oualaniensis (Lesson, 1830) **Fig.15, Table 4A-B**.

Loligo oualaniensis –Lesson, 1830: 240, pl. I, fig.2.

Ommastrephes oualaniensis –Steenstrup, 1880: 76

Symplectoteuthis oualaniensis –Pfeffer, 1900:180; -Pfeffer, 1912: 502, pl. 40-41, 42, figs.1-4; -Sasaki, 1929: 296, pl. xxx, fig.8, textfigs. 176-178; -Adam, 1954: 157; -Voss, 1963:134, fig. 29; -Voss & Williamson, 1971:74, pl. 23, figs. 20,27,30; -Roper *et al.*, 1984:180;

Sthenoteuthis oualaniensis –Zuev *et al.*, 1975:1475; -Nateewathana 1997: 453-464, figs. 2-5.

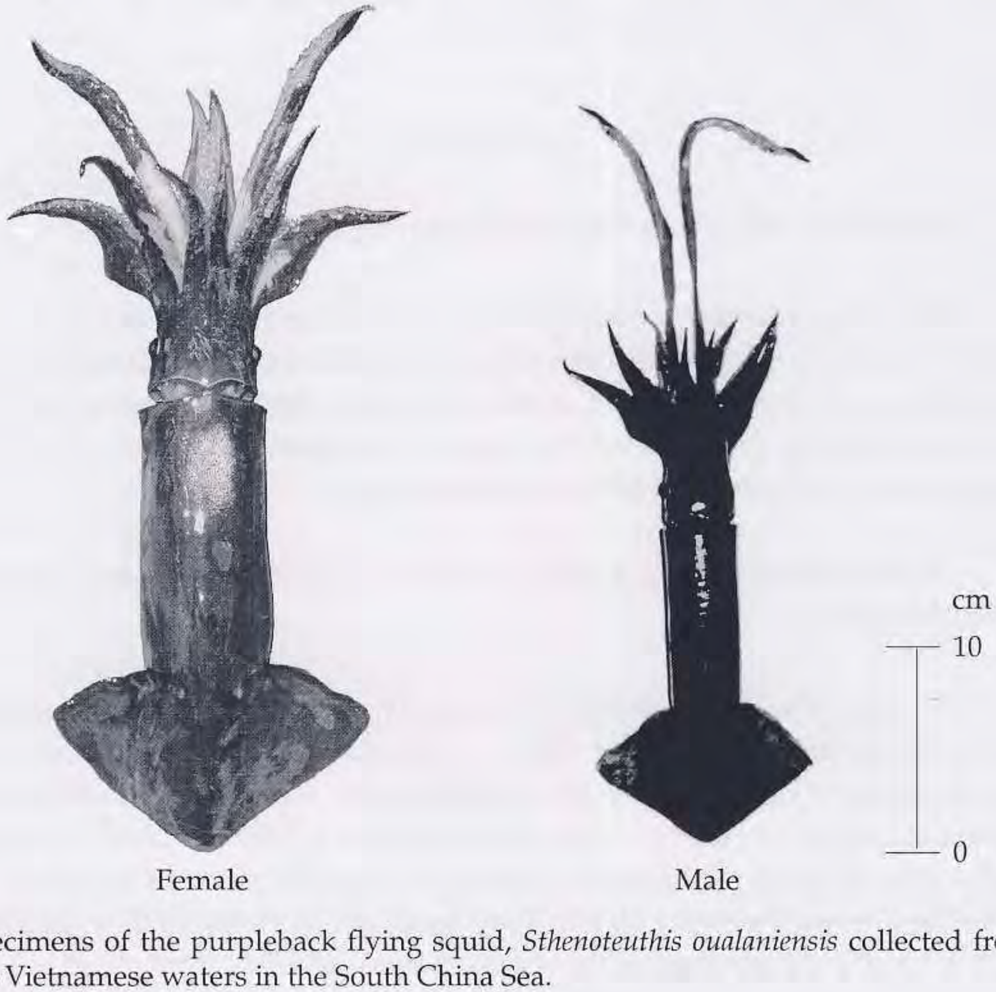


Fig. 15. Specimens of the purpleback flying squid, *Sthenoteuthis oualaniensis* collected from the Vietnamese waters in the South China Sea.

Table 4A Means, standard deviations and ranges of selected measurements and indices (in percent) of Sthenoteuthis oualaniensis. in the Area 1, Station no. 12. Lat. 16° 59.8N, Long. 117° 04.7E. Auto squid jigging, angling depth 100 m, time 1915-0130 hrs, surface temperature 27.8°C, M.V. SEAFDEC 25 April 1998, total catch in weight 100.299 kg and in number 739 pcs.

	MALES				FEMALES			
Index	N	mean	S.D. (n-1)	Range	n	mean	S.D. (n-1)	Range
ML (mm)	6	131.4	3.8	124.0-135.0	6	192.5	15.1	179.0-216.0
MWI	6	20.2	0.7	19.1-21.2	6	23.3	1.6	21.8-25.7
HLI	6	20.4	1.8	17.8-22.4	6	20.1	2.6	16.1-24.0
HWI	6	20.1	1.6	17.5-22.3	6	20.5	1.7	18.0-23.2
FLI	6	39	1.6	37.2-41.7	6	36.6	7.7	21.0-40.2
FWI	6	73	4.2	66.9-78.2	6	70.5	2.1	67.1-73.3
ALII	6	33.1	3.6	28.5-37.5	6	34.8	2.1	32.2-37.0
ALIII	6	36.7	2.1	34.6-40.7	6	38.9	3.5	33.6-43.7
ALIIII	6	37.5	3.3	32.1-41.5	6	41.1	2.2	37.0-43.3
ALIVI	6	37.6	1.6	36.0-40.3	6	41	2.5	37.0-44.3
TtLI	6	70.8	11.3	61.6-90.3	6	89.5	17.6	74.1-122.1
ClLI	6	27.1	1.9	23.3-28.6	6	35.4	2.8	30.2-37.9

Table 4B Means, standard deviations and ranges of selected measurements and indices (in percent) of Sthenoteuthis oualaniensis. in the Area 2, Station no. 16. Lat. 15° 02.5N, Long. 110° 58.8E. Auto squid jigging, angling depth 100 m, time 2015-0230 hrs, surface temperature 28.3°C, M.V. SEAFDEC, 7 May 1999, total catch in weight 52.59 kg and in number 492 pcs.

	MALES				FEMALES			
Index	N	mean	S.D. (n-1)	Range	n	mean	S.D. (n-1)	Range
ML (mm)	6	122.1	8	110.7-129.8	5	115.5	12.1	104.7-131.1
MWI	6	20.4	1	19.5-22.4	5	23.1	2.4	19.8-25.5
HLI	6	20.1	2.2	17.2-22.9	5	21.5	0.9	20.1-22.4
HWI	6	20.7	0.4	18.5-24.0	5	19.7	1.4	18.2-21.7
FLI	6	44.1	1	42.9-45.8	5	44.7	2.1	41.2-46.4
FWI	6	75	4.2	70.6-80.8	5	76.1	13.4	64.6-98.3
ALII	6	34	3.3	30.1-39.0	5	31.5	3.4	26.2-34.9
ALIII	6	37.6	1.5	36.0-39.7	5	37.7	1.1	36.8-39.4
ALIIII	6	41.3	1.6	39.0-43.4	5	40	3	36.3-44.5
ALIVI	6	38.5	1.5	37.0-41.3	5	38.9	3.1	35.5-43.8
TtLI	6	82.2	12	66.1-94.7	5	76.9	10.9	69.1-95.4
ClLI	6	32	1.5	29.8-34.0	5	28.8	2.8	25.8-32.5

4.1.1 Material Examined

Of the total of 4,251 specimens caught during the survey period from 1998-2000 in the South China Sea, there were 2,592 specimens from survey area I :Western Philippines, 1,412 specimens from survey area II: Vietnamese waters, and 253 specimens from survey area III: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters. Only 5-6 specimens were collected for identification from each squid sampling station in the Survey areas I and II. Data at the squid abundance station of survey Areas I and II are presented in **Table 3**.

4.1.2 Description

The Mantle (**Fig. 16A-a**) is long, slender, cylindrical, muscular, and tapering abruptly from the anterior margin of the fins to a sharp pointed end (**Fig. 16A-b**); the median antero-dorsal lobe is low rounded with the ventral mantle margin slightly concave below the funnel. Fin terminals, rather large, rhombic, occupying about 42-45% of the mantle length; anterior margins slightly convex; lateral margins pointed; posterior margins straight, continuous to the apex of mantle. Head large, as wide as the mantle, sharply set off from the neck by a transverse ridge; each side of the head has three nuchal folds connected to the transverse ridge (**Fig. 16B-a**). Eyes (encircled by a free eyelid, forming a rounded triangle, truncated posteriorly and with a sharp narrow anterior sinus (**Fig. 16B-a**). The Funnel is large, compact and set in a deep pit on the ventral side of the head; the funnel valve is large and well-developed; the dorsal funnel organ is large and of an inverted v-shape; the ventral pads are an elongate, oval shape; foveola (**Fig. 16B-b**) with 7-9 longitudinal folds in the central pocket and 3-5 lateral pockets on each side. The Funnel locking apparatus is an inverted T-shape and fused in its middle portion with the mantle groove (**Fig. 16B-c**).

The arms are moderately long, stout with pointed tips, unequal in order of III. II. IV. I. Arms are compressed with a sharp keel along the edges. Arm III is triangular, broad, strongly keeled on the proximal half of arm. Protective membranes are well developed with prominent trabeculae. Biserial suckers are present in all arms; arm suckers are rounded with about 12 sharp teeth laterally and distally, of which the median is largest (**Fig. 16B-d**). The left Arm IV of the males is hectocotylized (**Fig. 16C-a**), enlarged and thicker than the other arms; proximal half of arm with 12 suckers arranged in two longitudinal rows bordered by a heavy flap-like modification of the supports of the protective membrane; a series of pits in a single row are present along the base of protective membrane on each side of the proximal part of the arm (**Fig. 16C-b**); the distal arm is devoid of suckers and papillae.

The Tentacles are moderately long, stout, laterally compressed, and with elongated clubs (**Fig. 16C-c**). The protective membranes are slightly expanded on the

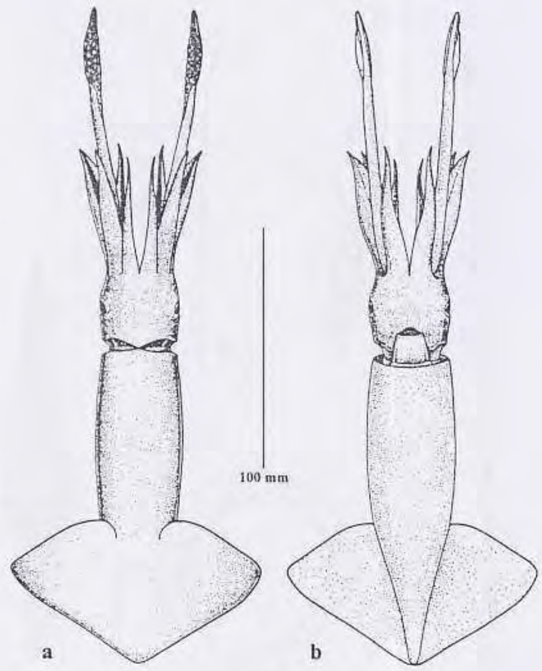


Fig. 16A. *Sthenoteuthis oualaniensis*: a) dorsal view and b) ventral view.

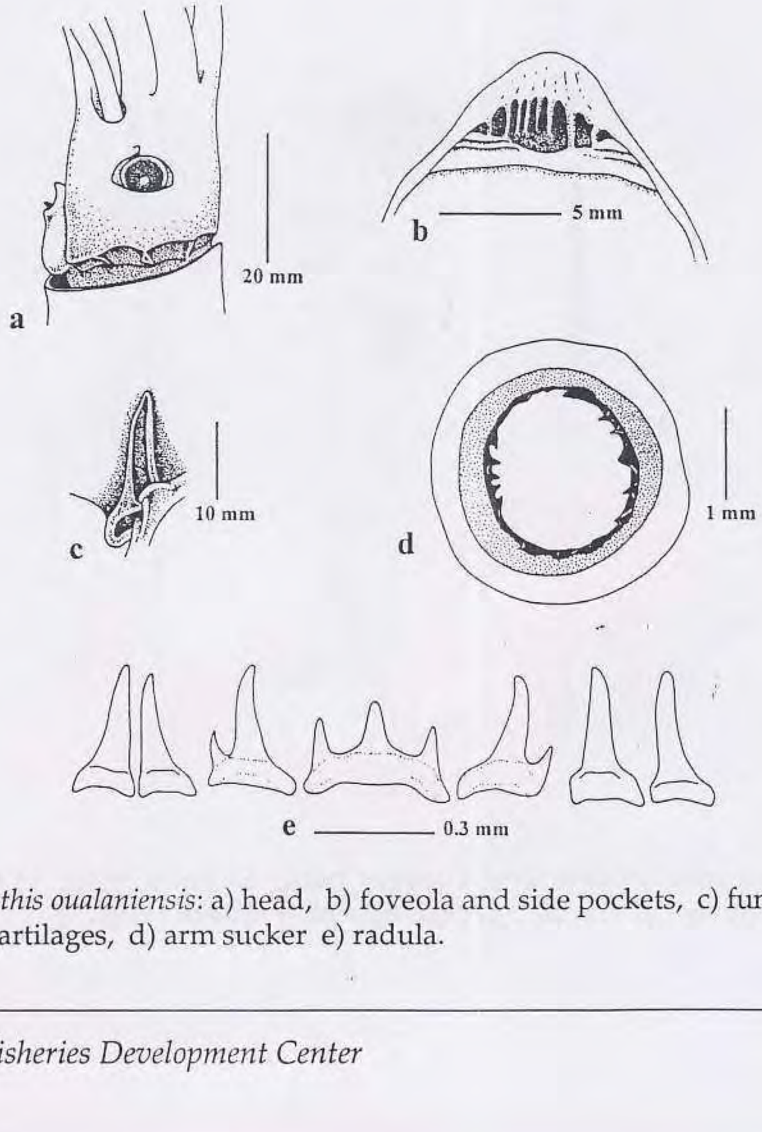


Fig. 16B. *Sthenoteuthis oualaniensis*: a) head, b) foveola and side pockets, c) funnel and mantle locking cartilages, d) arm sucker e) radula.

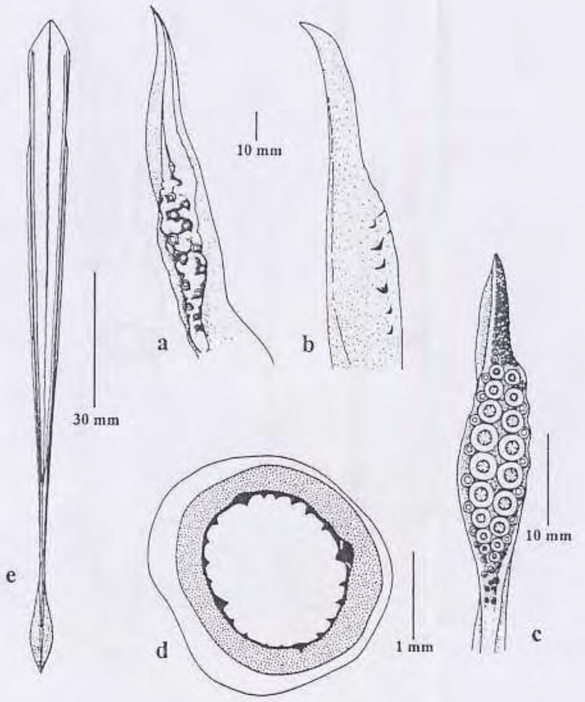


Fig. 16C. *Sthenoteuthis oualaniensis*: a) hectocotylised arm, b) lateral view of hectocotylised arm showing a series of pits, c) tentacular club, d) club sucker, e) gladius.

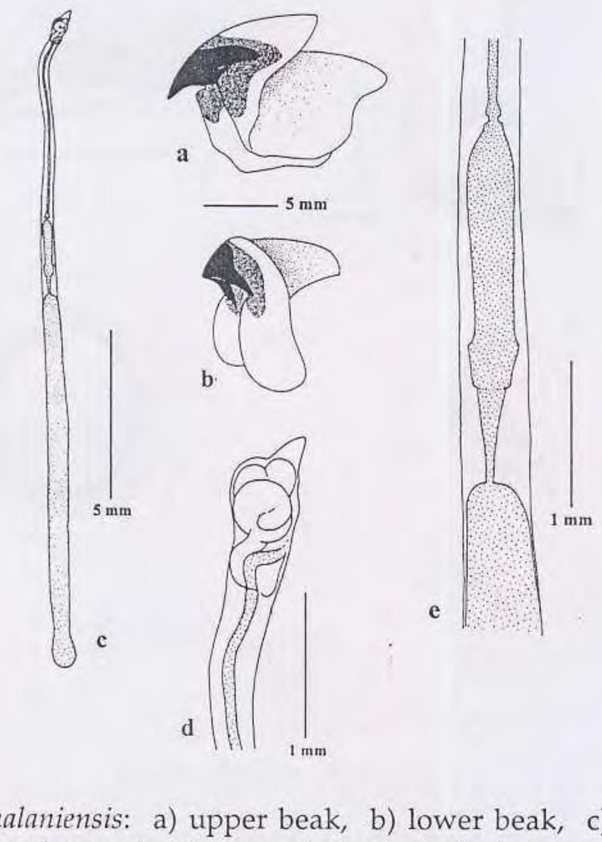


Fig. 16D. *Sthenoteuthis oualaniensis*: a) upper beak, b) lower beak, c) spermatophore, d) enlargement of oral cap, e) enlargement of cement body.

manus with trabeculae well developed. An Aboral keel is present along the club. Club suckers quadriserial on the dactylus and manus; two median rows of suckers 2-3 times larger than the lateral rows; carpal suckers are small, arranged in two irregular rows. Enlarged club sucker dentition on the dactylus and manus with about 20 sharp teeth and one in each quadrant enlarged (**Fig. 16C-d**); carpal suckers with smooth boney rings; one to four distinct tubercles or knobs present on the carpus.

Gladius (**Fig. 16C-e**) thin and very slender; rachis stout anteriorly, uniformly narrowing to the posterior tip, and with median rib and two marginal ribs along the edges; posterior end has a small vane about one-seventh of the total gladius length. The buccal membrane has seven buccal lappets, and strong ribs projecting beyond the margin in sharp points; two pores are present under arm I and between arm III, continuous with each other below the overhanging dorsal connective membranes; no suckers; numerous small oval seminal receptacles surround the mouth of mature females. Upper beak (**Fig. 16D-a**) with long, sharply pointed, curved rostrum tip; deep jaw angle; the hood length is almost half of the crest; lateral wall large. Lower beak (**Fig. 16D-b**) with short, conical rostrum; short hood; large wing; lateral wall long. Radula (**Fig. 16B-e**) with seven transverse rows of teeth; rachidian tooth tricuspid; first lateral tooth bicuspid, outer cusp small; second and lateral marginal teeth single and slightly curved.

Spermatophore (**Fig. 16D-c**) long and small, sperm mass comprises 50-60% of total length; cement body oval, slightly constricted at the posterior quarter of the body (**Fig. 16D-e**); ejaculatory apparatus coiled at oral end (**Fig. 16D-d**).

Colour in alcohol yellowish brown often with dark purple colouration in the mid-dorsal line of mantle.

4.1.3 Remarks

S. oualaniensis belongs to subfamily Ommastrephinae of family Ommastrephidae. It has unique character of the subfamily i.e. foveola and side pockets, another character, photophore, may be present or absent. Two forms of the species, both forms are represented by males and females, are known: one small, without dorsal photophore, another larger, with dorsal photophore (Clarke 1965; Roper *et al.* 1984). Besides the presence or absence of the dorsal photophore, they differ by the structure of the hectocotylus. Most investigators have suggested that the two forms might present two valid species, but they have not yet been described. Until Nesis (1993) has considered *S. oualaniensis* as a single species.

S. oualaniensis was first described as *Loligo oualaniensis* by Lesson (1830).

Later Pfeffer (1900) transferred to genus Ommastrephes, and subsequently to genus Symplectoteuthis the species. Finally, *Symplectoteuthis oualaniensis* (Lesson, 1830) and *Ommastrephes pteropus* Steenstrup, 1855 were united in the genus Sthenoteuthis (Zuev *et al*. 1975; Roeleveld 1982). The typical of the genus is the funnel and mantle cartilage fused at a single point. At present, the genus contains two species; *S. oualaniensis* and *S. pteropus*. The first species is distributed in the Indo-West pacific, while the latter lives in the Atlantic Ocean (Nesis, 1987).

4.2 Distribution, Abundance and Biological Features

Results from 30 samplings covered 3 survey areas in the South China Sea show that only one species of the purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by the automatic squid jigging gear. It indicates that males were generally smaller than females (see **Fig. 18**). Distribution, abundance and biological feature of the squid are described in detailed as classified by area as follows:

4.2.1 Western Philippines Waters

A total of 11 samplings were conducted in the Western Philippines waters. **Table 5** shows the information of sampling stations and catch results of the *S. oualaniensis*

Table 5 Sampling stations and catch results of the purpleback flying squid in the South China Sea: Western Philippines waters

Opt.	St.	Date	Location		Sounding	No.	No.	Effort	Total Catch		CPUE
No.	No.	(d-m)	Lat. (N)	Long.(E)	Depth (m)	of lines	of Jig	(h)	Weight (kg)	Number (ind)	Ind./line hour
1	1	17-Apr	20° 02.30'	119° 56.70'	3,620	8	240	5	25.920	116	2.900
2	5	19-Apr	18° 59.18'	118° 59.68'	3,820	8	128	2	5.760	29	1.813
3	7	21-Apr	18° 00.40'	119° 00.28'	1,180	8	156	4.55	71.505	422	11.593
4	9	22-Apr	16° 59.90'	120° 01.70'	1,505	8	156	4	5.109	50	1.563
5	12	25-Apr	16° 59.64'	117° 04.77'	4,031	8	178	5	100.299	739	18.475
6	14	27-Apr	15° 59.50'	118° 00.60'	4,041	8	176	4.5	23.014	141	3.917
7	17	29-Apr	15° 00.64'	118° 59.52'	4,559	8	176	5	23.485	131	3.275
8	21	30-Apr	14° 00.50'	117° 59.90'	1,777	8	176	6	39.635	267	5.563
9	27	5-May	13° 00.40'	117° 06.41'	1,672	8	176	8	16.506	138	2.156
10	30a	8-May	11° 59.80'	118° 45.30'	1,922	8	153	6.5	25.728	159	3.058
11	31a	9-May	12° 47.60'	119° 09.00'	544	6	176	8	62.190	400	8.333

from the survey area in terms of the catch-per-unit-effort (CPUE, number of squid per line hour). Drop-off rates for jigs fished on the jigging machines ranged from 0 to 0.33 squid/line hour.

4.2.1.1 CPUEs Distribution and Sex Compositions

Over the entire survey area, CPUE of the squid averaged 5.7 ind/line-hour. The minimum and maximum CPUEs of the squid were 1.6 and 18.5 ind/line-hour at St.#9 and St.#12, respectively. The CPUE value greater than 11 squids per line hour were found at St.#7 and St.#12. **Fig. 17** shows the CPUE distribution and sex composition of the squid caught at each sampling station. It is clearly shows that females formed the majority of the catch, accounting for 1,383 squid or 81% of the 1,701 total catch.

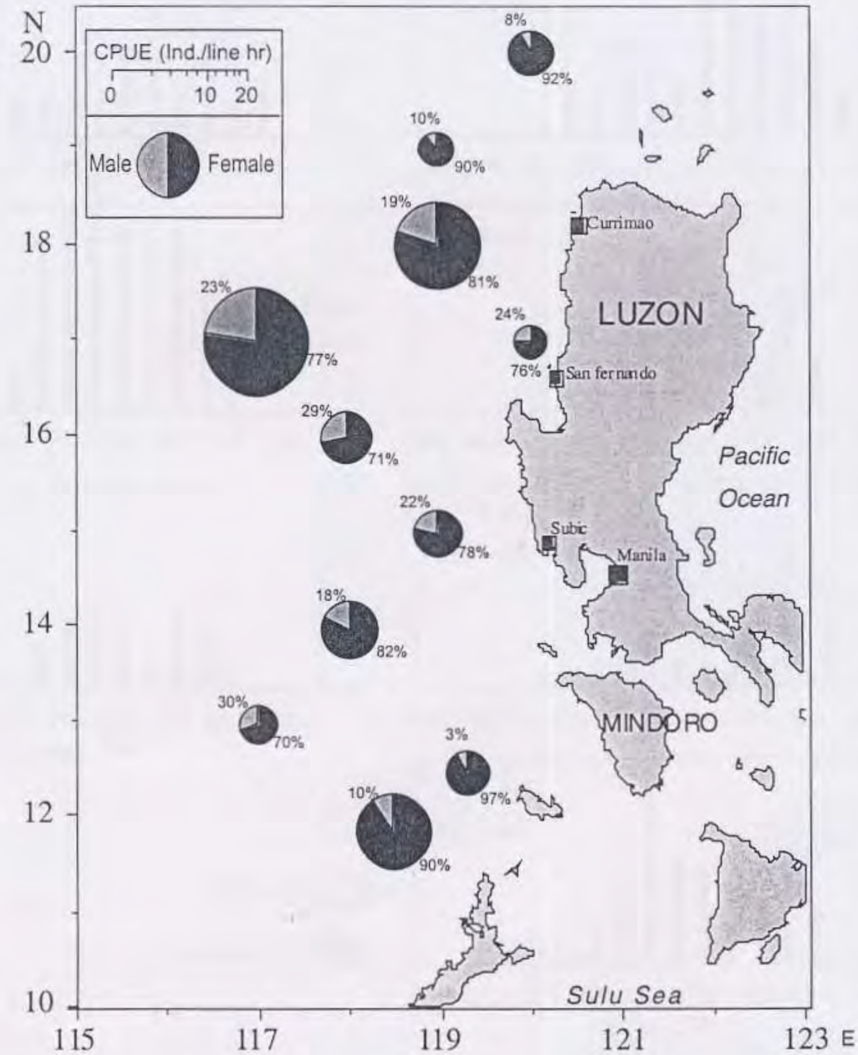


Fig. 17. Sex composition and CPUEs distribution of the purpleback flying squid in the South China Sea, Western Philippines waters during April-May 1998.

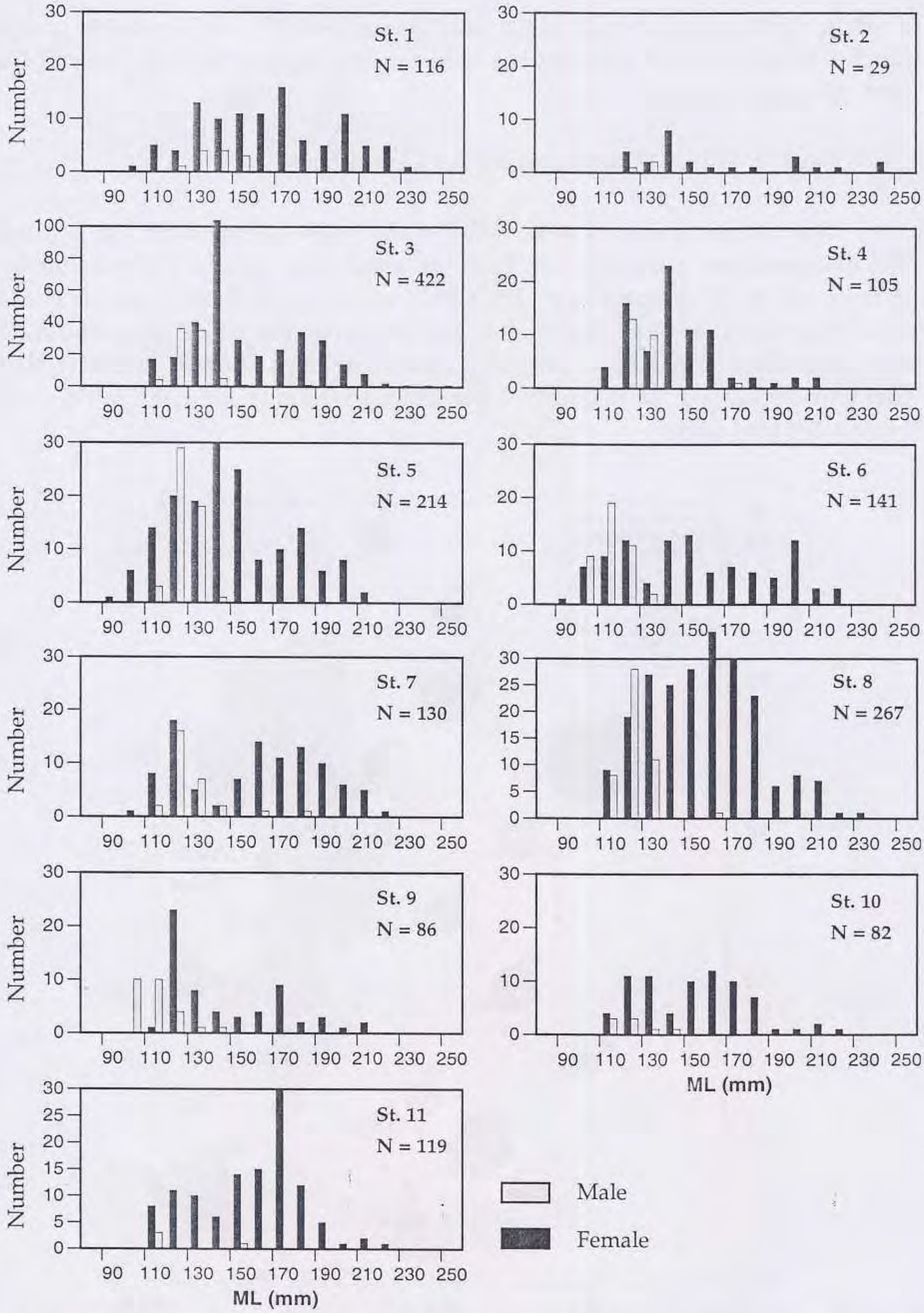


Fig. 18A. Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea, Western Philippines waters during April-May 1998.

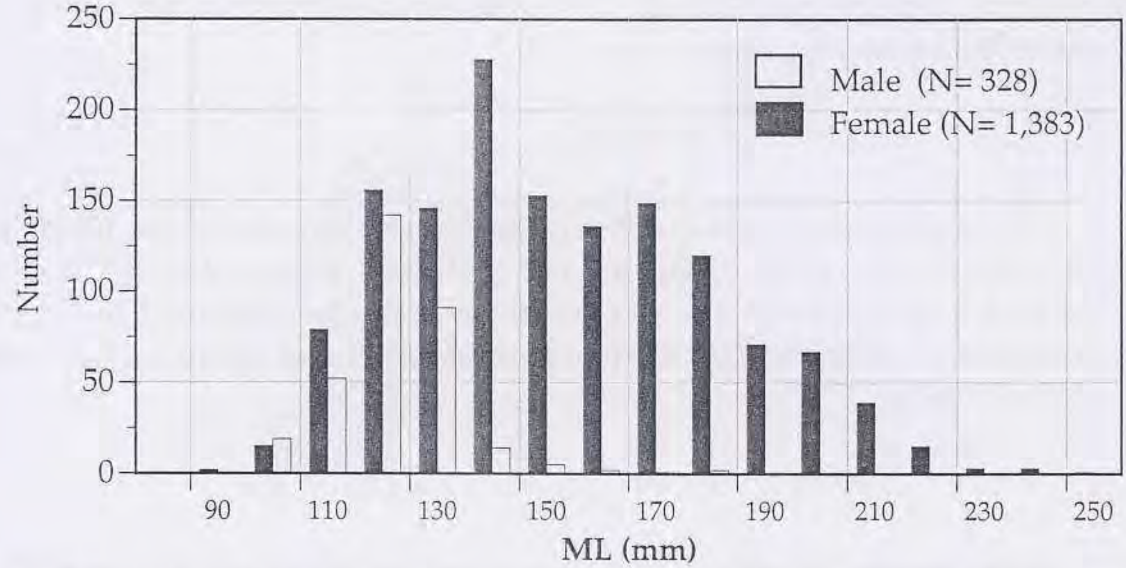


Fig. 18B. Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea, Western Philippines waters during April-May 1998.

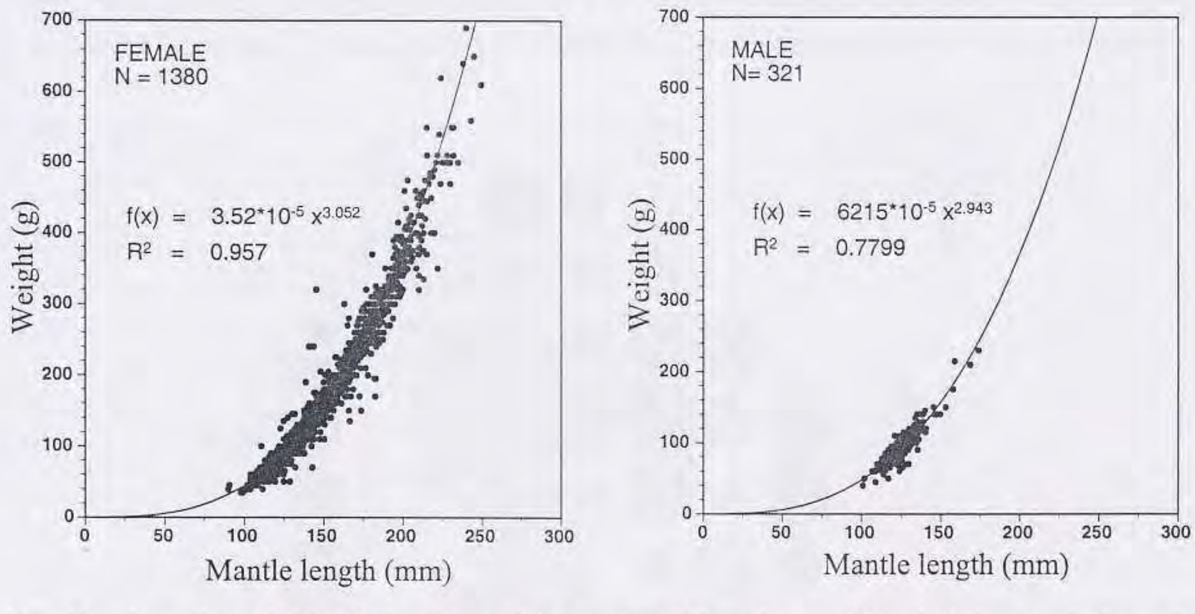


Fig. 19. Length-weight relationships of the male and female purpleback flying squid from the South China Sea, Western Philippines waters during April-May 1998.

4.2.1.2 Length Frequency Distribution

A total of 1,701 purpleback flying squid were measured and their mantle length ranged from 90 to 250 mm. The squid had a mean overall mantle length of 147 mm and an averaged weight of 170 g. **Fig. 18A** shows the mantle length frequency distribution of the purpleback flying squid in each sampling station in the western Philippines waters. **Fig. 18B** shows the overall mantle length frequency distribution of the squid in the survey area. From the results of the length frequency distribution, a single peak mode is indicated between 120 and 130 mm for males and between 140 and 150 mm mantle length for females, respectively.

4.2.1.3 *Length-Weight Relationship*

The length-weight relationship for males and females of the purpleback flying squid are presented in **Fig. 19**. The coefficient values of both female and male squid were 3.052 and 2.943, respectively. It can be concluded that there is no difference in length-weight relation between male and female in the western Philippines waters.

4.2.1.4 *Cephalopod Paralarvae Abundance and Distribution*

In the western Philippines waters, six paralarvae cephalopoda families were identified: Enoploteuthidae, Ommastrepidae, Onychoteuthidae, Brachioteuthidae, Cranchidae and Octopodidae. **Fig. 20** shows the abundance and distribution of the purpleback flying squid paralarvae in the western Philippines waters. The family Ommastrepidae was expressed by *Sthenoteuthis oualaniensis*. The paralarvae of *S.*

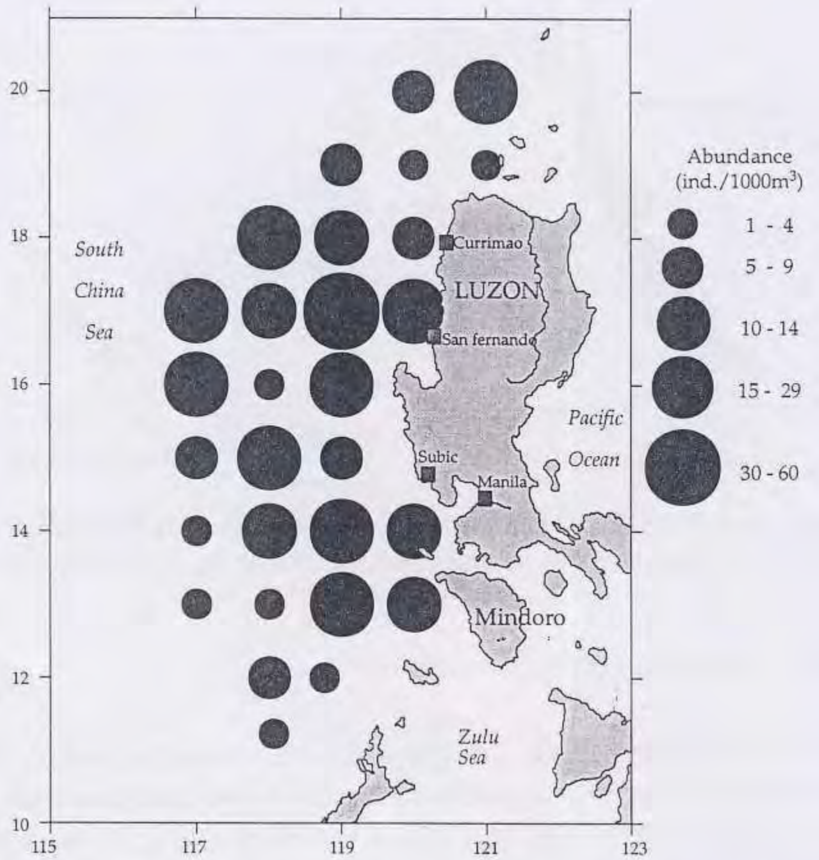


Fig. 20. Abundance and distribution of the purpleback flying squid paralarvae in the South China Sea, Western Philippines waters during April-May 1998.

oualaniensis was found at almost every station except St#16 and St#28. The highest density was observed at St#10 with 55 individual/1000m^3. **Table 6** shows the number of cephalopod paralarvae per 1000 m^3 at 31 stations in the western Philippines waters during the survey period in 1998.

Table 6 The number of cephalopod paralarvae per 1000 m3 at 31 stations in the western Philippines waters, during 7 April- 19 May 1998.

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Enoploteuthidae																
Enoploteuthis spp.	10	44	4	4	7	10	5	6	2	19	19	8	3	5	25	137
Abralia spp.	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Ommastrepidae																
Stenoteuthis oualaniensis	6	16	3	2	7	22	14	6	17	55	12	20	22	3	19	0
Onychoteuthidae																
Onychoteuthis spp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Brachioteuthidae																
Brachioteuthis spp.	6	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0
Cranchidae																
Leachia spp.	0	0	0	2	0	0	0	0	2	0	2	0	0	0	3	0
Liocranchia spp.	0	0	0	2	2	0	5	0	2	0	2	0	0	0	0	2
Octopodidae																
Octopus type I	0	2	0	0	0	0	0	3	2	0	2	0	6	0	0	5
Octopus type II	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type IV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown cephalopod sp. 1	0	5	0	0	7	9	0	3	2	0	2	5	0	2	12	0
Total	21	67	7	10	27	41	28	20	27	74	39	33	32	10	59	148

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	total
Enoploteuthidae																
Enoploteuthis spp.	13	37	11	7	3	28	22	38	11	4	7	3	5	8	29	534
Abralia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ommastrepidae																
Stenoteuthis oualaniensis	5	24	6	2	11	15	13	11	16	4	2	0	5	2	2	343
Onychoteuthidae																
Onychoteuthis spp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	5
Brachioteuthidae																
Brachioteuthis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Cranchidae																
Leachia spp.	0	0	2	0	5	3	15	0	0	0	0	0	4	2	0	40
Liocranchia spp.	0	0	0	0	6	0	0	0	0	0	0	0	1	2	0	24
Octopodidae																
Octopus type I	3	0	2	0	2	5	4	5	0	0	0	0	1	2	0	45
Octopus type II	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	9
Octopus type III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type IV	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Unknown cephalopod sp.1	1	0	0	0	3	0	0	0	0	0	0	0	3	0	2	56
Total	23	61	21	9	30	54	59	58	27	8	9	3	20	16	33	1074

4.2.2 Vietnamese Waters

A total of 10 samplings were conducted in the Vietnamese waters. **Table 7** shows the information from the sampling stations and the catch results of the *S. oualaniensis* in terms of the catch-per-unit-effort (CPUE, number of squid per line hour). Over the entire survey area, the CPUE of the squid averaged 3.08 ind/line-hour. Minimum and maximum CPUEs of the squid were 0.25 and 9.11 ind/line-hour at the St.#31 and St.#16, respectively. Drop-off rates for jigs fished on the jigging machines averaged 3.0 ind/line-hour.

4.2.2.1 CPUEs Distribution and Sex Compositions

Fig. 21 shows the CPUEs distribution of the *S. oualaniensis* in the overall survey area. High CPUE areas where more than 5 ind/line-hour were caught were found at St.#16 and St.#17.

Sex ratio of the catch in Vietnamese waters varied between 68 - 91% by females. The sex ratio observed in the Vietnamese waters and in the western Philippines is close to 80% by females but vary slightly between areas. The sex ratio of catch in the Vietnamese waters and western Philippines were averaged out to be 75% and 81% by females, respectively.

Table 7 Sampling stations and catch results of the purpleback flying squid in the South China Sea: Vietnamese waters during May 1999.

Opt. No.	St. No.	Date (d-m)	Location Lat. (N)	Long. (E)	Sounding Depth (m)	No. of line	No. of jig	Effort (h)	Total Catch Weight (kg)	Number (ind.)	CPUE (ind./line hour)
1	11	3-May	16° 01.4'	109° 58.0'	847	8	200	5.00	12.61	73	1.83
2	16	7-May	15° 02.5'	110° 58.8'	1,230	8	200	6.75	52.59	492	9.11
3	17	8-May	14° 06.5'	111° 56.5'	2,100	8	200	6.50	36.72	262	5.04
4	19	9-May	14° 10.7'	109° 58.9'	653	8	200	4.50	44.48	174	4.83
5	23	11-May	12° 55.3'	111° 00.3'	2,703	8	200	6.00	13.43	87	1.81
6	25	12-May	12° 00.1'	111° 59.5'	4,117	8	200	5.50	20.08	135	3.07
7	27	14-May	11° 46.2'	109° 56.1'	1,734	8	200	4.00	8.37	83	2.59
8	31	18-May	10° 59.7'	111° 01.0'	2,940	8	200	4.50	1.47	9	0.25
9	34	21-May	09° 59.9'	110° 00.3'	1,614	8	200	5.50	8.98	72	1.64
10	42	26-May	08° 01.2'	109° 49.9'	628	8	200	5.00	4.74	25	0.63

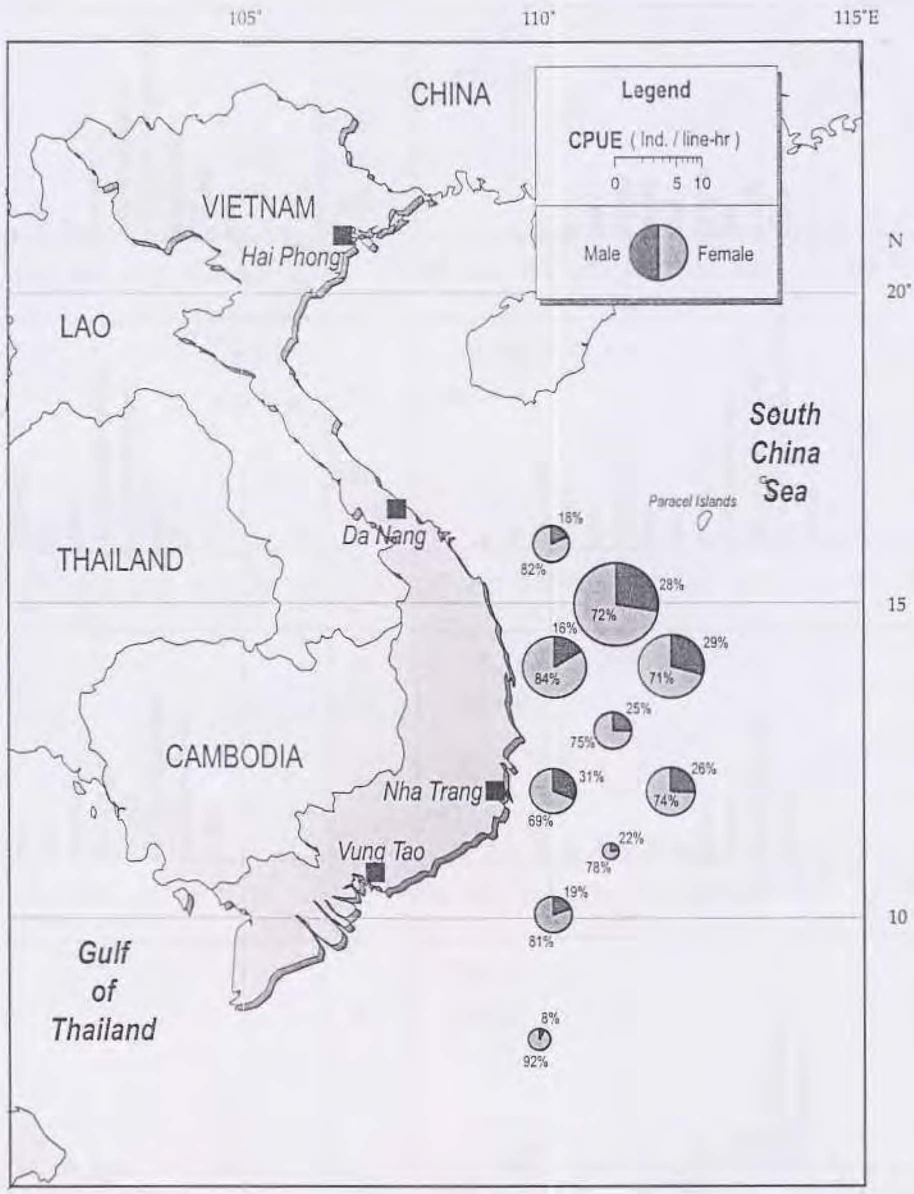


Fig. 21. Sex composition and CPUEs distribution of the purpleback flying squid in the South China Sea, Vietnamese waters during May 1999.

4.2.2.2 *Length Frequency Distribution*

Fig. 22A shows the length frequency distribution for the *S. oualaniensis* from each fishing station. Two sizes of specimens, small and large were found in the survey area. In abundant areas of squid, St.# 16 and St.#17, about 80% of the female specimens were of small size with a mantle length ranging between 110 and 150mm. About 40% of the large squid with a length ranging between 190 and 240mm were found at St.#19. Mantle length size of males was smaller than females.

Fig. 22B show the overall mantle length distribution of the squid, a total of

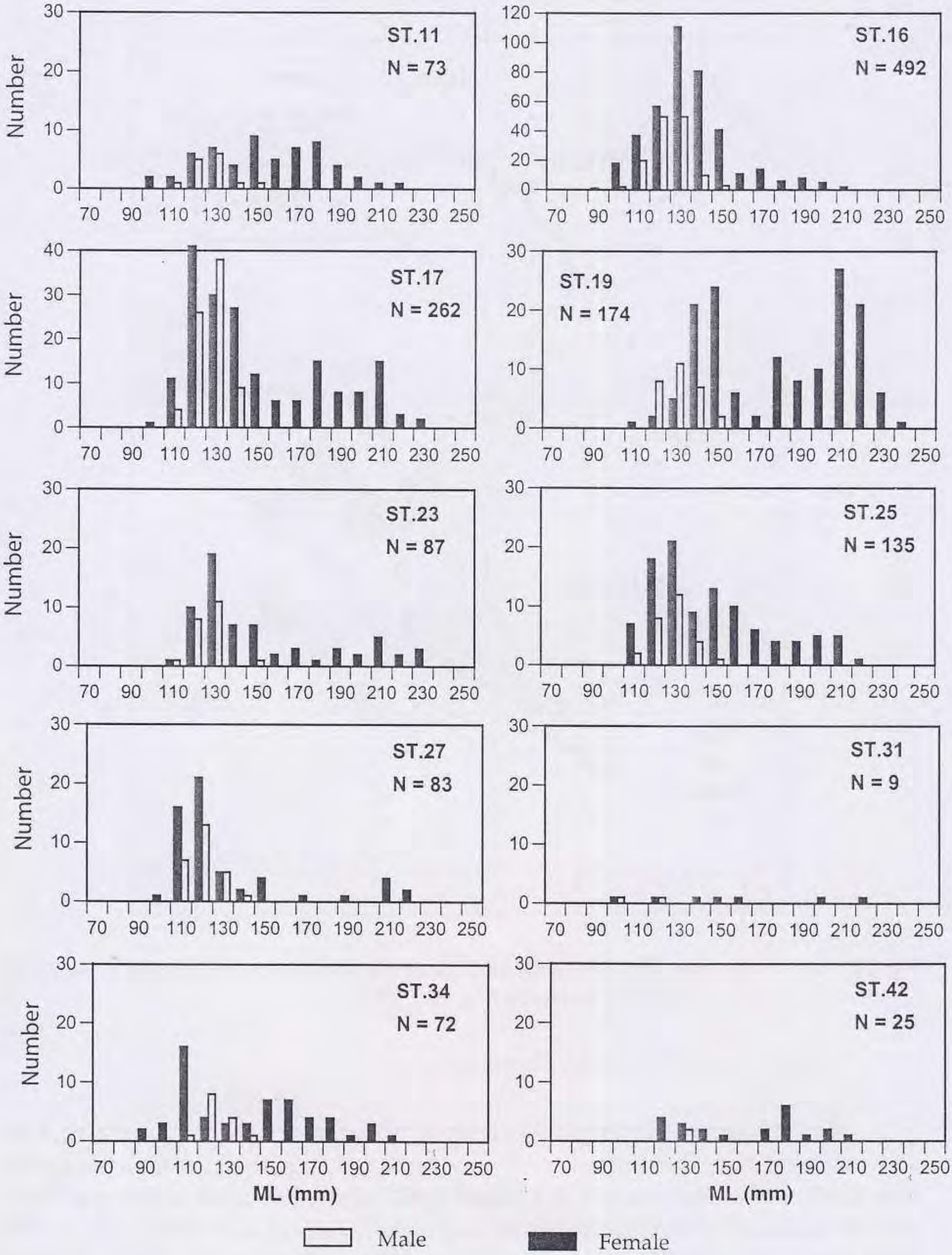


Fig. 22A. Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea, Vietnamese waters during May 1999.

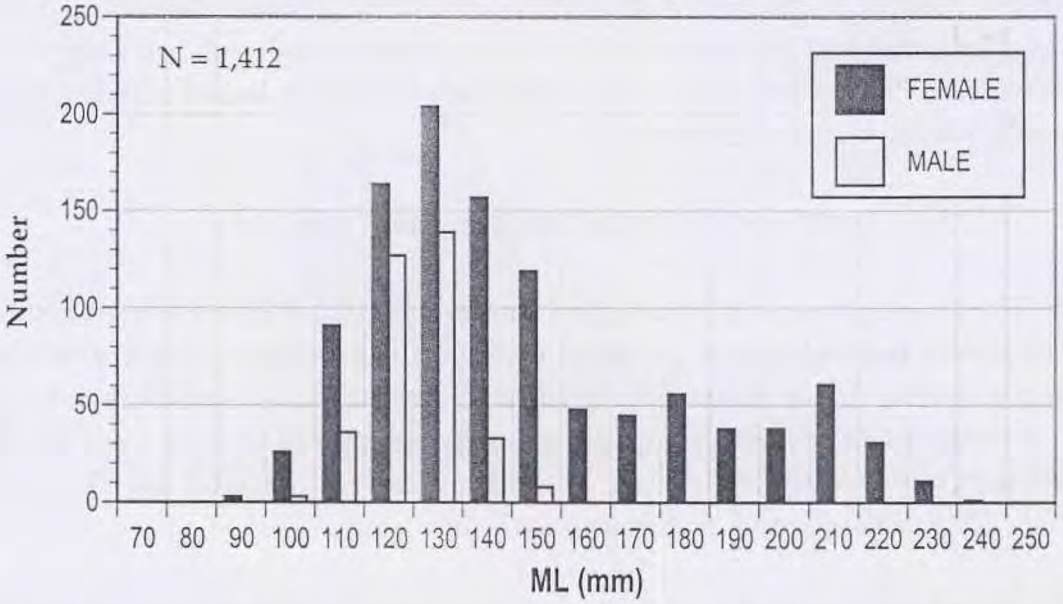


Fig. 22B. Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea, Vietnamese waters in May 1999.

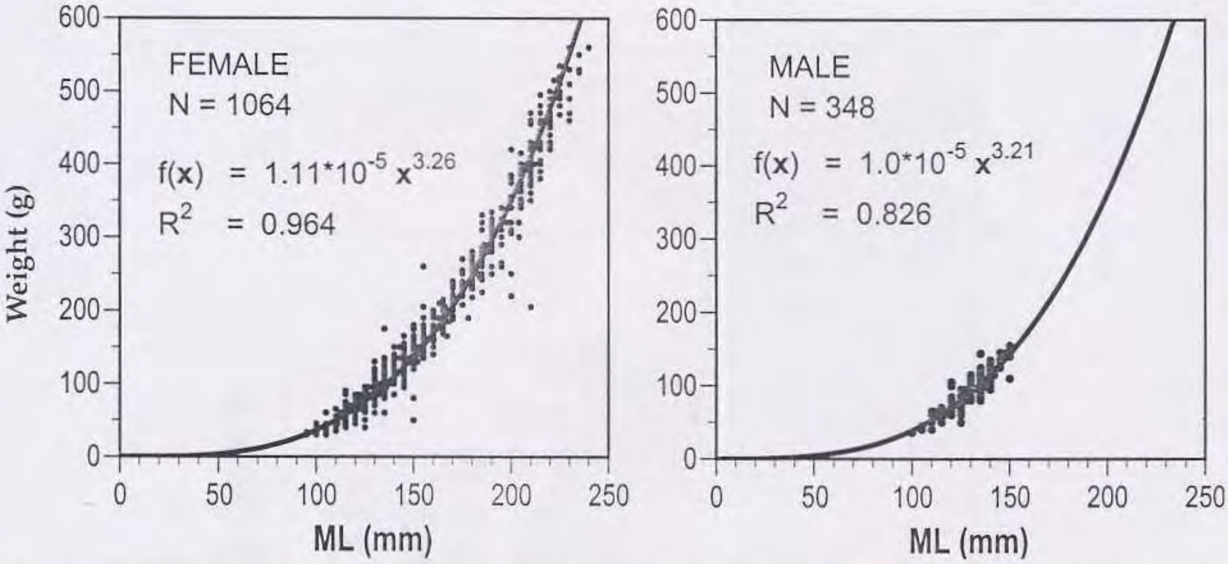


Fig. 23. Length-weight relationships of the male and female purpleback flying squid from the South China Sea, Vietnamese waters in May 1999.

1,439 specimens indicate that their mantle length ranged between 90 and 240mm with a mean length of 147mm and an averaged weight of 170g. Modal length of the squid for both females and males was 130mm with means of 150.5 and 127.5mm, respectively.

4.2.2.3 Length-Weight Relationships

Length-weight relationship coefficients for male and female *S. oualaniensis* are presented in **Fig. 23**. The coefficients for both male and female were about 3.2 and it may be concluded that there are no difference in length-weight relation between them. In the western Philippines waters, the coefficients of both male and female are smaller especially for the males at less than 3.

4.2.2.4 Cephalopod Paralarvae Abundance and Distribution

The investigation into cephalopod paralarvae in the Vietnamese waters showed that 15 genera belonging to 11 families were found as shown in **Table 8**. Some were economic species that are found in neretic and oceanic areas like *Sepia sp., Loligo spp.* and *Sthenoteuthis oualaniensis*. Some genera occurred only in oceanic areas like *Abralia sp., Watasenia sp., Onychoteuthis sp., Ctenopteryx sicula, Nototodarus sp., Thysanoteuthis rhombus, Liocranchia sp.*, and *Teuthowenia sp.*

Sthenoteuthis oualaniensis are found mostly in the central part of Vietnamese waters, particularly in the oceanic zone. The abundance and distribution of the squid during the survey period is shown in **Fig. 24**.

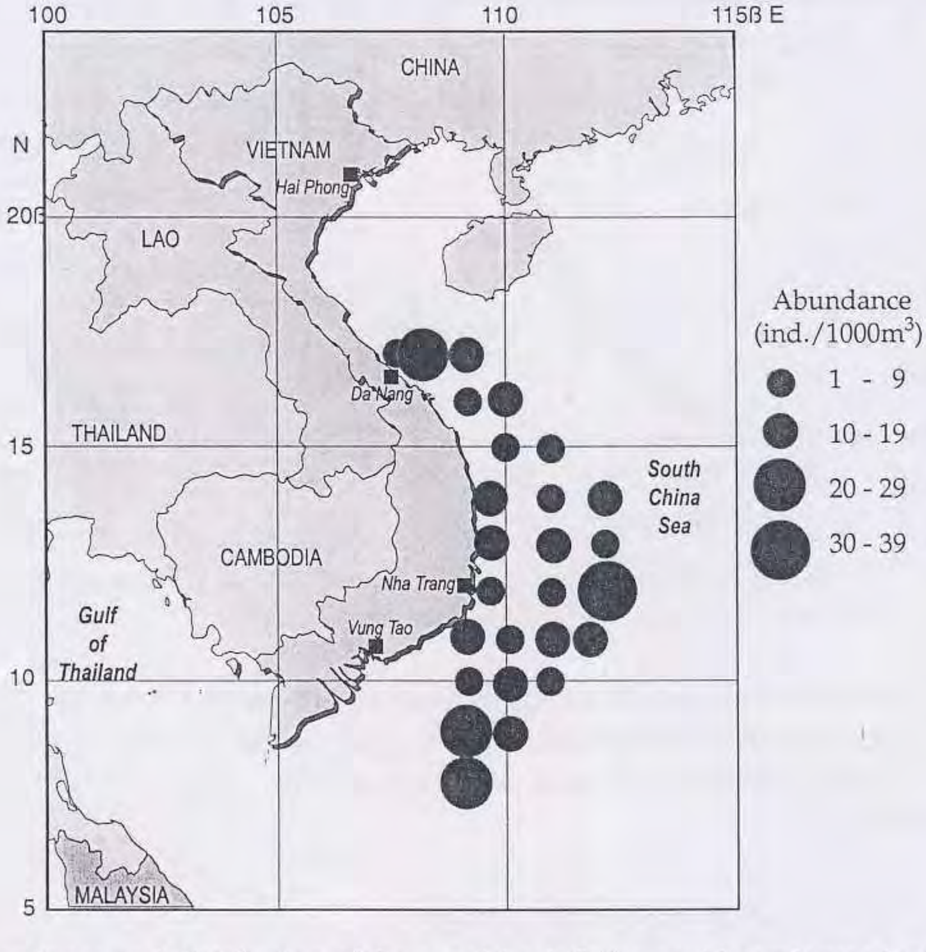


Fig. 24. Abundance and distribution of the purpleback flying squid paralarvae in the South China Sea, Vietnamese waters in May 1999.

Table 8 Number of cephalopod paralarvae per 1000 m^3 at 58 stations in the Vietnamese waters, during 30 April- 29 May 1999.

Station	Sepia sp.	Inioteuthis sp.	Loligo sp.	Enoploteuthis	Abralia sp.	Watasenia sp.	Onychoteuthis	Ctenopteryx sicula	Nototodarus sp.	Sthenoteuthis	Thysanoteuthis	Liocranchia sp.	Teuthowenia sp.	Octopus defilippi	Octopus type A	Octopus type B	Octopus type C	Tremooctopus sp.?	Unknown	Total
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
7	0	0	21	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	24
8	0	0	20	0	0	0	0	0	0	5	0	0	0	0	0	5	0	0	0	29
9	0	2	2	0	18	0	0	0	10	28	0	0	0	0	0	6	2	0	2	71
10	0	2	0	0	0	7	0	0	0	11	0	0	0	0	2	7	2	0	0	31
11	0	0	0	14	7	0	0	0	5	14	0	0	0	0	0	5	0	0	0	44
12	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	4	2	2	4	21
13	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
14	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
15	0	0	0	22	0	13	6	0	0	6	0	0	0	0	0	41	2	0	6	97
16	0	0	0	6	0	0	12	21	0	3	0	0	0	0	0	0	0	0	0	41
17	0	0	4	0	0	2	22	2	5	14	5	0	0	0	0	2	0	0	2	58
18	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	8	0	0	0	13
19	0	0	0	0	2	7	0	0	0	0	0	2	0	0	0	0	0	0	0	12
20	0	0	0	0	0	0	9	0	0	12	0	0	0	0	0	12	0	0	0	33
21	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	4	0	0	0	17
22	0	0	2	0	0	5	2	0	0	0	0	0	0	0	0	0	2	0	0	11
23	2	4	12	0	0	2	6	0	4	10	2	0	6	0	0	0	0	0	4	52
24	0	0	2	2	8	4	10	0	0	8	0	0	0	0	0	2	0	0	4	39
25	0	0	0	11	0	0	11	0	6	31	3	0	3	0	0	0	0	0	0	65
26	0	0	0	57	0	12	6	0	0	6	0	0	0	0	0	0	3	0	3	87
27	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8
28	0	0	2	0	0	2	2	0	0	5	0	0	0	0	0	2	0	0	0	15
29	0	0	0	0	0	0	0	0	2	11	0	0	0	0	0	2	0	0	4	20
30	0	0	0	0	0	0	4	0	0	2	0	0	0	0	2	2	2	0	0	13
31	0	0	8	0	0	8	0	0	8	15	0	0	0	0	0	0	0	0	15	53
32	0	0	0	0	3	3	0	0	0	10	0	0	0	0	0	0	0	0	3	20
33	0	0	0	0	5	11	8	0	0	5	0	0	11	0	0	0	0	0	13	53
34	0	0	0	12	5	0	0	0	0	12	0	0	0	0	0	0	0	0	2	31
35	0	0	0	6	2	0	0	0	0	8	4	0	0	0	0	4	2	2	0	26
36	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
37	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	9
40	0	0	12	9	7	0	7	0	5	26	2	0	0	0	0	2	0	0	5	76
41	0	0	0	0	0	0	7	0	2	12	0	0	0	0	0	0	0	0	0	22
42	0	0	3	0	3	8	0	0	0	0	0	0	0	0	0	0	0	0	0	13
43	0	0	0	7	0	0	2	0	0	20	0	0	0	0	2	0	0	0	0	32
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	7	0	4	30
45	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	5
46	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0	0	12
47	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	6
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	8
52	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	11	4	0	0	18
53	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0	13
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	13
55	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	19
56	0	0	18	0	0	0	0	0	0	0	0	0	0	0	11	11	4	0	0	43
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	25
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	5
total	2	17	165	169	60	86	116	22	47	294	16	2	19	2	28	236	40	4	72	1400

4.2.3 Sabah, Sarawak (Malaysia) and Brunei Darussalam Waters

A total of 10 samplings were conducted in the waters of Sabah, Sarawak (Malaysia) and Brunei Darussalam. **Table 9** gives the information of sampling stations and catch results for the *S. oualaniensis* in terms of the catch-per-unit-effort (CPUE, number of individual/line-hour). Drop-off rates for jigs fished on the jigging machines averaged 0.8 squid/line hour.

4.2.3.1 CPUEs Distribution and Sex Compositions

Over the entire survey area in the waters of Sabah, Sarawak (Malaysia) and Brunei Darussalam, the CPUE of the squid averaged 0.632 ind/line-hour. Minimum and maximum CPUEs of the squid were 0.16 and 1.52 ind/line-hour at the St.#21 and St.#15, respectively. The CPUE value greater than 1 squid per line hour were found at St.#13 and St.#15. **Fig. 25** shows the CPUE distribution and sex composition of the squid caught in each sampling station. Sex ratio of the catch varied between 89 - 100% by females. This clearly shows that females dominated the catch and males were not found at St.#7, St.#17, St.#19, St.#20 and St.#21.

4.2.3.2 Length Frequency Distribution

A total of 242 purpleback flying squid, *S. oualaniensis* were measured and their mantle length ranged from 58 to 230 mm. The squid had a mean overall mantle

Table 9 Sampling stations and catch results of the purpleback flying squid in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during

Opt. No.	St. No.	Date (d-m)	Location Lat. (N)	Location Long.(E)	Sounding Depth (m)	No. of lines	No. of Jig	Effort (h)	Total Catch Weight (kg)	Total Catch Number (ind)	CPUE Ind./line hour
1	7	22-Mar	05°45.27 N	111°29.45 E	452	8	200	5.5	3.070	10	0.227
2	8	23-Mar	06°21.73 N	110°63.33 E	1,237	8	200	6	3.920	19	0.396
3	9	24-Mar	06°85.02 N	111°37.63 E	1,880	8	200	5.25	7.900	40	0.952
4	11	25-Mar	05°25.17 N	113°01.25 E	1,257	8	200	4.5	1.500	12	0.333
5	13	26-Mar	05°62.65 N	113°78.57 E	2,150	8	200	4.5	3.640	48	1.333
6	15	27-Mar	06°16.94 N	114°32.80 E	1,975	8	200	5	11.300	61	1.525
7	17	28-Mar	06°56.51 N	115°17.87 E	1,516	8	200	7.5	3.200	17	0.283
8	19	29-Mar	07°03.25 N	113°52.17 E	1,836	8	200	4	1.700	8	0.250
9	20	31-Mar	07°06.74 N	112°24.15 E	2,003	8	200	4.8	8.050	33	0.859
10	21	1-Apr	06°19.83 N	113°06.10 E	1,592	8	200	4	0.690	5	0.156

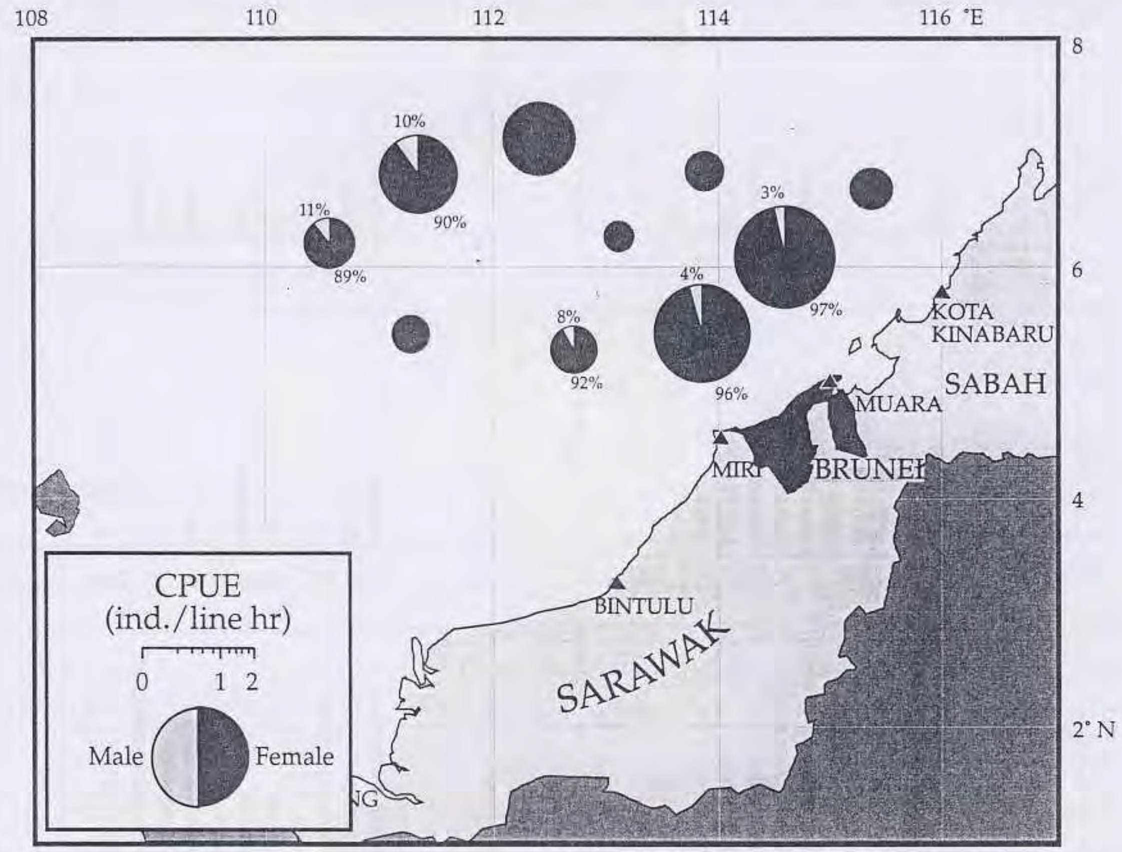


Fig. 25. CPUEs distribution and sex composition of the purpleback flying squid in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.

length of 160 mm and an averaged weight of 200 g. The females were of larger size with a mantle length ranging between 58 and 230mm meanwhile the males ranged between 97 and 130mm. **Fig. 26A** shows the mantle length frequency distribution of the purpleback flying squid at each survey station. At St.#13 and St.#15 where the CPUEs was larger than 1.0, the length frequency distribution of the squid indicate two modes of length at 110 -120mm and 180-190mm . **Fig. 26B** shows an overall mantle length frequency distribution of the squid. From the results of the length frequency distribution these indicate a two-peak mode at 120 and 180 mm for females and a single peak mode at 120mm for males, respectively.

4.2.3.3 *Length-Weight Relationship*

The length-weight relationship for males and females of the purpleback flying squid are presented in **Fig. 27**. The coefficient value of the females was 3.18.

4.2.3.4 *Cephalopod Paralarvae Abundance and Distribution*

Due to technical problem in analysis, there are no results from this subject.

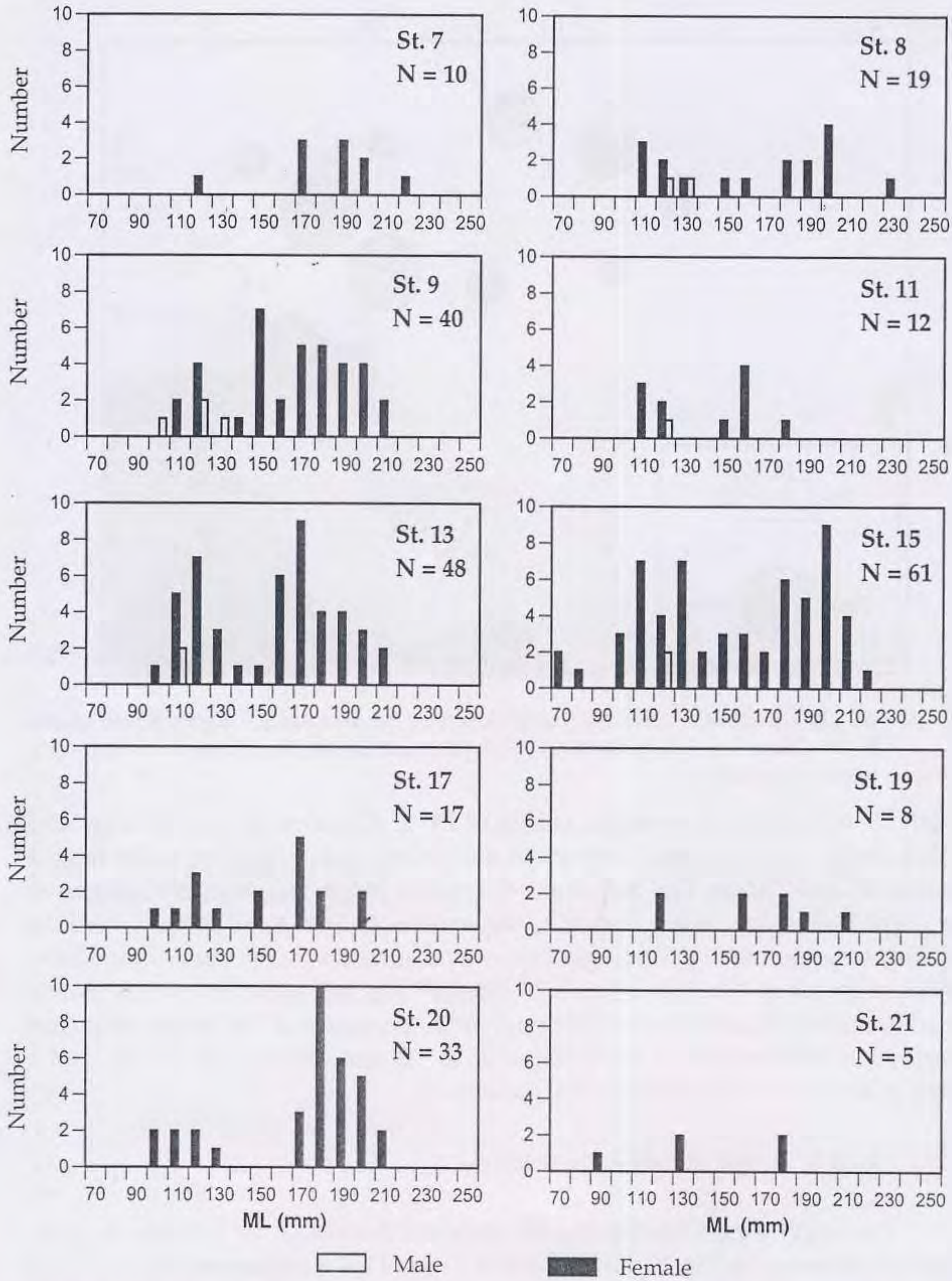


Fig. 26A. Mantle length distribution of the male and female purpleback flying squid from each samplings station in the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-Apr. 2000.

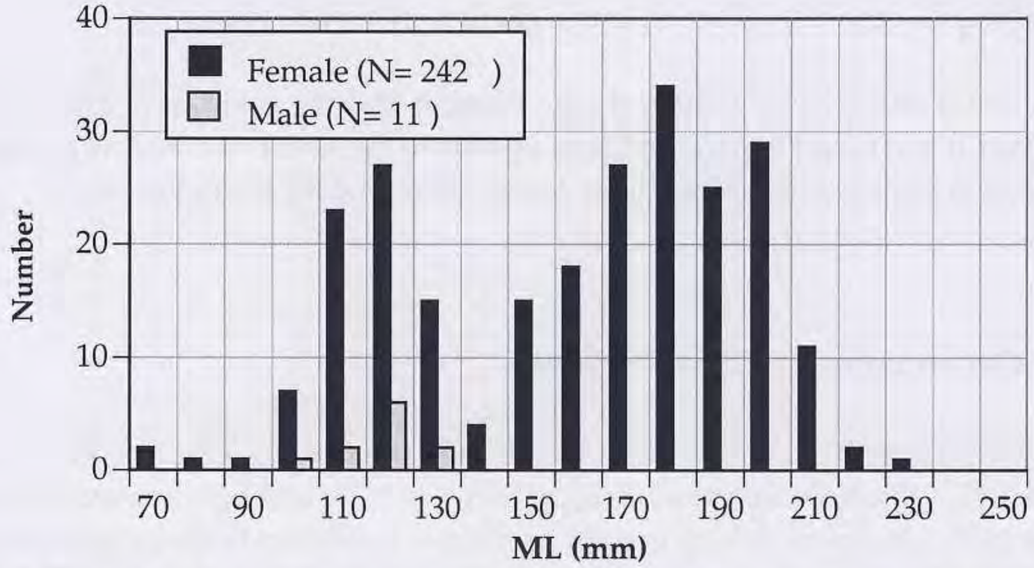


Fig. 26B. Overall mantle length distribution of the male and female purpleback flying squid from the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.

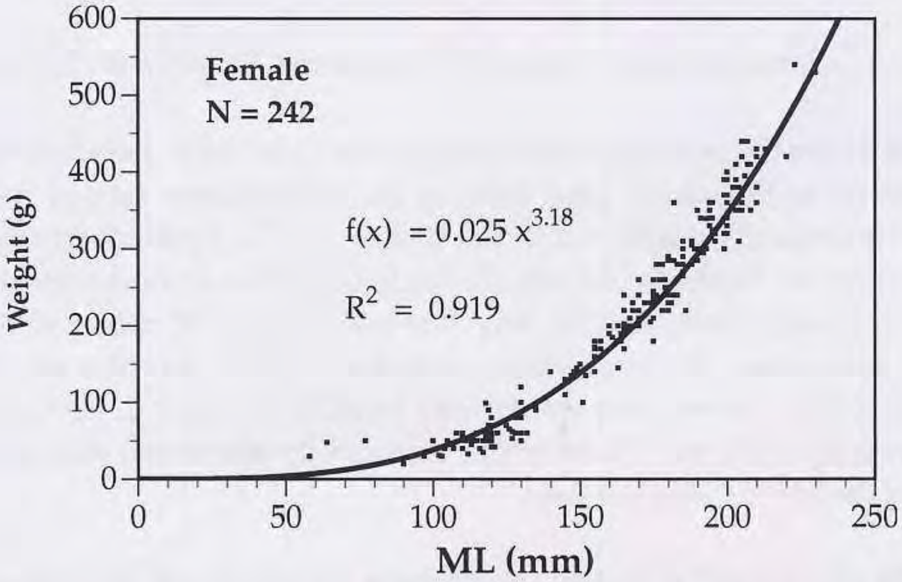


Fig. 27. Length-weight relationships of the female purpleback flying squid from the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during March-April 2000.

4.3 Diet and Feeding

From the diet and feeding habits of the *S. oualaniensis* it is found that the main prey of the squid were crustaceans, fishes (mainly flying fish) and squid (especially *S. oualaniensis*). Much of the stomach contents consisted of a mixture of fish and cephalopod, thus giving a high percentage of their occurrence in the diet. Otolith, eyelenses, vertebrae and bones of fish, fragments of exoskeletons and the appendages of crustaceans, cephalopod beaks, lenses gladii were found

It was observed by sight and echo sounder that the squid have a vertical diet migration, it was found that they migrate upward to the surface for feeding at dusk and night and downward to the deep layer before dawn and for the daytime.

4.4 Oceanographic Characteristics

Oceanographic characteristics including temperature, salinity, dissolved oxygen, chlorophyll a fluorescence value, transparency, sea color and light transmission were conducted to clarify the fishing ground conditions in relation to the catch results. The analysis indicates two fishing grounds of the *S. oualaniensis* in the western Philippines and central Vietnamese waters where upwelling was found.

4.4.1 Western Philippines Waters

4.4.1.1 Horizontal Distribution of the Temperature, Salinity and Fluorescence

Fig. 28 shows the horizontal distribution of temperature at the sea surface layer (a) and 100m (b) in the survey area. Most of the temperatures ranged from 28° to 30.7°c at the surface and from 18° to 23.5°c at 100m deep. The figure clearly shows cold water flows from the Pacific Ocean into the South China Sea around northern Luzon. At 18°N the sea temperature at 100m deep was low at about 18°c compared with the surrounded areas where the temperature was about 23°c, this cold water appeared at the surface where the sea temperature was found to be about 28°c. Anond (1999) reported a cyclonic eddy was found in this area and its occurrence was due to wind turbulence in the South China Sea Area.

Fig. 29 shows the horizontal distribution of salinity (a) and chlorophyll a fluorescence value (b) at the sea surface layer in the western Philippines during April-May 1998. The salinity and fluorescence value ranged from 33.7 PSS to 34.6 PSS and from 0.45 V to 0.65 V at the sea surface, respectively. High salinity water was found in the south and southeast at the same time as in the northeast of the survey area, these occurrences were due to the effect of inflowing water from the Pacific Ocean. The low salinity water was found generally in the coastal area off San Fernando, Subic and Manila. The fluorescence data was shown only in the higher latitudes from 15 to 20° N because of equipment faults after survey station No. 19. There was not much difference in the fluorescence value at the sea surface during the survey period.

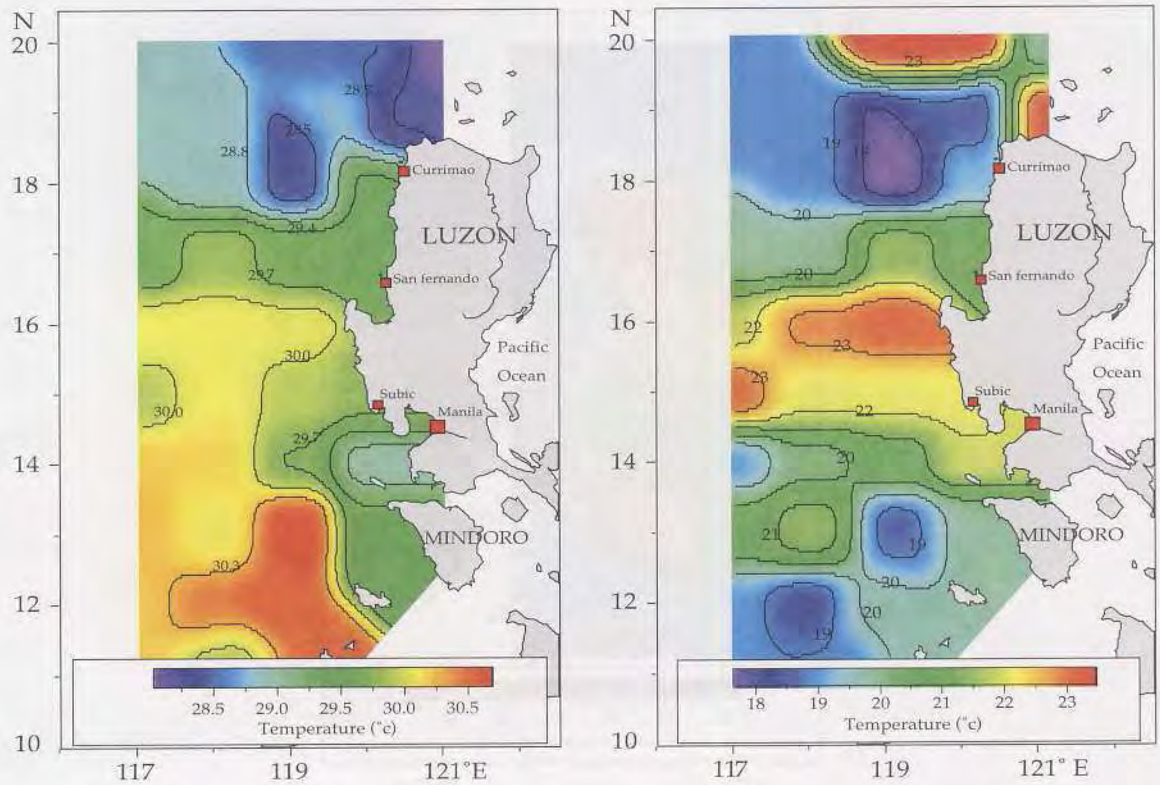


Fig. 28. 23 days synoptic chart of the sea surface temperature (a) and 100m deep (b) in the Western Philippines during 17 April - 9 May

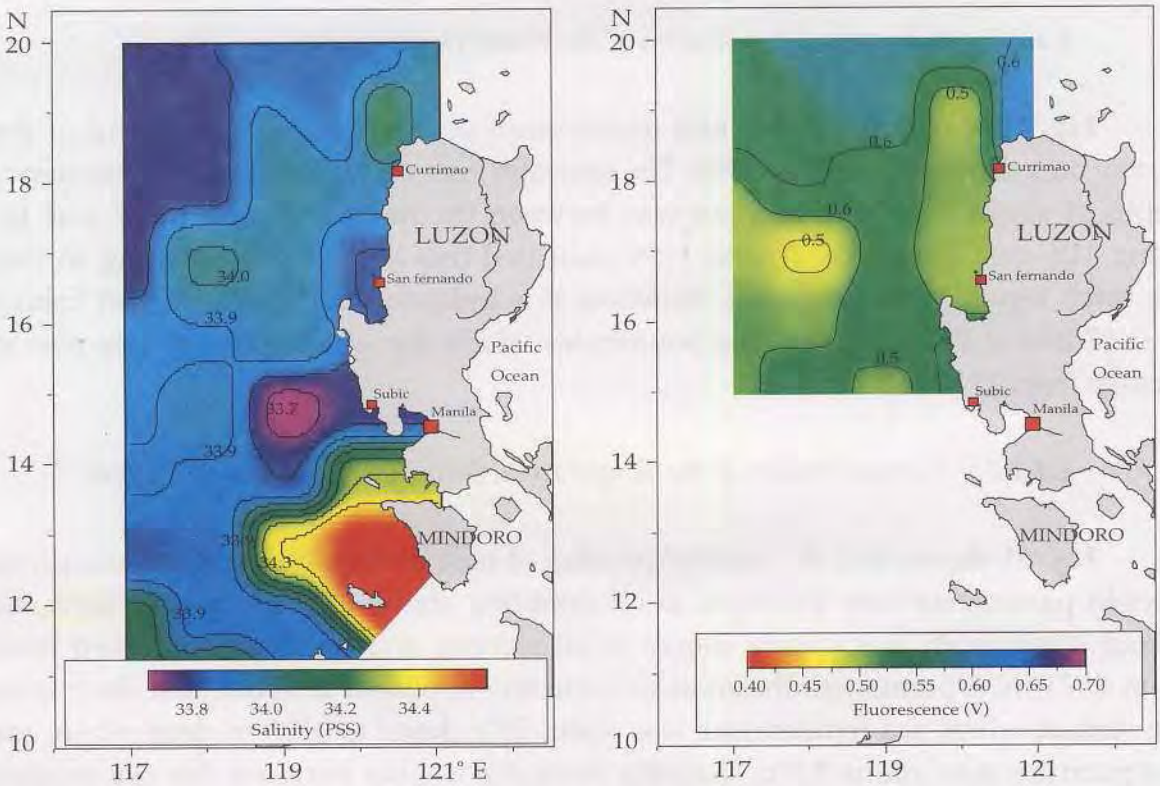


Fig. 29. 23 days synoptic chart of the salinity (a) and chlorophyll a fluorescence value (b) at the surface layer in the Western Philippines during 17 April - 9 May 1998.

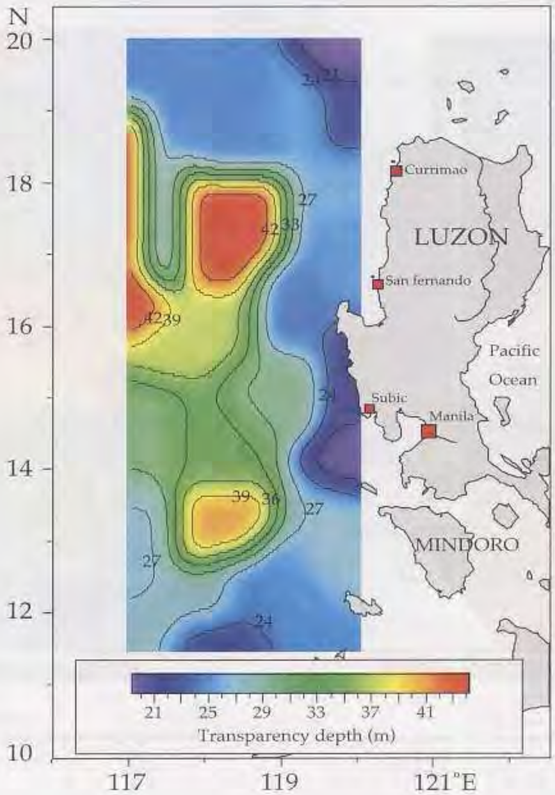


Fig. 30. 23 days synoptic chart of the water transparency depth in the Western Philippines during 17 April - 9 May 1998.

4.4.1.2 Horizontal Distribution of the Water Transparency

Fig. 30 shows the horizontal distribution of water transparency (m) of the survey area during April-May 1998. The seawater was very clear with a transparency depth of about 44m, this location was between the north latitudes of 17 and 18° along 118° east longitude. Anond 1999 indicated this area as downwelling so that the catch results were very poor. However it is indicated that there is good fishing at st.#7 and st.#12 located at the boundaries where the water transparency was in a range from 27 m to 33 m.

4.4.1.3 Vertical Profiles of the Temperature, Salinity and Dissolved Oxygen

Fig. 31 shows that the vertical profiles of temperature, salinity and dissolved oxygen parameters vary by depth at all sampling stations. In the survey area, the mixed layer depth was clearly shown at all stations and the depth observed from 12 m to 71 m. A permanent thermocline generally appeared at about 50m deep from the surface where sea temperature was about 28°c down to 1500 m deep where sea temperature was about 2.7°c. Salinity from the depths between the sea surface to 150 m deep irregularly changed from 33.7 to 34.6 PSS, the salinity at deeper than 150m was almost constant about 34. 5 PSS. For dissolved oxygen near the

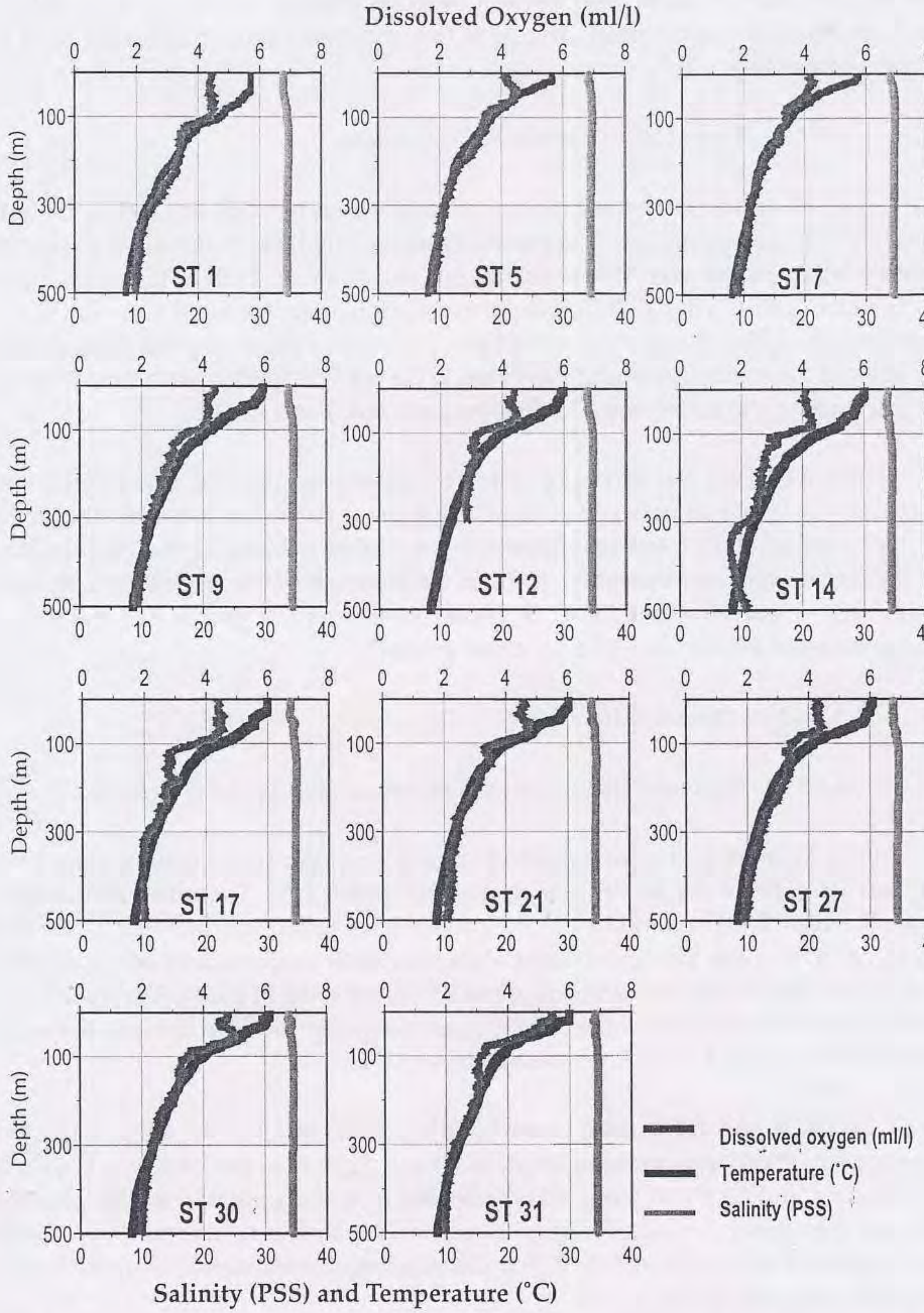


Fig. 31. Vertical profiles of temperature, salinity and dissolved oxygen at each squid samplings station in the Western Philippines during 17 April - 9 May 1998.

sea surface down to 150m deep showed irregular changes within 4.4 ml/l and 3.1 ml/l, respectively and slightly decreased to a constant value of about 2.0 ml/l at depths greater than 400m.

4.4.1.4 Vertical Distribution of the Temperature

Fig. 32 shows the vertical contour of temperature at LINE A, LINE B, LINE C and LINE D (see Appendix 2). The vertical profiles along LINE A and LINE C indicate that the mixing layer was not much changed, it was about 40-50 m for LINE A and 50-60 m for LINE C. Along LINE B, the thermocline represented by 27°C is located at a depth of about 22 m in the north at st.#5 and 7, while at a depth of about 70 m, deeper by 48 m, in the south. Upwelling was found at the st.# 7. A similar north-south change of thermocline was found along LINE D between st.#12 and st.#19.

Fig. 33 shows the vertical profile of temperature at LINE 1 to LINE 8 (see Appendix 2). West-east variation of thermocline was found not to be remarkable in the waters south of LINE 2, but significant along the LINE 1. Along LINE 1, the position of the thermocline represented by 28°c and the thickness of the mixing layer showed significant west-east variations. It is noted that the vertical profile of temperature along west-east section showed no thermal gradient.

4.4.2 Vietnamese Waters

4.4.2.1 Horizontal Distribution of Temperature, Salinity and Fluorescence

Fig. 34 show the horizontal distribution of temperature at the sea surface layer (a) and 100m (b) in the survey area during April-May 1999. The water temperature were between 24.04 and 30.15°c at the surface layer (10m) and between 17.15° and 23.15°c at 100m deep. The figure clearly shows the water temperature was low, ranging between 24 and 27°c in the north and about 30°c in the south at the surface layer. In the central part of Vietnamese waters where squid samplings were carried out, the water temperatures of the surface layer were between 28° and 30°c.

At 14°N and 111°E, cold water of 18°c was found at 100m deep, while the surrounding temperatures were between 20 and 22°c. This cold water was 14°c at 200m deep and 22.9°c at 50m. It is likely that upwelling existed in this location during the survey period of May or southwestern monsoon season. Fuyo Ocean Development and Engineering (1998) has reported the existence of upwelling in the same area and season.

Fig. 35 shows the horizontal profiles of salinity (a) and chlorophyll a fluorescence

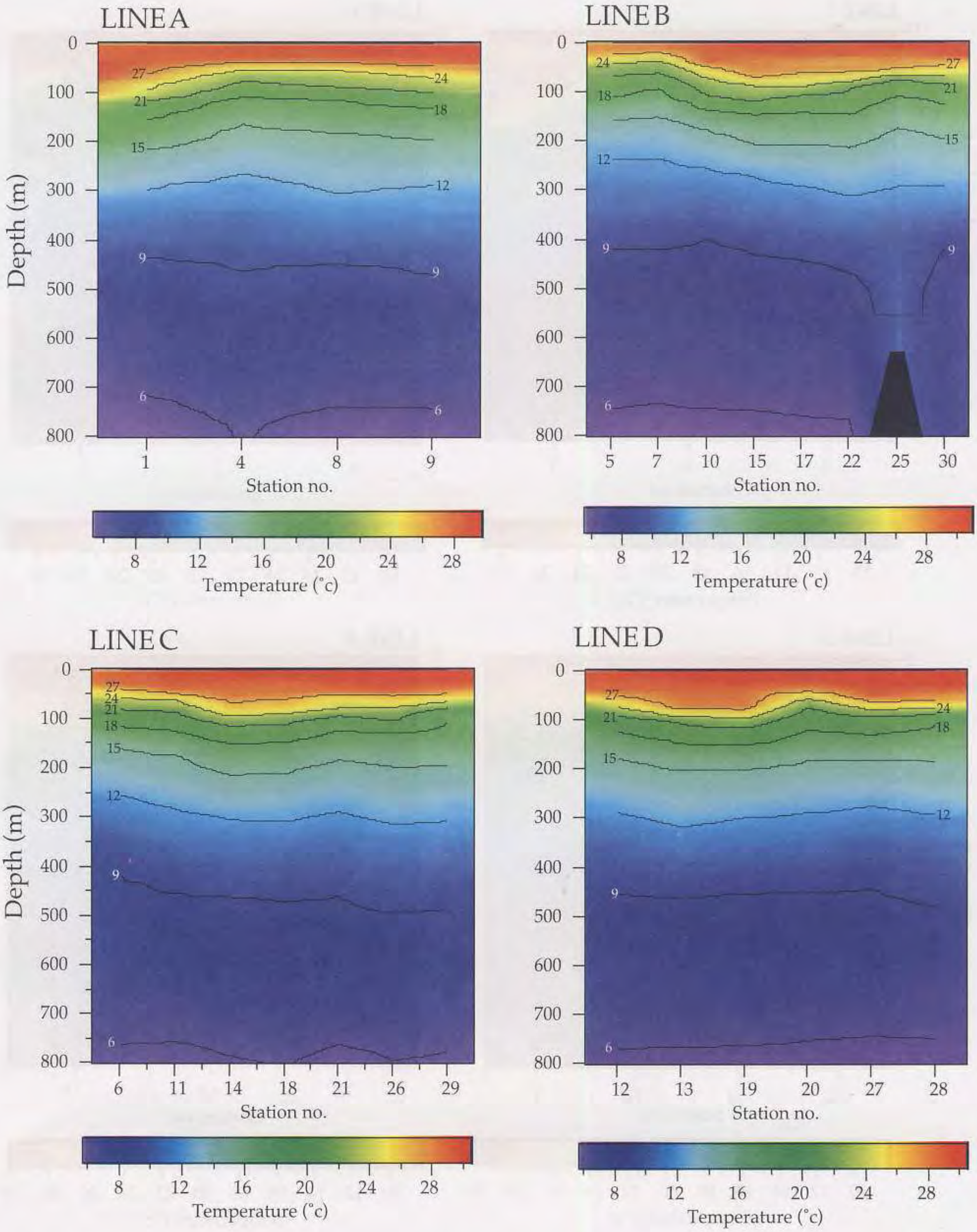


Fig. 32. Vertical distribution of temperature (3°c interval) at the cross section of LINE A, LINE B, LINE C, and LINE D in the Western Philippines during 17 April - 9 May 1998.

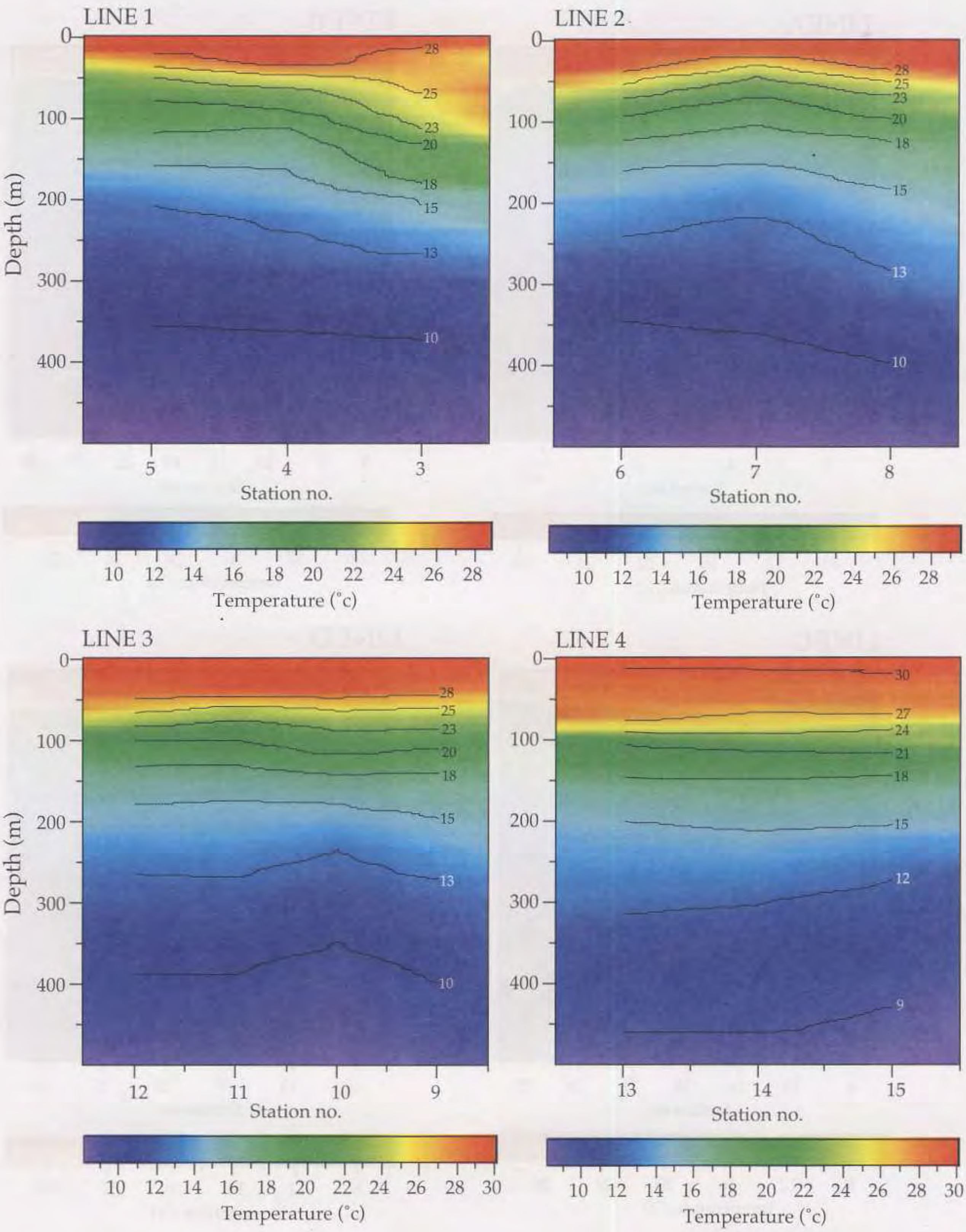


Fig. 33-1. Vertical distribution of temperature (3°c interval) at the cross section of LINE 1, LINE 2, LINE 3, and LINE 4 in the Western Philippines during 17 April - 9 May 1998.

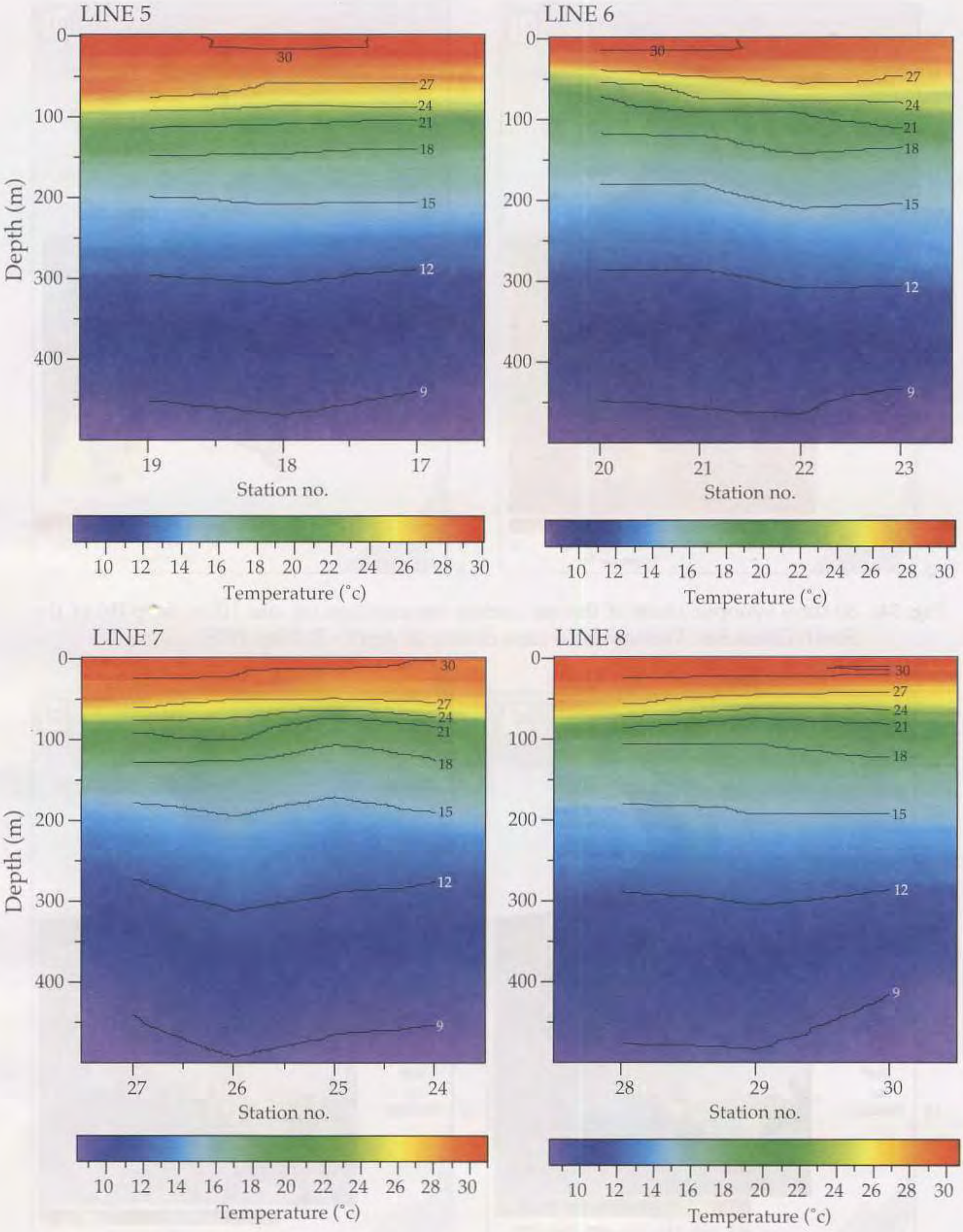


Fig. 33-2 Vertical distribution of temperature (3°c interval) at the cross section of LINE 5, LINE 6, LINE 7, and LINE 8 in the Western Philippines during 17 April - 9 May 1998.

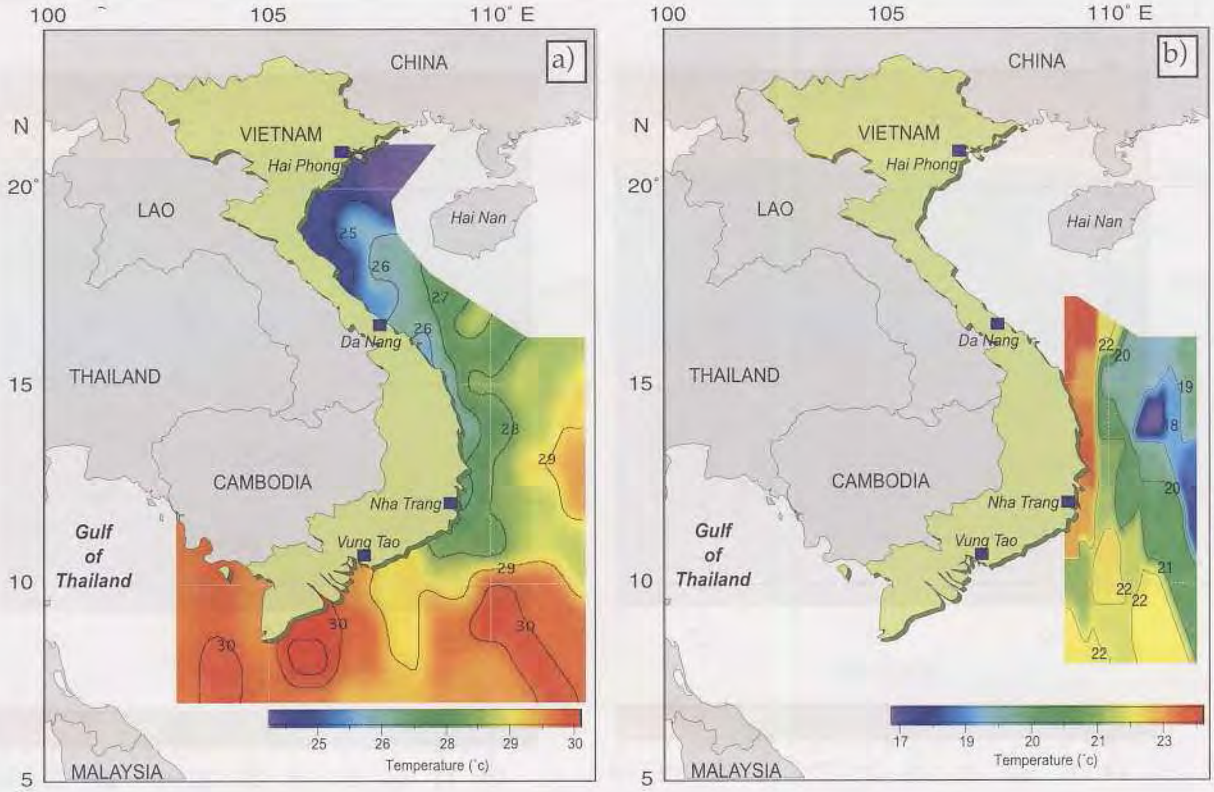


Fig. 34. 30 days synoptic chart of the sea surface temperature (a) and 100m deep (b) of the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

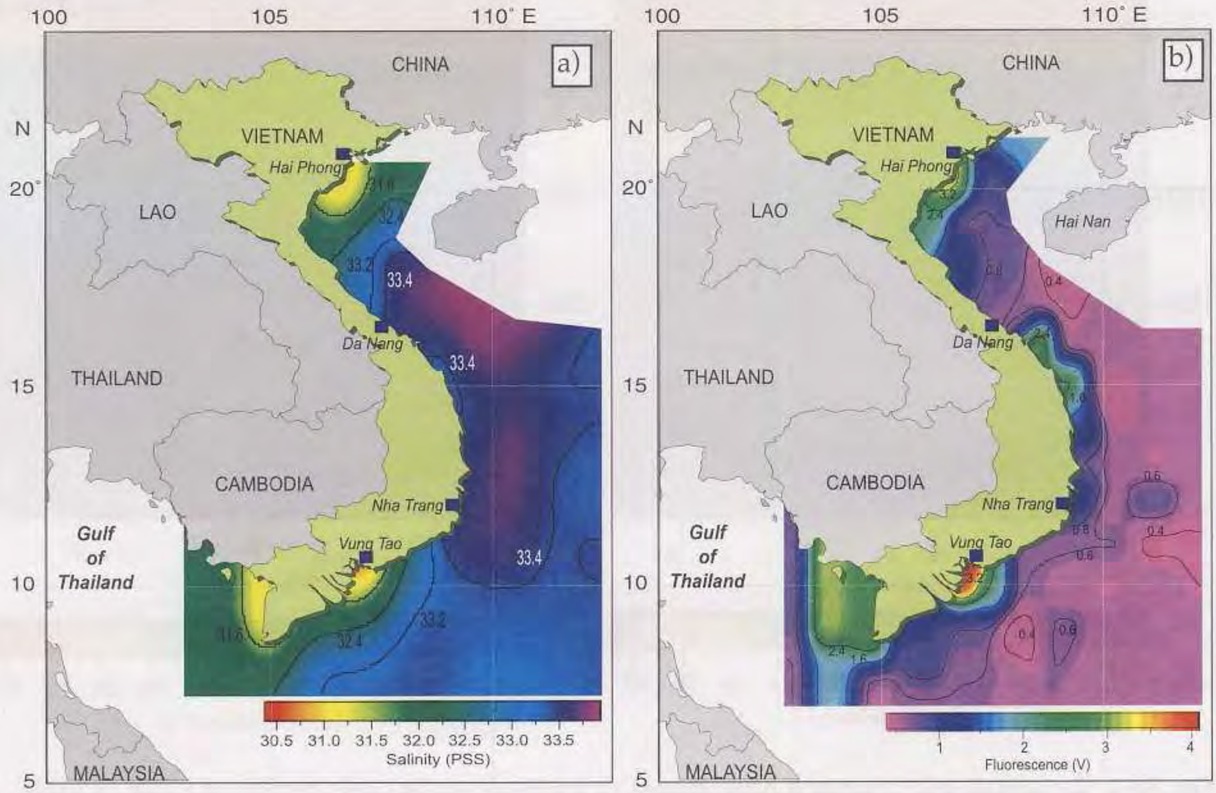


Fig. 35. 30 days synoptic chart of the salinity (a) chlorophyll a fluorescence value (b) at the sea surface in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

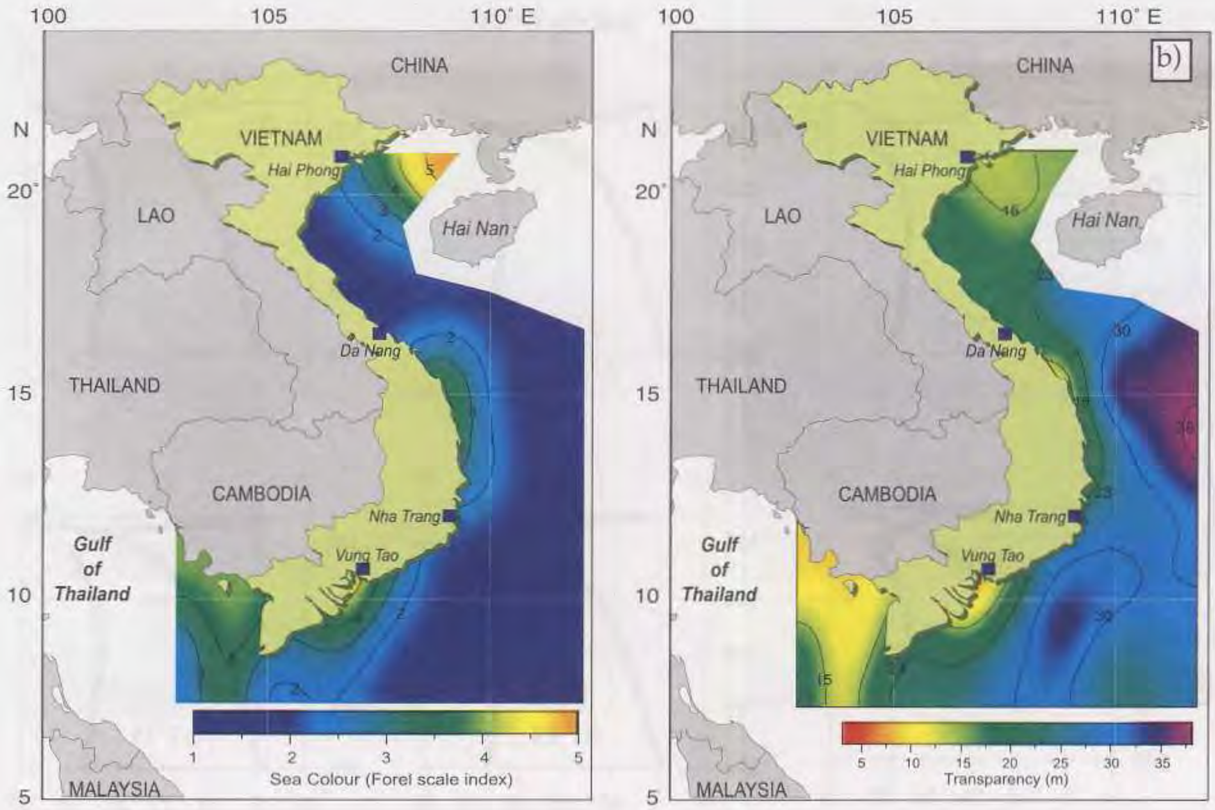


Fig. 36. 30 days synoptic chart of the sea color (a) transparency depth (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

(b) at the surface layer. The salinity showed a remarkable variation at the surface. Low salinity was observed in the north at Station # 1-4 and in the south particularly at the river mouth where the lowest value of about 31.6 PSS appeared. In the low saline water, it was found that the water temperature was almost homogeneous at around 30°c in the South and about 25°c in the north. These indicate the existence of a mixing layer. At the central area from Danang to NhaTrang, the salinity of the surface water was high at about 33.4 PSS. A water temperature variation was observed in the range between 26 and 29°C.

The fluorescence values at the sea surface were high and varied between 1.6 and 3.2V at the station near the shore especially at the river mouths off Haiphong, VungToa and Danang. In the central area, where the squid were caught, it was found that the fluorescence at the surface was low at about 0.4-0.6 V. This indicates that the fluorescence at the surface has no relationship to the fishing ground

By the results of water temperature and salinity distribution, it is clearly shown that water of high salinity was transported along the coast of Vietnam to the south by the northeast monsoon, so that the low saline water from the Mekong discharge was rapidly carried away by the strong currents off the coast.

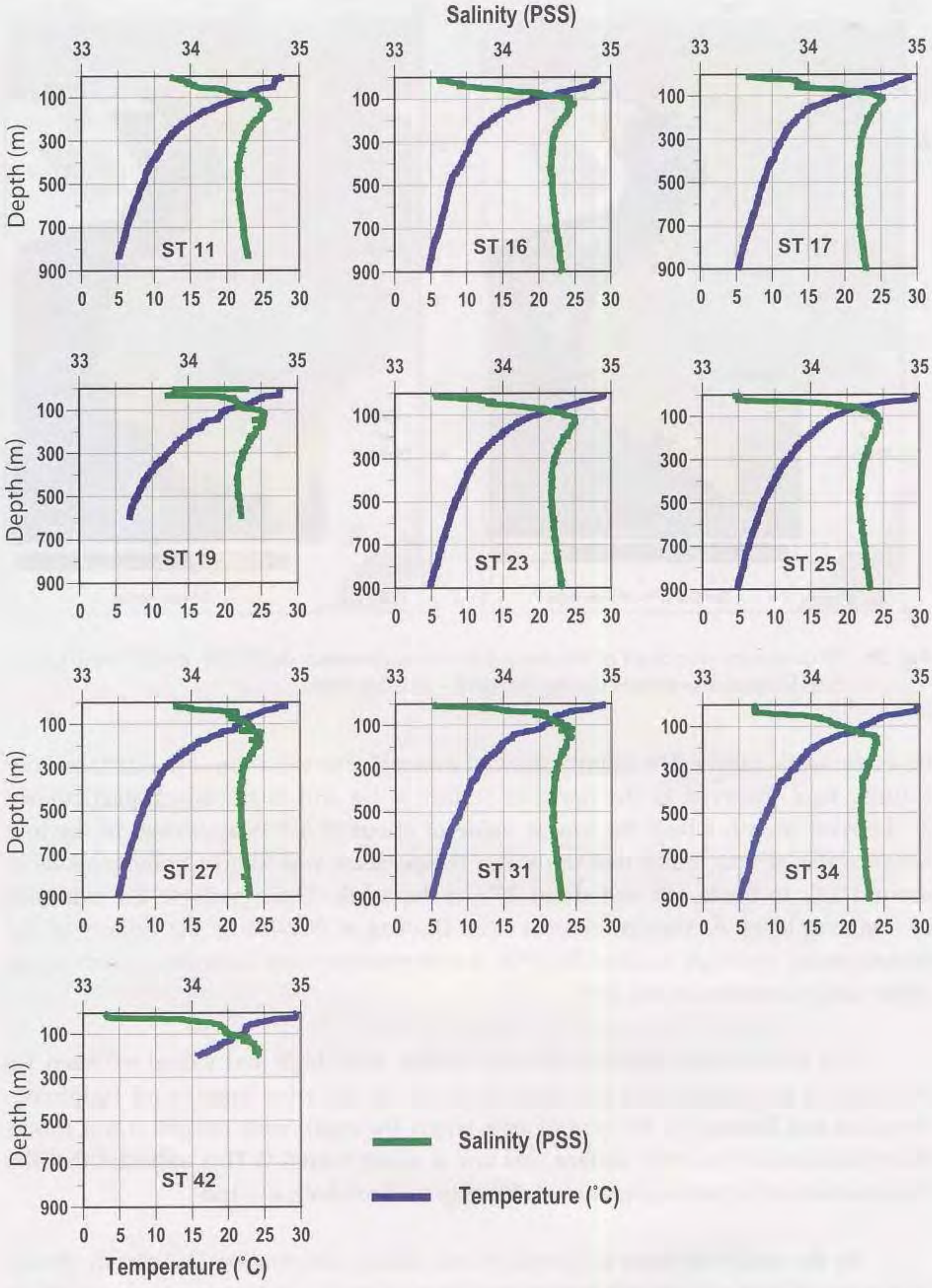


Fig. 37. Vertical profiles of the salinity and temperature of each squid samplings station in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

4.4.2.2 Horizontal Distribution of Transparency and Sea Color

Fig. 36 shows a horizontal distribution of the sea color (a) and the water transparency depth (b) of the survey area. The clear water with a water transparency depth value of more than 41m were found at St.#24 off NhaTrang and St.#40 off Vuntao. The water transparency depth in the Central area where fishing activities were carried out ranged between 30 and 38m. Comparisons with the catch results indicate that at the good fishing ground at Station #17 the transparency depth value was deep up to 38m.

4.4.2.3 Vertical Profiles of the Temperature and Salinity

Fig. 37 shows the vertical profiles of salinity and temperature varied by depth down to 900m at each fishing station. In these areas, it clearly shows that the mixed layer was very narrow and shallow and ranged from the sea surface down to about 15m. A permanent thermocline appeared at about 15m deep from the surface where the sea temperature was about 28°c in the north and 29.5°c in the south down to 1,500m deep where the sea temperature was about 2.9°c. Salinity from depths between the surface to 110m deep irregularly changed from 33.31 to 34.69 PSS, the salinity deeper than 110m slightly reduces from 34.47 PSS at the depth of about 300-500m deep, and then increases to be a constant of about 34.6 PSS.

4.4.2.4 Vertical Distribution of the Temperature and Salinity

Fig. 38 shows the vertical profile of the water temperature at LINE 1 and LINE 2 along longitude 110° and 111°E (see Appendix 3). The vertical profiles along the LINE 1 and LINE 2 indicate that the mixing layer did not change much being in a range from 15 to 45m for LINE 1 and 15m for LINE 2. Along LINE 1, the thermocline represented by 27°c was located at a depth of about 40m in the north from latitude 12° to 15°, while at a depth of about 25m, shallower by 15m, at latitude 11°N. Along LINE 2, the thermocline represented by 28°c was located at a depth of about 15m in the north to south of latitude 15°-11°N, while at 10°N, was at 35m.

Fig. 39 shows the vertical profile of salinity at LINE 1 and LINE 2 along longitude 110° and 111°E. Salinity showed remarkable variation near the sea surface. The results of the salinity profile showed a remarkable relationship to the water temperature. It was found that the upper layer surface (0-15m) where the water temperature was higher than 27°c the salinity was lower than 33.8 PSS. For the 24°c and 20°c water masses, the salinity was about 34.1 and 34.4 PSS, respectively.

Fig. 40 shows the vertical profile of temperature at LINE A, B, C and LINE D (see Appendix 3). Along all LINES, the position of the thermocline represented by 27°c and the thickness of the mixing layer showed significant west-east variation. Low temperatures of 27°c at the surface were found in the coastal areas and off shore at 29°c.

It is noted that the vertical profile of the temperatures along LINE 1, the upwelling of 18°c cold water moved upwards to 80m deep in longitude 111°E at Station #18. Because of this appearance, many squid were caught near the upwelling front/border in longitude 112°E at St.#17.

4.4.3 Sabah, Sarawak (Malaysia) and Brunei Darussalam Waters

4.4.3.1 Horizontal Distribution of the Temperature, Salinity and Fluorescence

Fig. 41 shows the horizontal distribution of the temperature at the surface layer (a) and 100m (b) in the survey area 3. Most of the temperatures ranged between 27.2° and 29.2°c at the surface and between 20.8° and 23.2°c at 100m deep. The surface temperature was high in the coastal areas off Brunei Darussalam and Bintulu of Sarawak (Malaysia). Cold water of 27°c at the sea surface and about 21°c at 100m deep was found at 6° N and 110° E, off Kuching. Another cold water rising up from the deep to near the surface layer was also found at 7°N and 112° 30'E where the temperature was around 21°c at 100m deep.

Fig. 42 shows the horizontal profile of salinity (a) and chlorophyll a fluorescence value (b) at the sea surface layer in the survey area. Low salinity of about 32 PSS and high fluorescence values were found at the sea surface in the coastal area off Brunei Darussalam and Kota Kinabaru, Sabah (Malaysia). High fluorescence values were found in the waters off Brunei Darussalam at 5° 30'N and 114°E, and at 7°N and 112° 30'E where the cold water rises up from the deep.

4.4.3.2 Horizontal Distribution of Water Transparency and Sea Color

Fig. 43 shows a horizontal distribution of the water transparency (m) and sea color reference to forel scale index in the survey area. The seawater was very clear with a transparency depth of about 34m at 6°N and 113°E in the waters of Brunei Darussalam between the low transparency depth near shore and at 7°N and 112° 30'E.

4.4.3.3 Vertical Profiles of the Temperature, Salinity, and Fluorescence

Fig. 44 shows the vertical profile of the fluorescence, Temperature and Salinity parameters varied by depth at all sampling stations. In the survey area, the surface

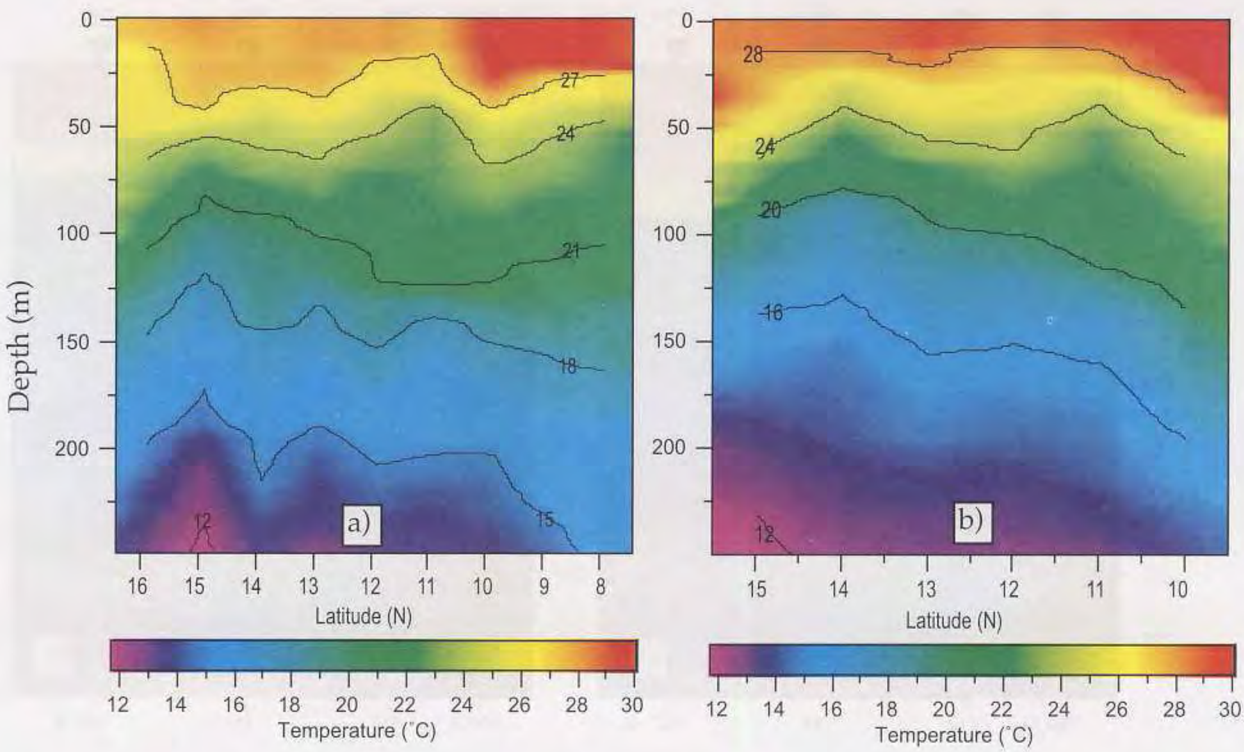


Fig. 38. Vertical distribution of the temperature at the cross section of LINE 1 (a) and LINE 2 (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

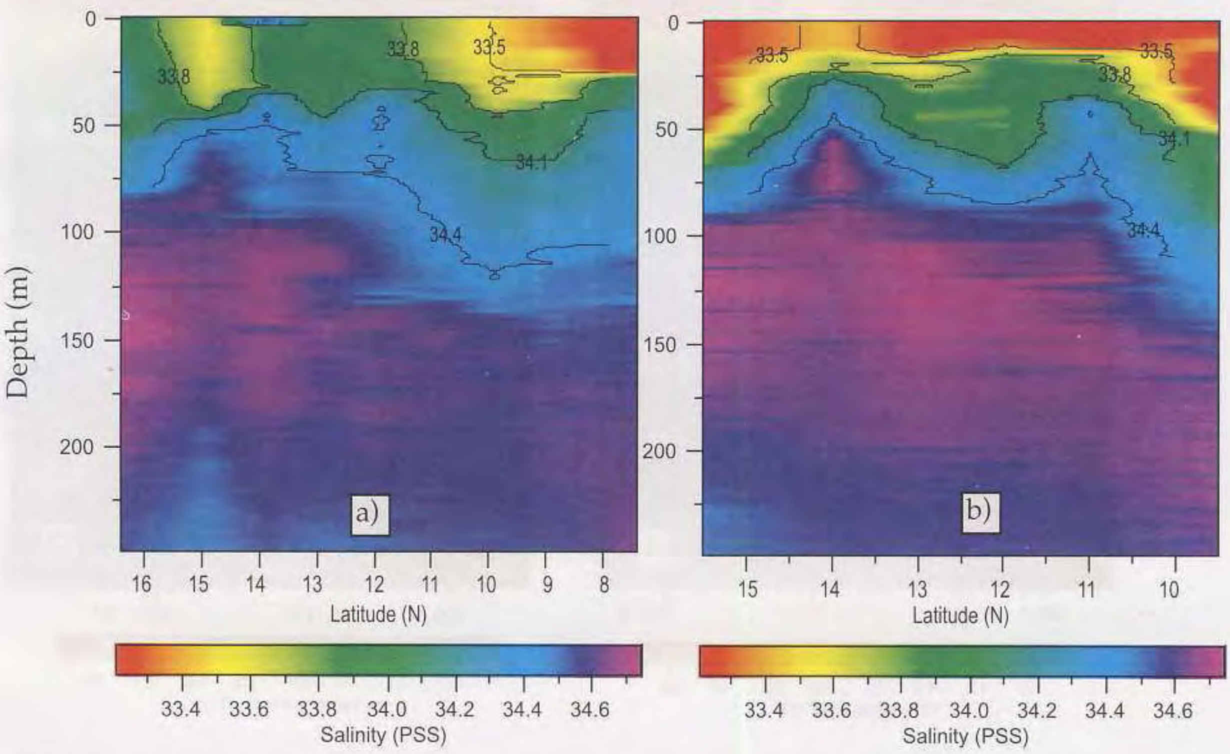


Fig. 39. Vertical distribution of the salinity at the cross section of LINE 1 (a) and LINE 2 (b) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

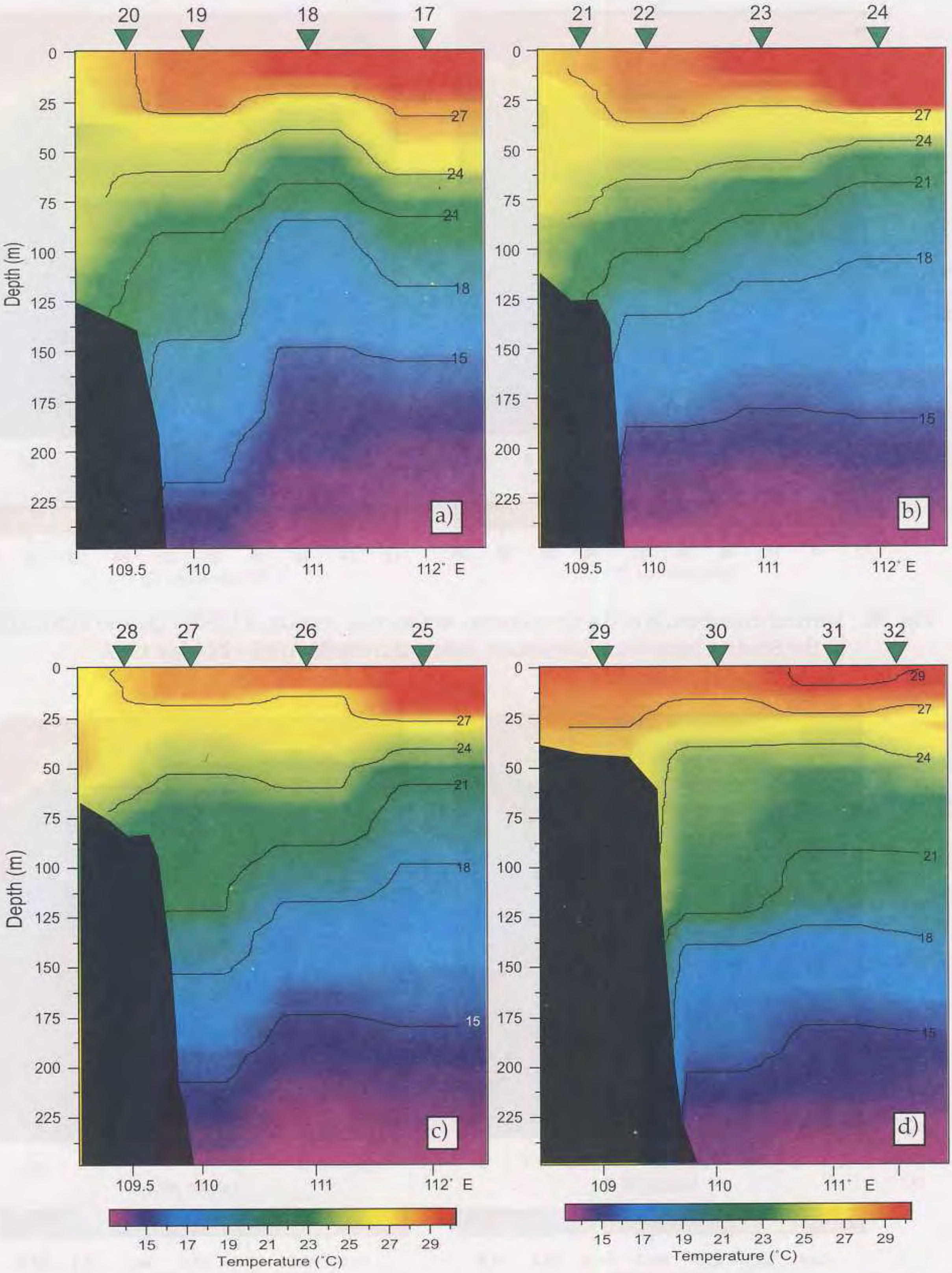


Fig. 40. Vertical distribution of the temperature (3°c interval) at the cross section of LINE A (a), LINE B (b), LINE C (c) and LINE D (d) in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

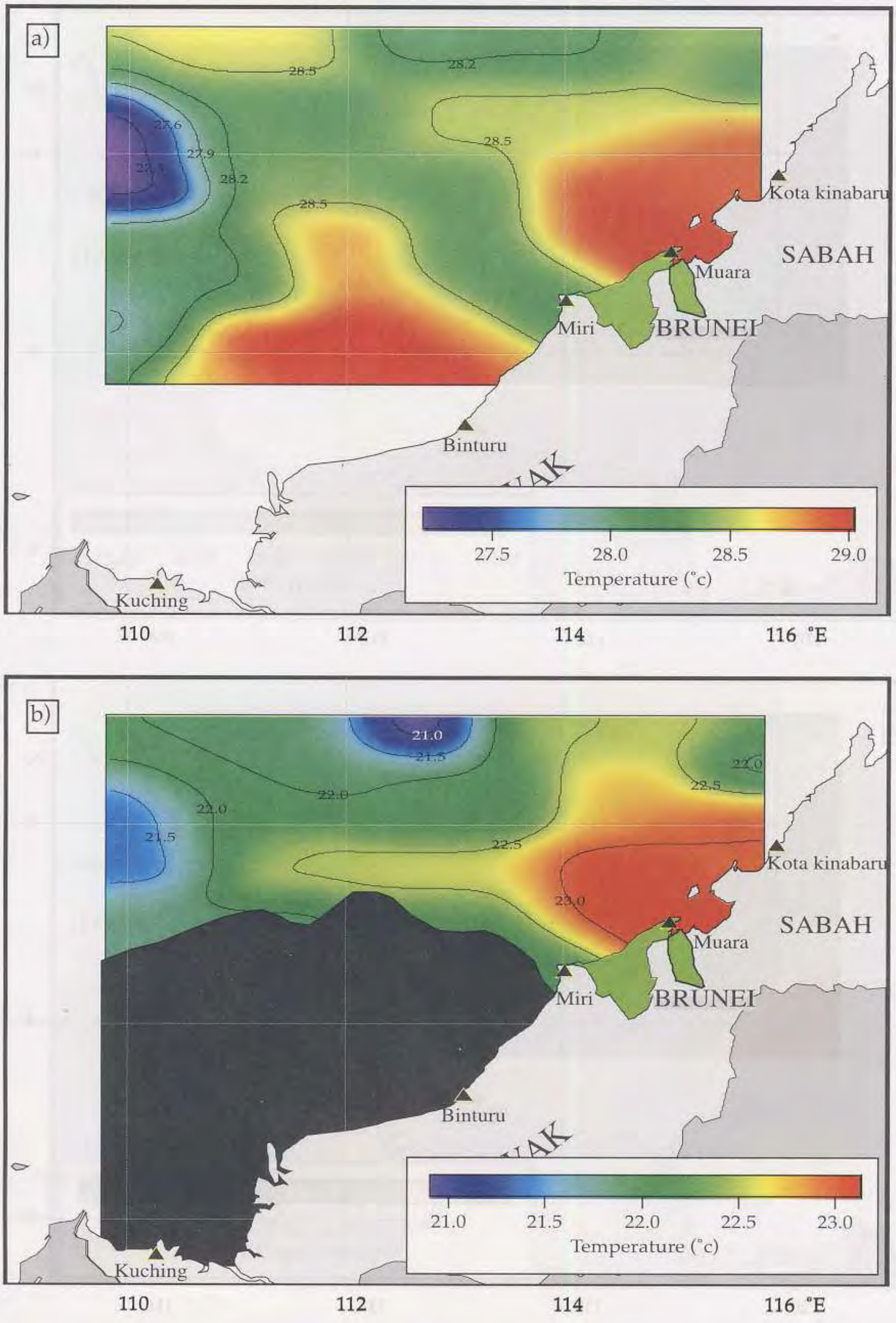


Fig. 41. 20 days synoptic chart of the sea surface temperature (a) and 100m deep (b) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.

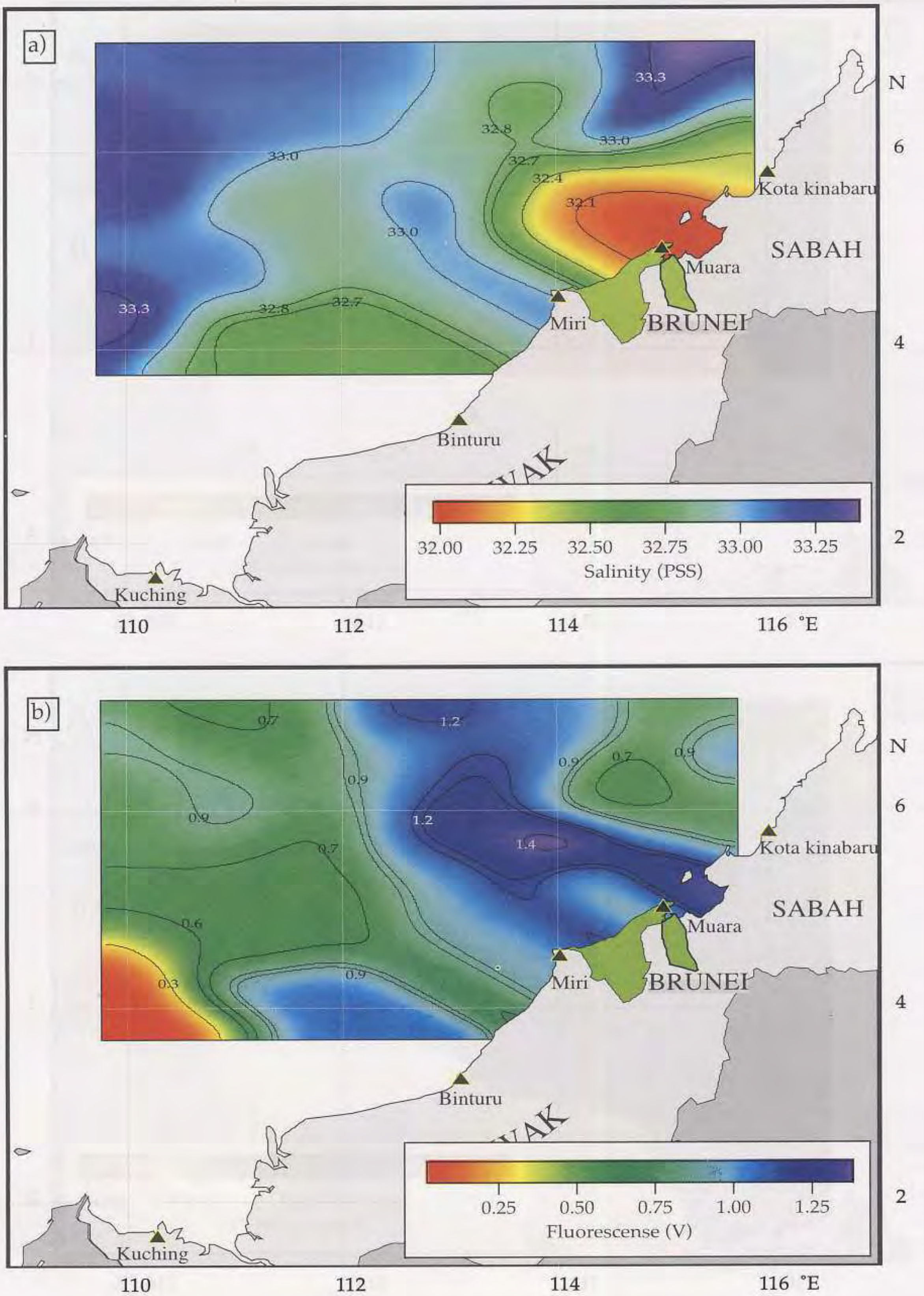
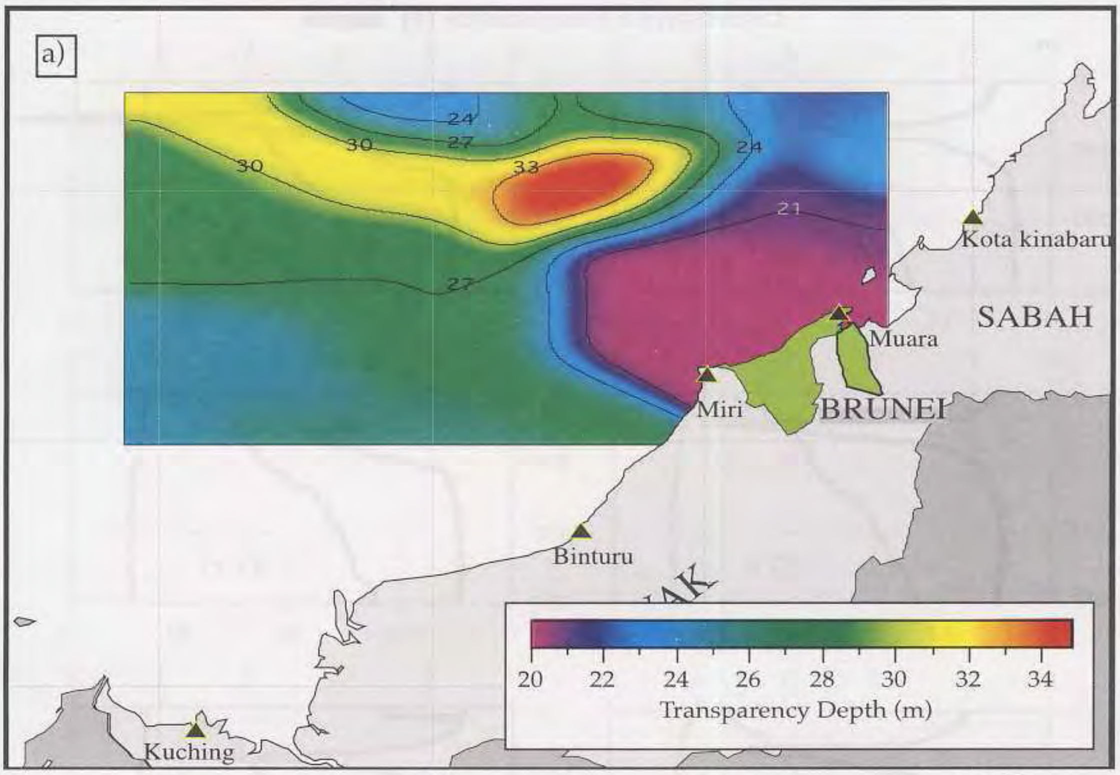


Fig. 42. 20 days synoptic chart of the salinity (a) and chlorophyll a fluorescence value (b) at the surface layer of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.



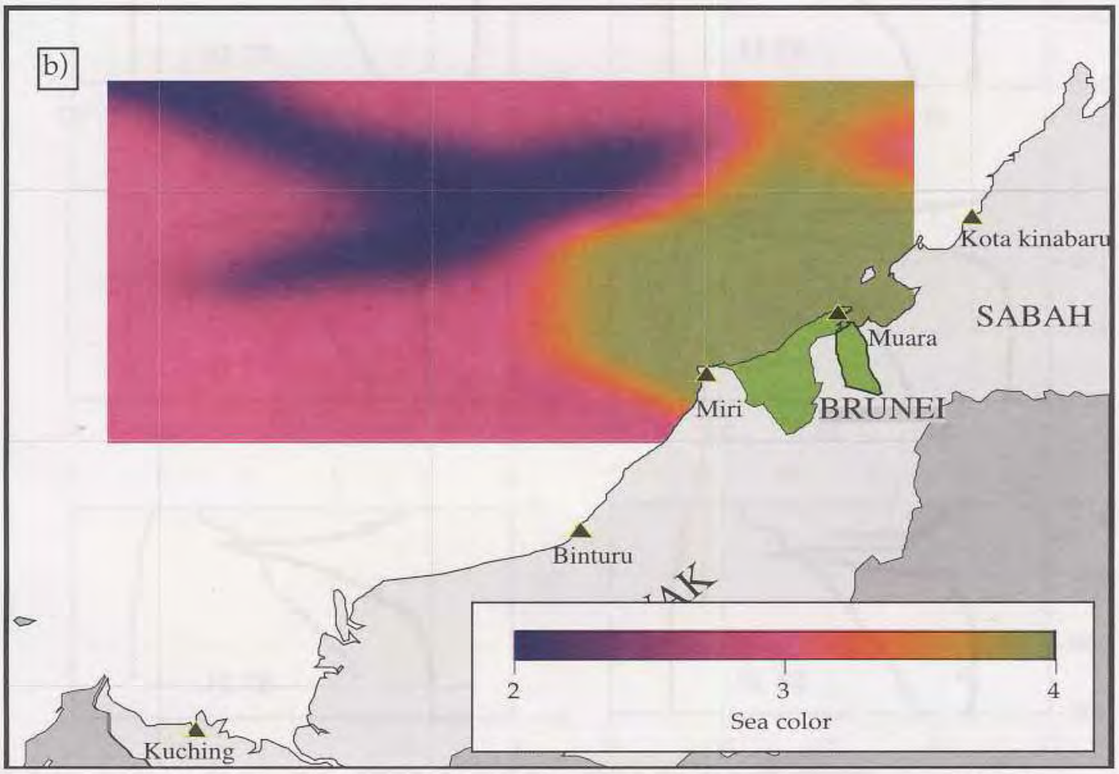


Fig. 43. 20 days synoptic chart of the water transparency depth (a) and sea color value (forel scale index) at the surface layer of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.

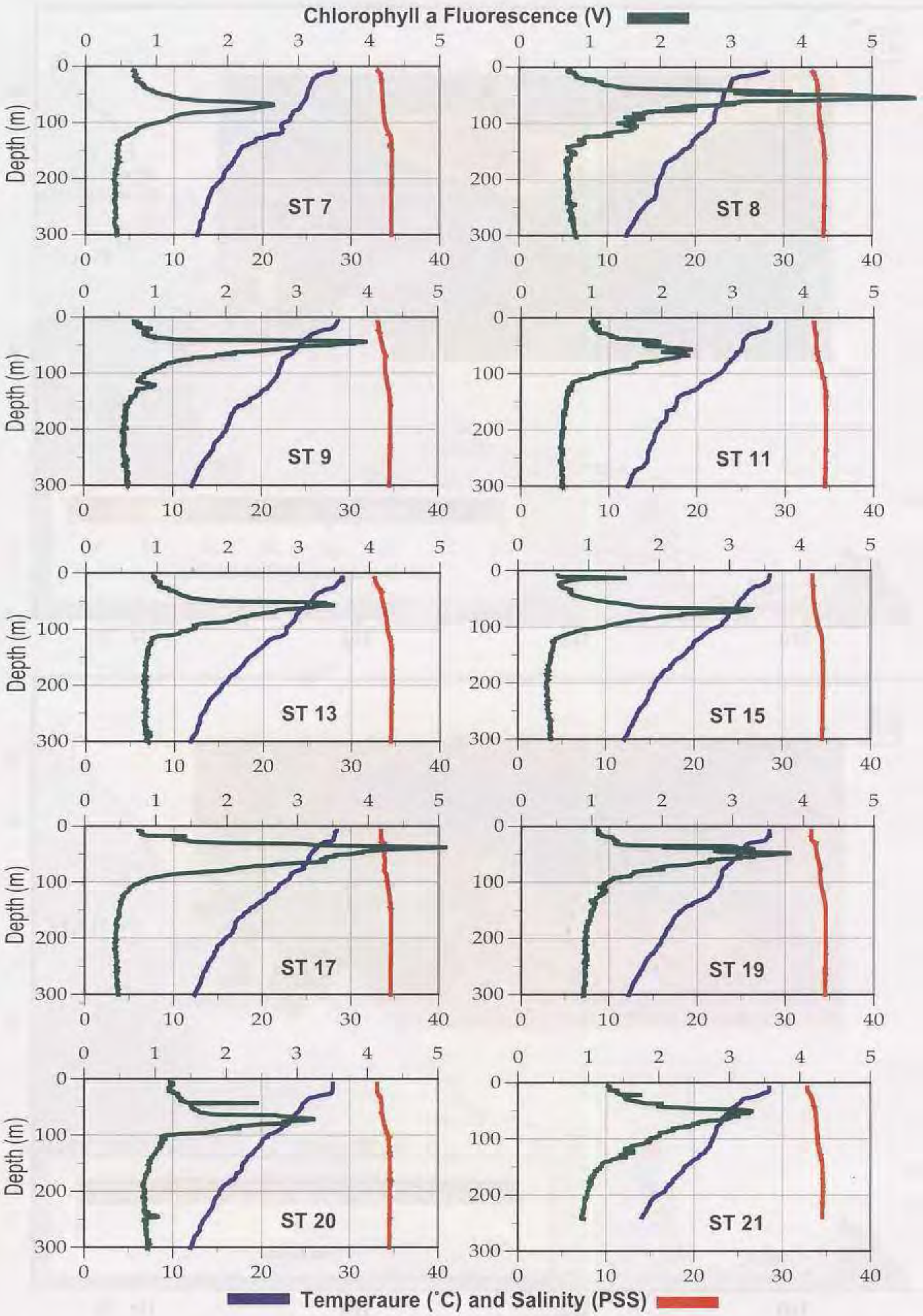


Fig. 44. Vertical profiles of the salinity and temperature and chlorophyll a fluorescence value at squid samplings station of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.

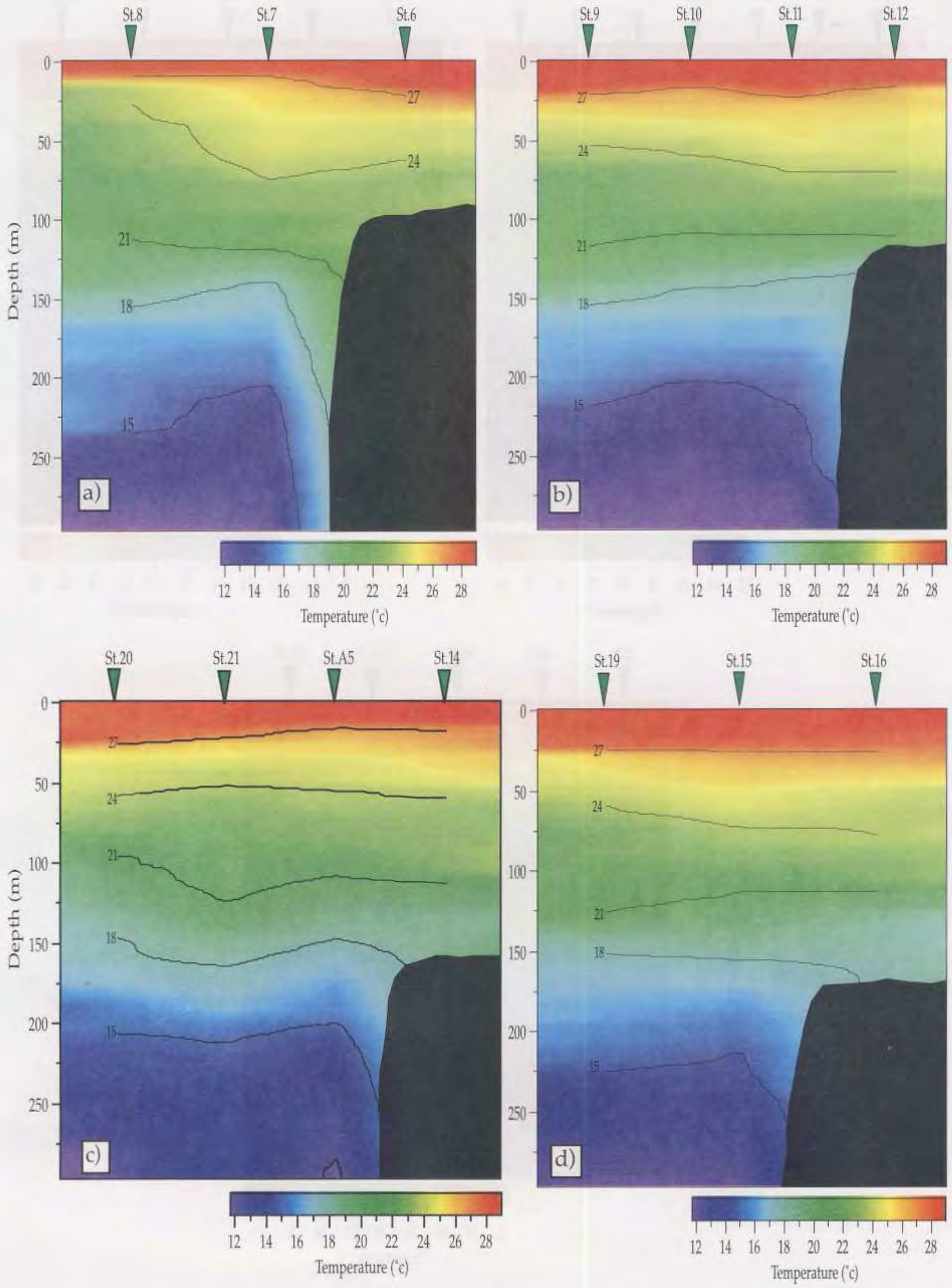


Fig. 45. Vertical distribution of the temperature (3°c interval) at the cross section of LINE A (a), LINE B (b), LINE C (c) and LINE D (d) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.

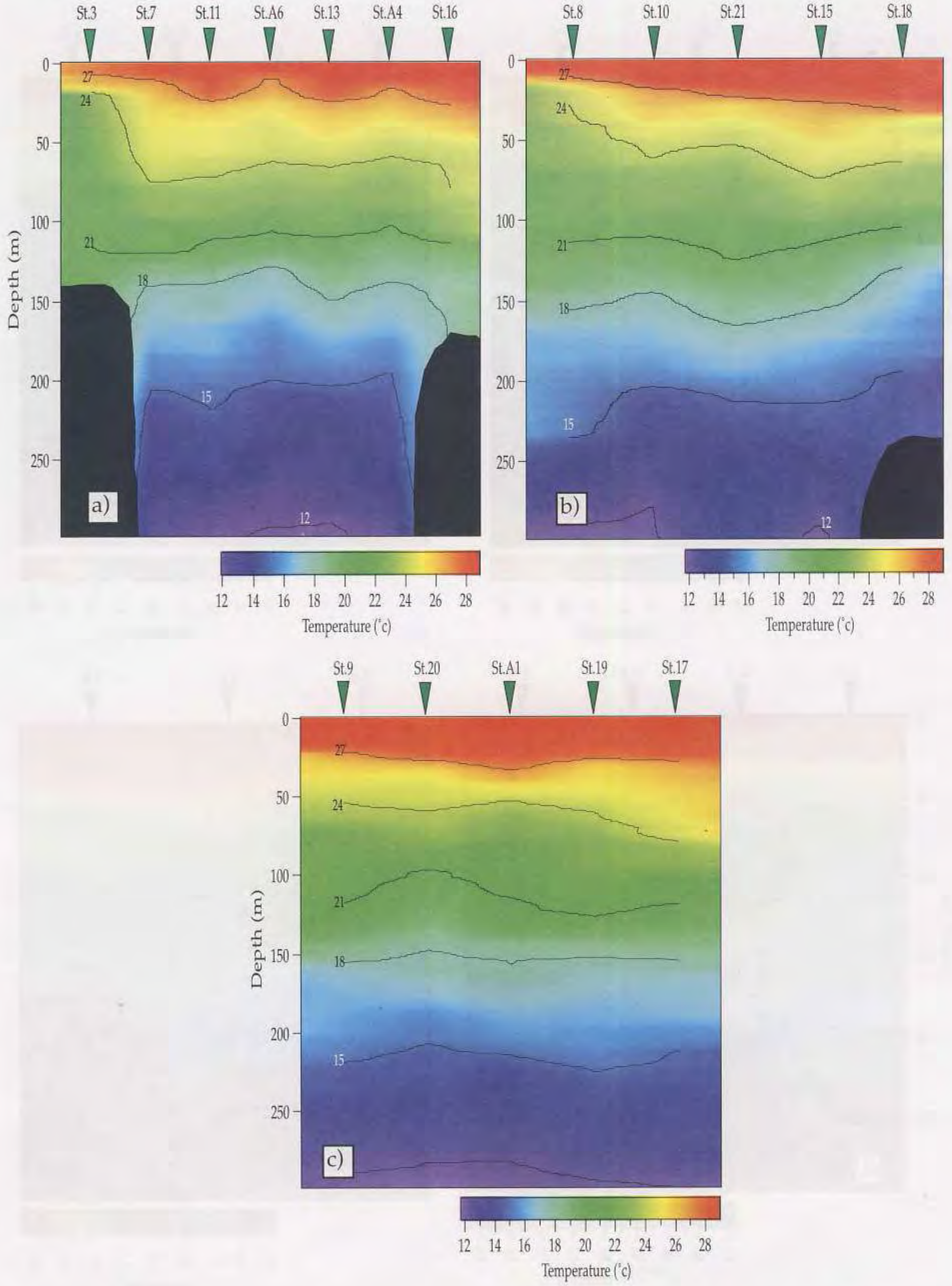


Fig. 46. Vertical distribution of the temperature (3°c interval) at the cross section of LINE 1 (a), LINE 2 (b), and LINE 3 (c) of the South China Sea: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters during 20 March - 8 April 2000.

mixed layer depth was a very narrow layer at all squid sampling stations at the depth observed from the surface down to around 10-25m. A seasonal thermocline layer appeared at about 25m down to about 50m where the temperature changed from 28.5 to 24.0°C. The permanent thermocline was observed at a depth greater than 100m where the temperature was about 23.0°C.

Chlorophyll a fluorescence value was observed between 0.7 and 1.3 V at the surface. The fluorescence maximum was found at depths between 60 and 80m whereas the fluorescence value ranged between 2.5 and 5.8 V. High fluorescence was found at sampling station nos. 8 and 17.

Salinity at the depth between the surface and 150 m slightly increased from 33.15 to 34.54 PSS, the salinity deeper than 150m was almost constant at about 34. 5 PSS.

4.4.3.4 Vertical Distribution of the Temperature

Fig. 45 shows the vertical distribution contour of temperature at LINE A, LINE B, LINE C and LINE D (see Appendix 4). The vertical profiles along the LINE A, B, C and LINE D indicate that the 27°C contour line was observed at depths between 12m and 25m, and it was between 50m and 75m for the 24°c contour line except for the St.# 8 in which a low temperature of 24°c was found at the depth of 25m. The 21°C and 18°C contour lines were observed at depths between 100m and 125m and between 145m and 165m, respectively. Below 200m deep, the temperature was lower than 15°C.

Fig. 46 shows the vertical distribution contour of temperature at LINE 1 to LINE 3 (see Appendix 4). The result was as same as that shown in **Fig. 45**. No significant upwelling was found in this survey area.

4.5 Angling Depth

From sight observation it was found that the squid have an aggregative nature and positive phototaxis. They, sometimes, came up to the surface at night to feed. A school of this squid was not great in number, at around 30-50 individuals.

The results from fishing trials by automatic squid jigging gear found that the purpleback flying squid, *S. oualaniensis* are scattered, covering the entire area of the South China Sea and are generally caught at depths ranging from the surface down to 200 m at night. **Fig. 47** shows the echo traces of the purpleback flying squid and sinker observed from the dual frequencies of the colour echo sounder at 200 Hz. The abundance depth of the squid ranged between 50m and 100m where some of them were caught and identified as *S. oualaniensis.*

During fishing at night the quantum light intensity at 50m deep (I_z) was measured to be $0.048\mu Em^{-2}s^{-1}$. From the Jerlov's equation, the existing depth of the *S. oualaniensis* in day time can be computed to be at about 350m deep where the light intensity at the surface (I_0) was observed to be about $200\mu Em^{-2}s^{-1}$. In daytime, the optimum light intensity of the squid (I_z) was $0.048\mu Em^{-2}s^{-1}$ and the attenuation coefficient (k) was 0.01 m^{-1} obtained from the experiment. This information is very useful for daytime fishing.

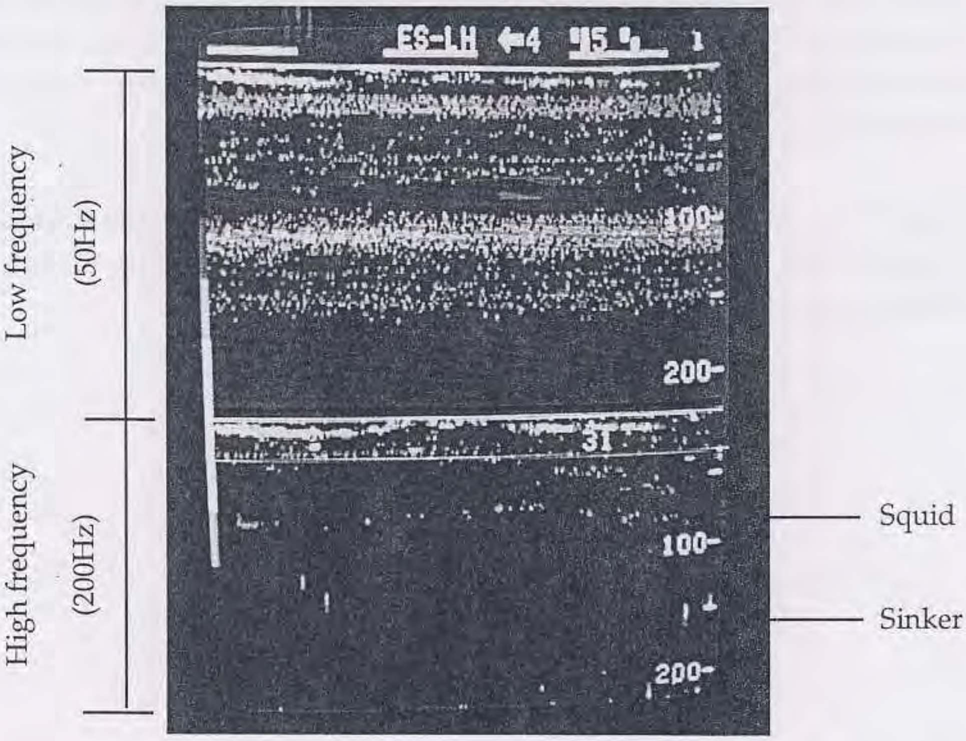


Fig. 47. Echo traces of the purpleback flying squid and sinker observed from the dual frequencies of colour echo sounder at 200 Hz.

4.6 Lunar Effects

Fig. 48 shows the results of catch *S. oualaniensis* in CPUE from each survey area in the South China Sea plotted in relation to percentage of moon illumination referred by phases of the moon. High CPUEs were observed during a period of the last quarter to the new moon wherein the moon illumination is less than 60%. A similar result was reported by Nakamura *et al.*(1992) showing that the oceanic squid species are generally active on feeding under dim light or less illumination from the moon. However, it will also depend upon the fishing ground conditions.

Consideration of the results from the western Philippines waters found that the good fishing grounds, for example, the station nearby the upwelling area is more important than the influence of moonlight or phases of the moon. It was observed that at sampling St. #11, the catch in CPUE was still high although sampling was in a period of waxing gibbous to full moon during which the percentage of illumination is more than 90%.

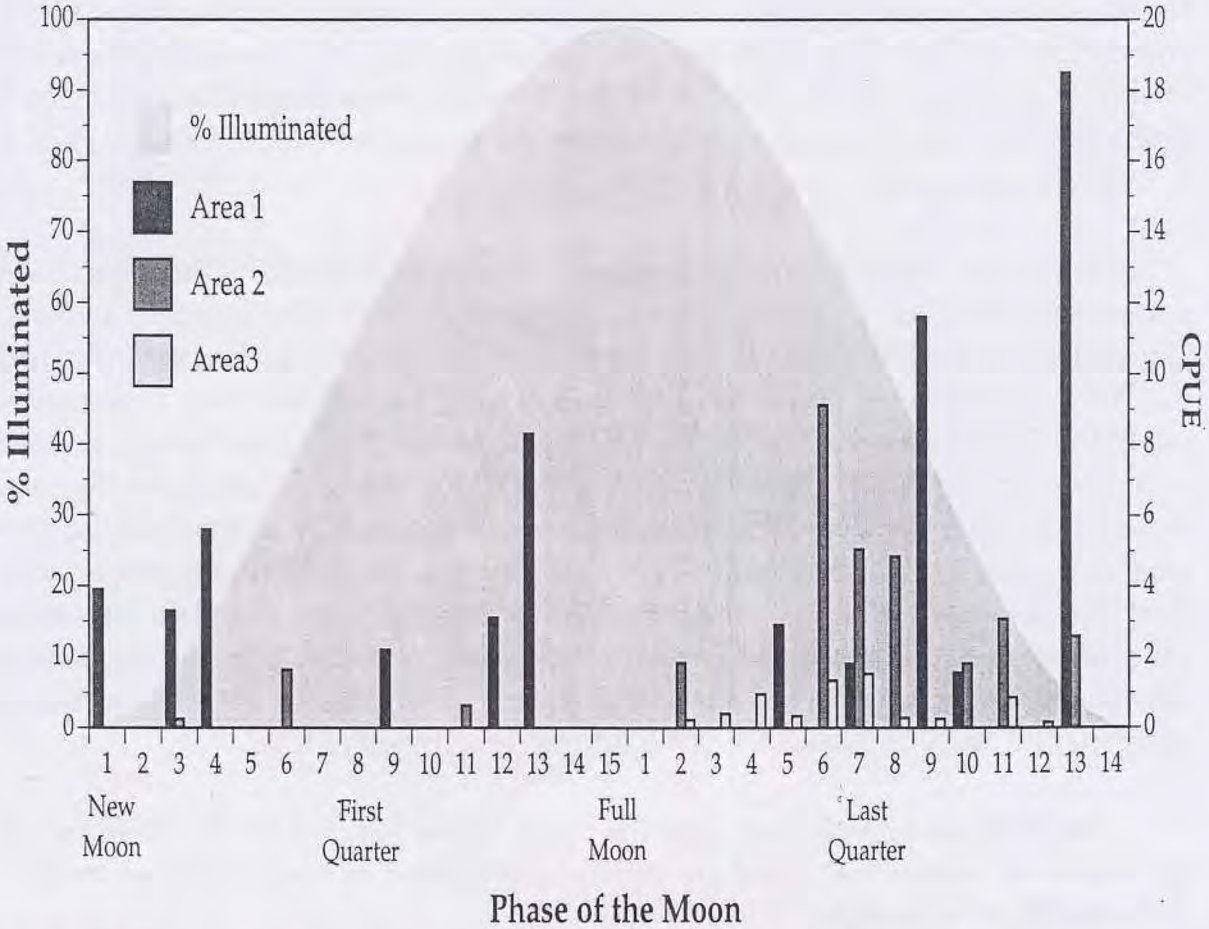


Fig. 48. Relationship between the result of catch in CPUE and phase of the moon referred to the percent of illumination from the moon in different survey area in the South China Sea.

5. Discussion

Sthenoteuthis oualaniensis (Lesson, 1830) is a large pelagic squid, for which jigging fisheries have ever been undertaken in Okinawa, Philippines, Taiwan and Vietnam on a small scale. The general biological information has been thoroughly reviewed by Young (1978) followed by Okutani & Tung (1978). Nesis (1977) first claimed that *S. oualaniensis* consists of different "superpopulations", viz. those matured at different size and exhibiting some morphological and distributional differences as well. He confirmed the existence of individuals that have no dorsal photogenic patch since Clarke (1965) had first reported such form. These are currently recognized as different species, than infraspecific variability (Roeleveld, 1982).

Exploratory fishing by the R/V Shoyo-Maru in 1976 in the Indian Ocean discovered another population of giant purpleback flying squid, *S. oualaniensis* attaining over 42cm ML. This population was re-investigated by Yatsu *et al.* using the same ship. Nesis (1993) called the three types of *S. oualaniensis*, "the dwarf (photophoreless)", "the middle size (most common)" and "the giant (Red and Arabian Seas)". As was posed by Nesis (1993), the genetic/phylogenic relationships among populations and infra- or supra-specific microevolution of *S. oualaniensis* are still unsolved questions. Consideration of the *S. oualaniensis* caught from the South China Sea, there were only two types namely the dwarf and middle size. No giant *S. oualaniensis* was found.

Silas *et al.* (1982) reported seven oceanic squids in the Indian Ocean, including *Eucleoteuthis luminosa, Todarodes angolensis, Nototodarus sloani, Ommastrephes bartramii, Thysanoteuthis rhombus, Onychoteuthis banksi* and *Sthenoteuthis oualaniensis,* of which the latter was the most dominant. Few studies on *S. oualaniensis* have been carried out in the South China Sea. Under the SEAFDEC Fishery Resources Survey on the *S. oualaniensis* in the South China Sea during 1998-2000, the results indicate the same dominance of *S. oualaniensis*. This species was found to distribute on the shelf and shelf edge of the South China Sea basin where as the bottom topographical depth are more than 150m as shown in **Fig. 49**. Under this survey, Labe (1999) estimated the biomass of the *S. oualaniensis* in the waters of western Philippines to be 283 thousand metric tons; the density was everaged to be 7.2 ton/km^3, where as the abundant area was as high as 26.4 ton/km^3 in 17-18°N and 117-119°E during the summer of 1998.

We have no growth data from the South China Sea, but the *S. oualaniensis* in the Hawaiian waters was found by Bizikov (1991: cited in Nesis, 1993) as reaching 22-26cm ML in 7-8 months.

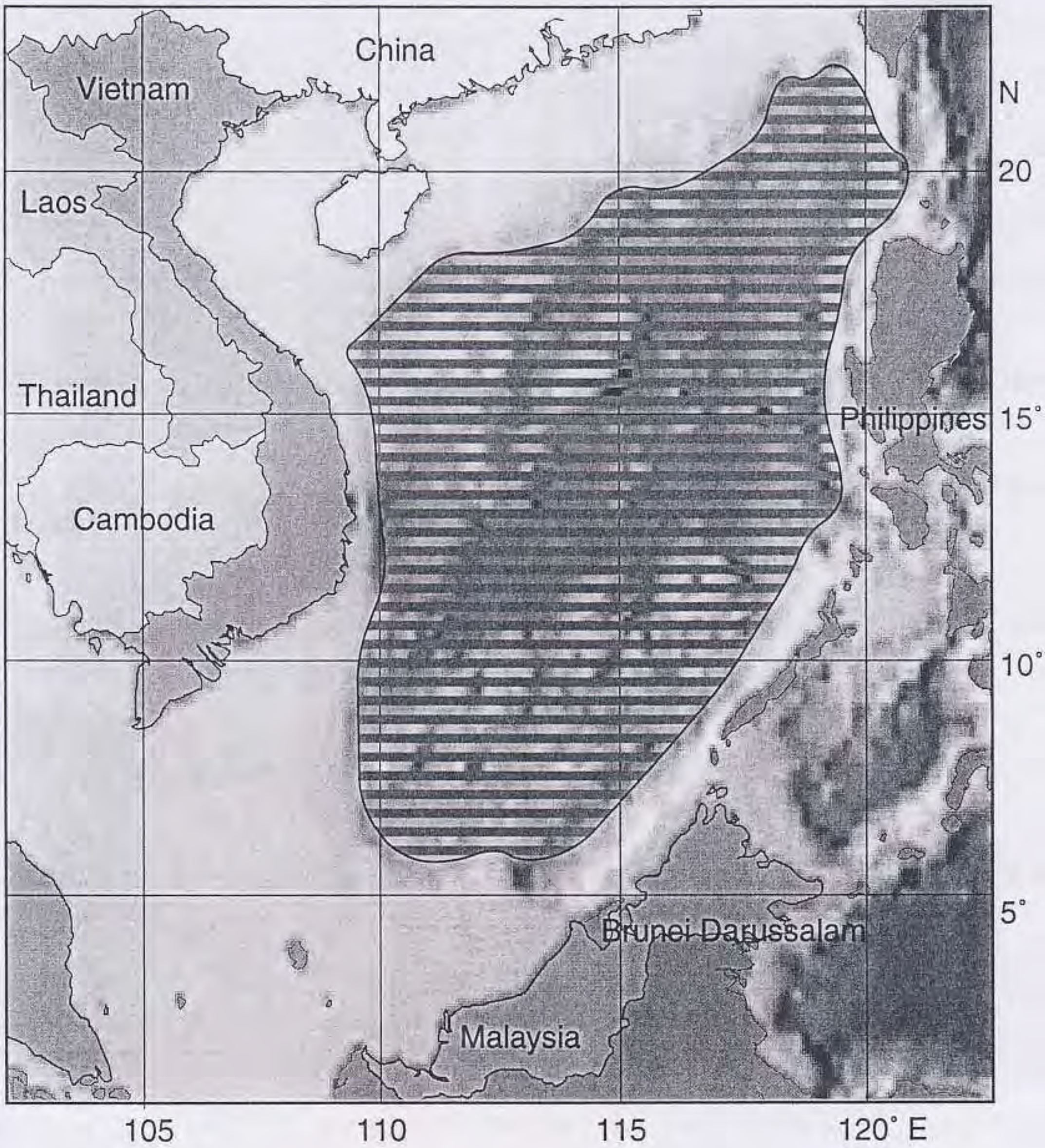


Fig. 49. Distribution of the *Sthenoteuthis oualaniensis* in the South China Sea.

Acknowledgments

I wish to thank the Secretary General of SEAFDEC, Mr. Panu Tavarutmaneegul for his fully support to make this project possible, and the crew of MV SEAFDEC for their excellent assistance and support to this work. I am greateful to Dr. Anuwat Nateewathana and Ms. Jutamas Jivaluk for help in sampling and biological analysis of the specimens and paralarvae. I also thank Dr.Yuttana Theparoonrat and Mr. W.R.B. Elstow for their suggestions to improve the manuscript.

References

______. 1998. The Marine Resources Study in Vietnam. Fuyo Ocean Development & Engineering.

Adam, W., 1954: Cephalopoda. Part 3. IV –Cephalopodes a l'exclusion des genres Sepia, Sepiella et Sepioteuthis. -Siboga-Expeditie 55c: 123-193

Brunetti, N. E., 1990: Description of rhynchoteuthion larvae of *Illex argentinus* from summer spawning subpopulation. *J. Plankton Res.*, 12: 1045-1057.

Chikuni, S., 1983: Cephalopod resources in the Indo-Pacific region. In: Caddy, J.F. (ed.). Advances in assessment of world cephalopod resources. pp. 264-305. FAO Fisheries Technical Paper 231.

Clarke, M.R., 1965: Large light organs on the dorsal surfaces of the squids *Ommastrephes pteropus, Symplectoteuthis oualaniensis* and *Dosidicus gigas*. Proceeding of the Malacology Society of London 36(5): 319-321.

Dong, Z., 1963: A preliminary taxonomic study of the Cephalopoda from Chinese waters. Studia Marina Sinica, 4:125-162.

FAO, 1983: Advance in assessment of world cephalopod resources. FAO Fish. Tech. Paper 231.

Japan Marine Fishery Resource Research Center, 1977: Report of feasibility study on squid jigging fisheries in the southwestern pacific Ocean, JAMARC Rep., (18):163 p.

Jerlov, N.G., 1976: Marine optic. Elsevier, Amsterdam, pp.127-150.

Kubodera, T. and Okutani, T., 1981: The Systematics and Identification of Larval Cephalopods from the Northern North Pacific. *Res. Inst. Pac.Fish.*, Hokkaido Univ., Special vol.: 131-159.

Labe, L. L., 1999: Catch rate of oceanic squid by jigging method in the Western Philippines, in the Proc. of the 3rd. Tech.Sem. on Marine Fisheries Resources Survey in the South China Sea, Area III: Western Philippines. Spcial Paper No. SEC/SP/41. SEAFDEC, Bangkok, pp.19-31.

Lesson, R.P., 1830: Mollusques. In: Lesson, R.P. & P. Garnot. 1826-1830. Zoologie du voyage autour du monde sur la Coquille pendant 1822-25 Par M.L.I. Duperry, etc. 2:239-246. Paris.

Nakamura, Y. and Siriraksophon, S., 1992: Ecological Aspects of the Neon flying squid *Ommastrephes bartramii* in summer off the west coast of the US. Nippon Suisan Gakkaishi, 58(10), 1918-1825.

Nateewathana, A., 1997: Two species of oceanic squids from the Andaman Sea, Indian Ocean. Phuket Marine Biological Center Special Publication 17(2): 453-464.

Nateewathana, A., Munprasit, A. and Dithachey, P., 1999: The Systematics and Distribution of Oceanic Cephalopods, in the Proc. of the 3rd. Tech.Sem. on Marine Fisheries Resources Survey in the South China Sea, Area III: Western Philippines. Spcial Paper No. SEC/SP/41. SEAFDEC, Bangkok, pp.76-100.

Nesis, K.N., 1977: Geographical groups of pelagic cephalopods in the western tropical Pacific. Trudy Inst. Okeanol. Acad. Sci. USSR. 107: 7-14.

Nesis, K.N., 1987: Cephalopods of the World. T.F.H. Publications, Inc. ltd. New Jersey. 351 pp.

Nesis, K.N., 1993: Population structure of oceanic ommastrephids, with particular reference to *Sthenoteuthis oualaniensis*: a review. In: Okutani, T., R.K. O'Dor & T. Kubodera (eds.) Pp. 375-383. Recent advances in Fisheries Biology. Tokai University Press, Tokyo.

Okutani, T., 1966: Studies on Early Life History of Decapodan Mollusca-II. Planktonic Larvae of Decapodan Cephalopods from the Northern North Pacific in Summer Seasons during 1952-1959. *Bull. Tokai Reg. Fish. Res.Lab.*, 45: 61-79.

Okutani, T., 1968: Studies on Early Life History of Decapodan Mollusca- III. Systematics and Distribution of Larvae of Decapod Cephalopods Collected from the Sea Surface on the Pacific Coast of Japan, 1960-1965. *Bull. Tokai.Reg. Fish. Lab.*, 55: 9-57.

Okutani, T., 1980: Useful and latent cuttlefish and squids of the world. Tokyo, National Cooperative Association of Squid Processors, 66p.

Okutani, T. and McGowan, J. A., 1969: Systematics, Distribution and Abundance of the Epiplanktonic Squid (Cephalopoda, Decapoda) Larvae of the California Current April, 1954-March, 1957. *Bulletin of the Scripps Institution of Oceanography*, University of California Press, Vol. 14, 90 p.

Osako, M. and Murata, M., 1983: Stock assessment of cephalopod resources in the Northwestern Pacific. In: Caddy, J.F. (ed.). Advances in assessment of world cephalopod resources. pp. 55-82. FAO Fisheries Technical Paper, 231.

Okutani, T. and Tung, I. H., 1978: Reviews of biology of commercially important squids in Japanese and adjacent waters, I. *Symplectoteuthis oualaniensis* (Lesson). Veliger, 21(1): 87-94.

Pfeffer, G., 1900: Synopsis der oegopsiden Cephlopoden. Mitteilungen aus dem Naturhistorischen Museum Hamburg 17(2): 145-198

Pfeffer, G., 1912: Die Cephalopoden der Plankton-Expedition. Ergebnisse der Plankton-Expedition der Humboldt-Stiftung 2: 815 pp.

Roeleveld, M.A., 1982: Interpretation of tentacular club structure in *Sthenoteuthis oualaniensis* (Lesson, 1830) and Ommastrephes bartrami (Lesueur, 1821) (Cephalopoda, Ommastrephidae). Annals of the South African Museum 89(4): 249-264.

Roper, C.E.F., Sweeney, M.J. and Nauen, C., 1984: Cephalopods of the World, Vol.3, An annotated and illustrated catalogue of species of interest to fisheries. FAO Fisheries Synopsis No. 125, Rome, 277pp.

Roper, C.F.E and Voss, G.L., 1983: Guidelines for taxonomic descriptions of cephalopod species. Memoirs of the National Museum of Victoria 44: 49-63.

Roper, C.F.E., Sweeney, M.J. and Nauen, C.E., 1984: FAO species catalogue Vol.3. Cephalopods of the world. An annotated and illustrated catalogue of species of interest to fisheries. FAO Fisheries Synopsis 125(3): 277 pp.

Sasaki, M., 1929: A monograph of the dibranchiate cephalopods of the Japanese and adjacent waters. Journal of the College of Agriculture, Hokkaido Imperial University 20 (Supplement 10): 1-357.

SEAFDEC, 1978: Fishery Statistical Bulletin for the South China Sea Area 1976.

SEAFDEC, 1979: Fishery Statistical Bulletin for the South China Sea Area 1977.

SEAFDEC, 1980: Fishery Statistical Bulletin for the South China Sea Area 1978.

SEAFDEC, 1981: Fishery Statistical Bulletin for the South China Sea Area 1979.

SEAFDEC, 1982: Fishery Statistical Bulletin for the South China Sea Area 1980.

SEAFDEC, 1983: Fishery Statistical Bulletin for the South China Sea Area 1981.

SEAFDEC, 1984: Fishery Statistical Bulletin for the South China Sea Area 1982.

SEAFDEC, 1985: Fishery Statistical Bulletin for the South China Sea Area 1983.

SEAFDEC, 1986: Fishery Statistical Bulletin for the South China Sea Area 1984.

SEAFDEC, 1987: Fishery Statistical Bulletin for the South China Sea Area 1985.

SEAFDEC, 1988: Fishery Statistical Bulletin for the South China Sea Area 1986.

SEAFDEC, 1989: Fishery Statistical Bulletin for the South China Sea Area 1987.

SEAFDEC, 1990: Fishery Statistical Bulletin for the South China Sea Area 1988.

SEAFDEC, 1991: Fishery Statistical Bulletin for the South China Sea Area 1989.

SEAFDEC, 1992: Fishery Statistical Bulletin for the South China Sea Area 1990.

SEAFDEC, 1993: Fishery Statistical Bulletin for the South China Sea Area 1991.

SEAFDEC, 1994: Fishery Statistical Bulletin for the South China Sea Area 1992.

SEAFDEC, 1995: Fishery Statistical Bulletin for the South China Sea Area 1993.

SEAFDEC, 1996: Fishery Statistical Bulletin for the South China Sea Area 1994.

SEAFDEC, 1986: Fishing Gear and Methods in Southeast Asia: I. Thailand.

SEAFDEC, 1989: Fishing Gear and Methods in Southeast Asia: II. Malaysia.

SEAFDEC, 1995: Fishing Gear and Methods in Southeast Asia: III. Philippines.

Segawa, S., Hirayama, S. and Okutani, T., 1993: Is *Sepioteuthis lessoniana* in Okinawa a single species? Pp. 513-522. In Okutani, T., R.K. O'Dor & T. Kubodera (eds.), Recent Advances in Fisheries Biology. Tokai University Press, Tokyo.

Silas, E. G., Satyanarayana Rao, K., Sarvesan, R., Prabhakaran Nair, K. and Meiyappan, M.M., 1982: The exploited squid and cuttlefish resources of India: A review. *Mar. Fish. Info. Serv. T. & E. Ser.*, 34: 1-17.

Siriraksophon, S., Nakamura, Y., Suerunggrong, S. and Sukramonkol, N., 1999: Ecological aspects of oceanic squid *Sthenoteuthis oualaniensis* in the South China Sea, Area III: Western Philippines, in the Proc. of the 3rd. Tech.Sem. on Marine Fisheries Resources Survey in the South China Sea, Area III: Western Philippines. Spcial Paper No. SEC/SP/41. SEAFDEC, Bangkok, pp.101-117.

Siriraksophon, S., Sukramonkol, N. and Nakamura, Y., 2001: Exploration of Oceanic Squid,*Sthenoteuthis oualaniensis* Resources in the South China Sea,Vietnamese Waters, in the Proc. of the 4th. Tech.Sem. on Marine Fisheries Resources Survey in the South China Sea, Area IV: Vietnamese waters. Spcial Paper No. SEC/SP/43. SEAFDEC, Bangkok, pp.182-198.

Steenstrup, J., 1880: The interrelationships of the Ommastrephes-like cephalopods. An orientation. Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger 1880-81: 73-110. In: Volsoe, A., J. Knudsen & W. Rees, trans. 1962. The cephalopod papers of Japetus Steenstrup:12. Copenhagen: Danish Science Press, Ltd.

Sweeney, M.J., Roper, C.F.E., Man, K.M., Clarke, M.R. and Boletzky, S.v., 1992: Larval and Juvenile Cephalopods: A manual for Their Identification. Smithsonian Institution Press Washington, D.C., 282 p.

Tsuchiya, K., Nagasawa, T. and Kasahara, S., 1991: Cephalopod Paralarvae (Excluding Ommastrephidae) Collected from the Western Japan Sea and Northern

Sector of the East China Sea during 1987-1988: Preliminary Classification and Diatribution. *Bull. Japan Sea Natl. Fish. Res. Inst.*, 41: 43-71.

Tung, I. H., 1976: On the reproduction of the common squid, *Symplectoteuthis oualaniensis* (Lesson). Report of the Institute of Fishery Biology of Ministry of economic Affairs and national Taiwan University,3(2):26-48.

Voss, G.L., 1963: Cephalopods of the Philippine Islands. Bulletin of the United States National Museum 234: 1180.

Voss, G.L., 1973: Cephalopod resources of the world. FAO Fish. Circ. 149: 75 p.

Voss, G.L. and Williamson, G.R., 1971: Cephalopods of Hong Kong. Hong Kong Government Press. 138 pp.

Yamamoto, K. and Okutani, T., 1975: Studies on Early Life History of Decapodan Mollusca-V. Systematics and Distribution of Epipelagic larvae of Decapod Cephalopods in the Southwestern Waters of Japan during the Summer in 1970. *Bull. Tokai Reg. Fish. Lab.*, 83: 45-96.

Yatsu A., Katto, K., Kakizoe, F., Yamanaka, K., and Mizuno, K., 1998: Distribution and biology of Sthenoteuthis oualaniensis in the Indian Ocean- Preliminary results from the research cruise of the R/V Shoyo-Maru in 1995, in the Contributed Papers to International Symposium on Large Pelagic Squids. JAMARC. 145-154.

Yoshikawa, N., 1978: Fisheries in Japan : squid and cuttlefish. Tokyo, Japan Marine Products Photo Materials Association, 161p.

Young R.E. and Harman, R.F., 1985. Early Life History Stages of Enoploteuthin Squids (Cephalopoda:Teuthoidea: Enoploteuthidae) from Hawaiian Waters.Vie Milieu, 35 (3/4), 181-201.

Young, R.E., 1978: Vertical distribution and photosensitive vesicles of pelagic cephalopods from Hawaiian waters. *Fishery Bulletin*, U.S. 76(3): 583-615.

Zuev, G.V., Nesis, K.N. and Nigmatullin, Ch. M., 1975: System and evolution of the squid genera Ommastrephes and Symplectoteuthis (Cephalopoda, Ommastrephidae). Zoologicheskii Zhurnal 54: 1468-1479 (in Russian).

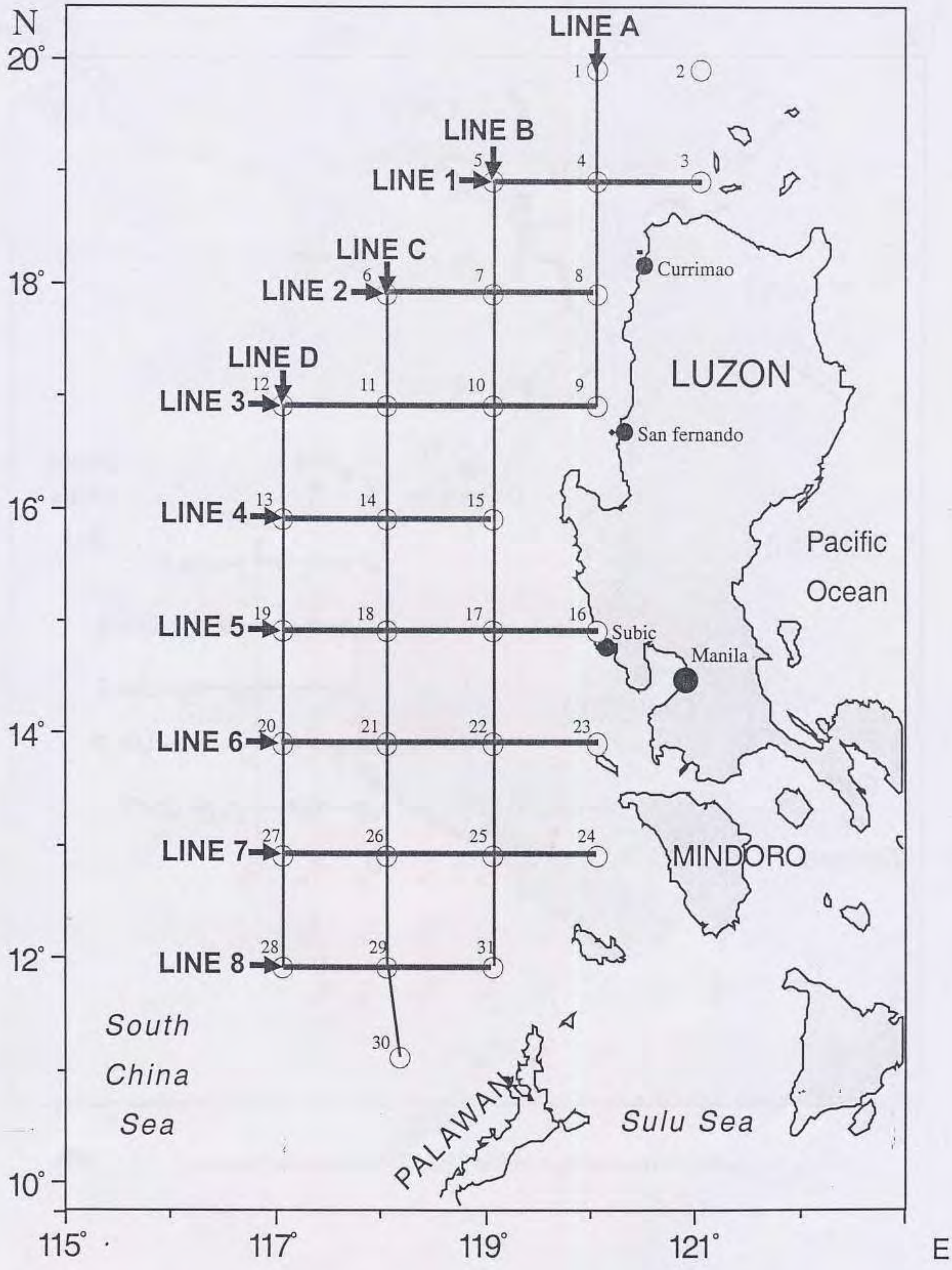
APPENDIX

Appendix 1

Principal Particulars of MV SEAFDEC

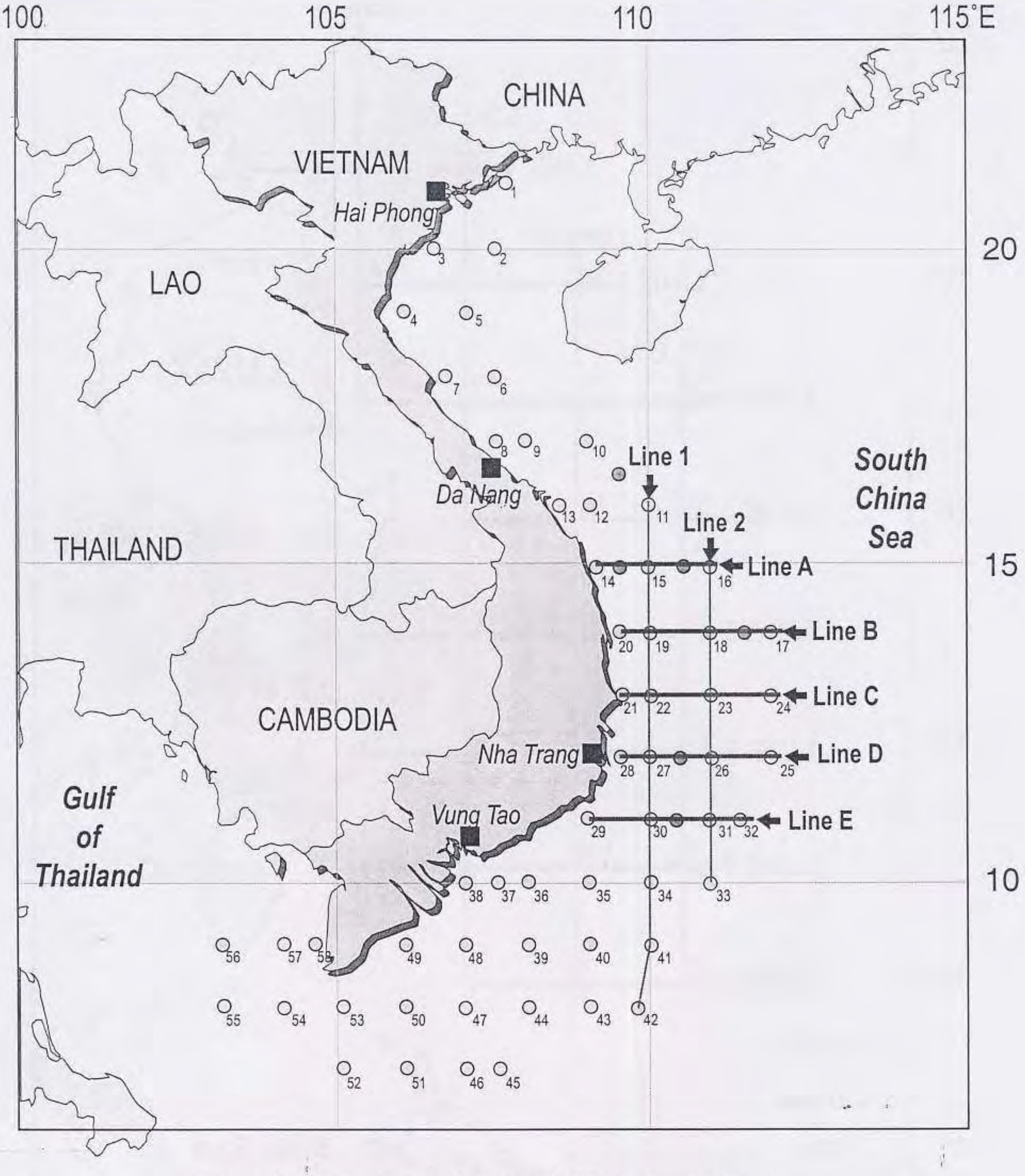
Length over all	65.02m
Length between perpendiculars	57.00m
Breadth, molded	12.00m
Depth to superstructure deck, molded	7.10m
Depth to upper deck, molded	4.70m
Draft, molded	4.658m
Service speed at 4.50m draft	14.3knots
Maximum sea trial speed (measured)	16.640knots
Deadweight	744.42 t
Classification	NK, NS*, MNS*, Fisheries Training and Research Vessel
Official number	35 09 0085 5
Call sign	HSHE
Flag	Kingdom of Thailand
Port of registry	Bangkok, Thailand
Gross tonnage	1178 t
Net tonnage	354 t
Total complement	63P
Ship operation part	33P
Researcher	2P
Instructor	2P
Trainee	26P
Fish hold capacity (bale)	145.38m^3
Freezing room capacity (grain)	20.48m^3
Freezing ability (brine)	20t/day
(airblast)	1.6t/36h
Builder	Miho Shipyad Co., Ltd.

Appendix 2



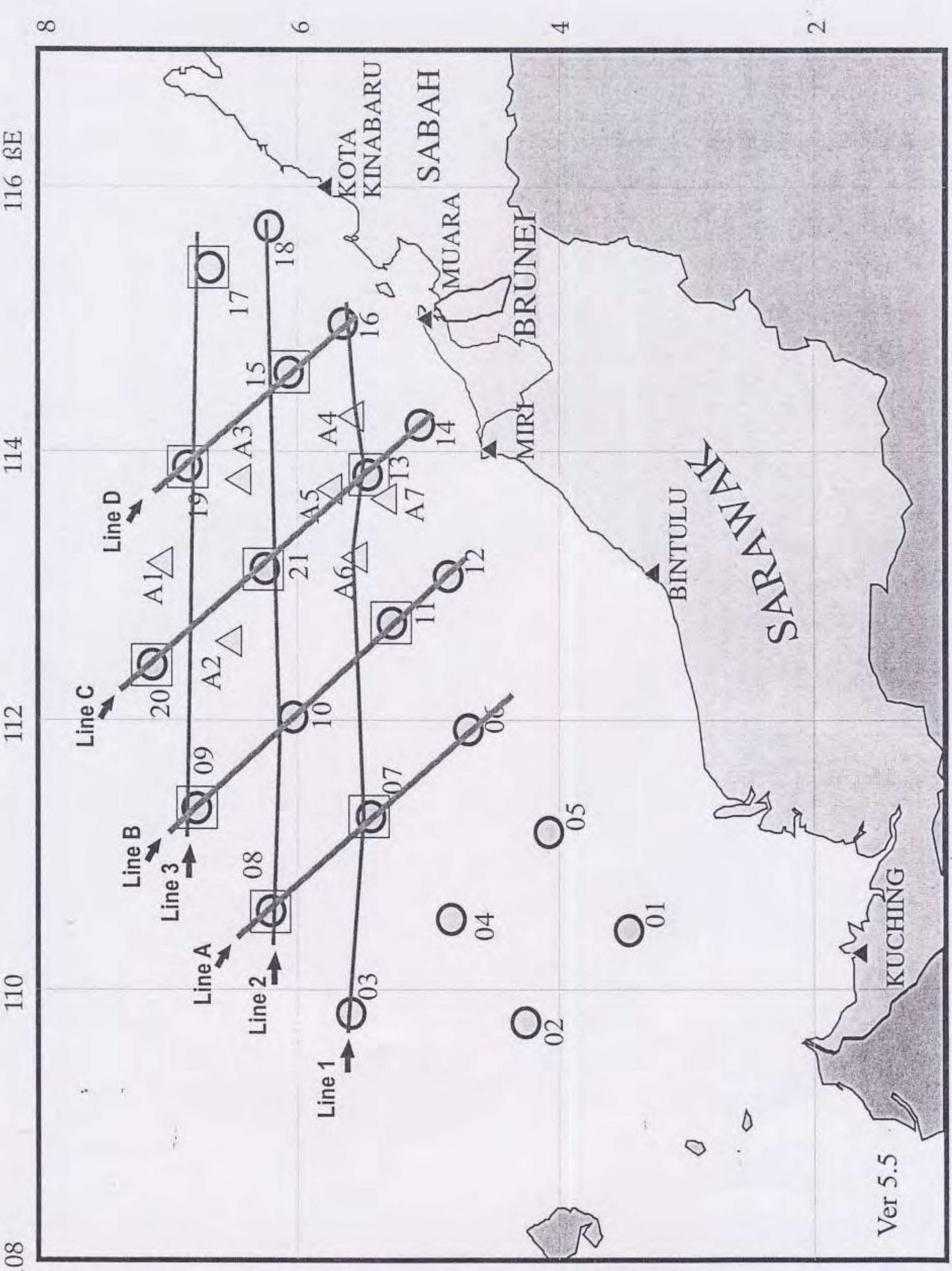
Line of cross section in the Area I: Western Philippines

Appendix 3



Line of cross section in the Area II: Vietnamese waters

Appendix 4



Line of cross section in the Area III: Sabah, Sarawak (Malaysia) and Brunei Darussalam waters