

The *Mutiara 4* Surveys in the Java and Southern South China Seas, November 1974 to July 1976^a

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Abstract

This account, which consolidates data from two earlier reports, presents the methodology and major results of a series of Indonesian-German trawl survey cruises conducted in the mid-1970s with *FRV Mutiara 4* in the Java Sea, and the southernmost tip of the South China Sea, to serve as background for detailed analyses of the demersal communities thus sampled.

Abstrak

Makalah ini, yang menggabungkan data dari dua laporan terdahulu, mempresentasikan metode dan hasil utama beberapa kali survei trawl Indonesia-Jerman dalam pertengahan tahun 1970-an dengan kapal penelitian Mutiara 4 di perairan Laut Jawa dan bagian selatan Laut Cina Selatan, sebagai dasar analisis rinci komunitas sumberdaya ikan demersal.

Introduction

The Indonesian-German Demersal Fisheries Project reported upon here was one of the outcomes of the *Seminar on the Possibilities and Problems of Fisheries Development in Southeast Asia*, which took place in 1968, in Berlin, under the sponsorship of the German Foundation for Developing Countries and FAO (Tiews 1969). In 1972, the Indonesian Government and that of the Federal Republic of Germany agreed to cooperate in carrying out a survey of the bottom fishes in the Java Sea and adjacent areas, to provide the basis for a development of the trawl fisheries similar to the one that

had occurred earlier in the Gulf of Thailand.

This account covers the first operational phase of the project, from late 1984 to mid-1986 (see below for details on the second phase), and is based on Saeger et al. (1976) and Martosubroto and Pauly (1976).

Materials and Methods

Institutional Arrangements and Personnel

The executing agencies were, on the Indonesian side, the Directorate General of Fisheries (DGF), with Mr. V. Susanto as counterpart Project Manager. On the German side, the executing agencies were "GAWI" and "BFE", both predecessors

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of the German Agency for Technical Cooperation (GTZ), which fielded Dr. J. Saeger as Project Manager.

The project started with the construction of a trawler, the *Mutiara 4* (Box 1, Fig. 1).

The Marine Fisheries Research Institute (MFRI) in Jakarta, where the project was based, provided as biologists Messrs. Purwito Martosubroto, Johannes Widodo, Badrudin, Ir. Achmad Sudradjat, Achmad Basyori, Ir. Isom Hadisubroto, and Toman Panggabean. Mr. Wasilun and Mr. Widji Santosa also participated in the activities of the project.

The counterpart scientists functioned under the general supervision of the late Mr. M. Unar (MFRI Director), Daniel Pauly was assigned by GTZ to the project from May 1975 to

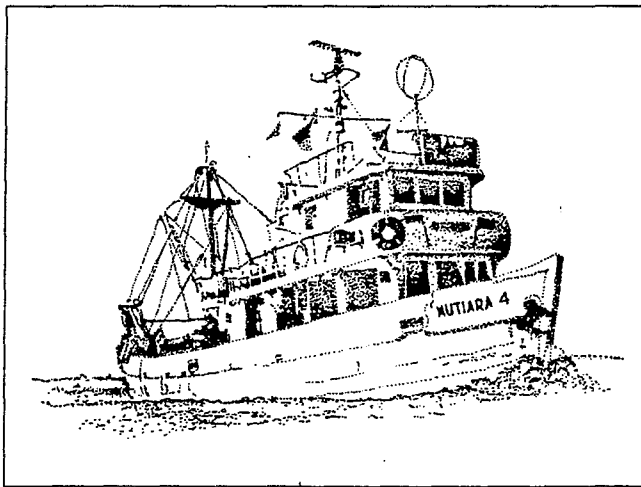


Fig. 1. The fisheries research trawler *Mutiara 4* (see also Box 1).
[Gambar 1. Kapal penelitian trawl Mutiara 4 (lihat juga Box 1).]

Box 1. The *Mutiara 4*.
[Boks 1. *Mutiara 4*.]

The *Mutiara 4* ("Pearl" in Indonesian) is a wooden stern trawler. She is equipped with a 316-hp main engine (nominal rating), auxiliary engines and echosounders. The fishing winch allows trawling at depths down to 100 m. The cooled fish hold has a capacity of 12 tonnes. A two-drum oceanographic winch allows studies of water properties as well as benthos and plankton sampling. The principal dimensions of *FRV Mutiara 4* are:

Length overall	24.15 m
Length designed WL (=DWL)	23.00 m
Length between perpendicular	21.00 m
Breadth moulded	5.80 m
Breadth overall	5.92 m
Depth moulded a midship	2.87 m
Draft moulded (DWL)	2.23 m
Draft max. aft (DWL)	3.02 m
Drag of keel	1.00 m
Tonnage of keel	111 GRT ^a
Fish hold capacity	45 m ³ approx.
Fuel oil capacity	12.2 t in two tanks
Freshwater capacity	8.92 t
Crew	13 persons (1 captain, 4 officers, and 8 other crew)
Main engine output (t) (tropical conditions)	286 hp at 1,650 Rpm (Deutz B/ 12M716)

The trawler was built at the IPPA Shipyard in Semarang, Central Java, under the supervision of GTZ which provided the abovementioned equipment while the DGF funded the construction of the hull.

^a1 GRT = 100 cubic feet = 2.83 m³.

December 1976. Captain P. Jarchau replaced Captain W. Spiering during his home leaves in 1974 and 1975, and permanently from 1976 on.

The Survey Area

The survey area covered much of the Sunda Shelf, about 772,500 km², or 238,400 nm², and was divided in six areas as shown on Fig. 2. Area 6, the Malacca Strait, is not reported upon here (but see Martosubroto et al., this vol.).

The distribution of the various depth ranges in the six areas was estimated by drawing isobaths on maps as large as possible, cutting out the figures thus obtained and weighing the paper pieces. The percentage weight of the various depth horizons was then related to the total area. Mangrove and other areas of intertidal vegetation and coralline areas were all included in the 0-9 m depth range. Areas deeper than 70 m were all put in the "70+" category. These results are shown in Table 1 and were used for all subsequent analyses. To avoid the fixed gears of small-scale fishers, no trawling occurred at depths of 0-9 m;

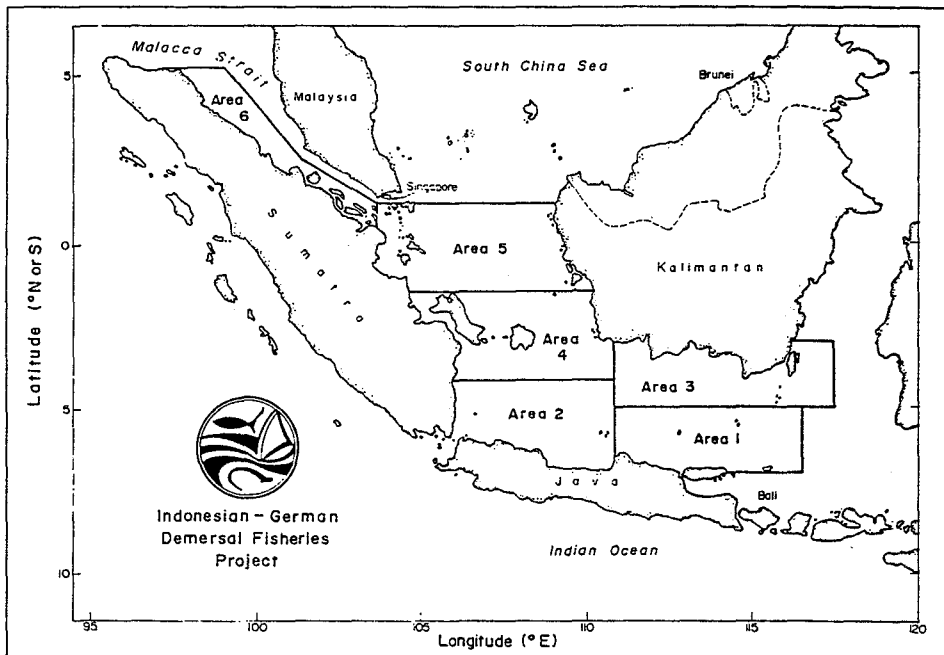


Fig. 2. The area surveyed by *Mutiara 4* from November 1974 to July 1976 (excluding the Malacca Strait, treated by Martosubroto et al., this vol.).
[Gambar 2. Daerah survei Mutiara 4 dari November 1974 hingga Juli 1976 (tidak termasuk Selat Malaka yang dibahas dalam Martosubroto et al., pada volume ini).]

Table 1. Surface of the Sunda Shelf in km² surveyed by *Mutiara 4* from November 1974 to July 1976^a.

[Tabel 1. Luas paparan Sunda dalam km² yang disurvei oleh *Mutiara 4* dari November 1974 hingga Juli 1976^a.]

Depth (m)	Area 1	Area 2	Area 3	Area 4	Area 5	Total
0-9	3,740	6,787	14,161	24,403	10,341	59,432
10-19	2,063	8,118	17,838	28,880	22,960	79,859
20-29	5,932	23,688	24,782	28,880	35,054	118,336
30-39	6,706	14,239	27,097	55,016	54,333	157,391
40-49	13,025	50,836	27,914	7,220	36,105	135,100
50-59	16,378	24,886	15,523	-	13,671	70,458
60-69	42,042	3,593	5,447	-	2,103	53,185
70+	39,076	931	3,268	-	526	43,801
Total	128,962	133,078	136,030	144,399	175,093	717,562

^aExcluding Area 6 (Malacca Strait, treated in Martosubroto et al., this vol).

consequently, this depth range was excluded from all standing stock estimates, as were the stations used for selection experiments (Box 2) for inferences of fish behavior (see Box 5 below), or for obtaining live fish for tagging and aquarium experiments, not reported here.

Trawl Sampling and the Swept Area Method

Throughout the whole survey, a trawl has been used which was similar to the one developed in Thailand at the onset of this country's expanding trawl fisheries expansion, and commonly known as the "Thailand trawl" (Fig. 3). This was

Box 2. Mesh selection experiments.

[Boks 2. Percobaan seleksi mata jaring.]

A selection experiment was conducted on 18 November 1975 close to the harbor of Semarang at depths ranging from 20 to 30 m. For this, the codend of the trawl, with a mesh size of 40 cm (stretched mesh), was covered with a codend of 12 cm (stretched mesh). The results were as follows:

Genus/Species	Number in codend		Mean selection length (TL, cm) ^a
	Inner	Outer	
<i>Rastrelliger kanagurta</i>	318	327	10
<i>Arothron leopardus</i>	119	38	6 ^b
<i>Upeneus</i> spp.	300	806	10.2
<i>Gerres</i> spp.			
<i>Pentaprion longimanus</i>	62	123	8.8
<i>Dussumieria hasselti</i>	136	102	9.5
<i>Saurida undosquamis</i>	63	445	13 ^b
<i>Apogon ceramensis</i>	47	106	8

^aMean length at first capture, i.e., L_c or L₅₀.

^bRough estimates.

Aoyama (1973) published mean selection lengths for 15 species for codend of different mesh sizes. His values and ours can be compared only for *Apogon*, the only fish covered both by his and our experiments. Here, the results correspond nicely, as he gives 8.2 cm mean retention length for a mesh size of 3.8 cm, while we found 8 cm for a mesh size of 4.0 cm.

slightly modified in June 1976 (see Martosubroto, this vol.), presumably without marked impact on catch rates.

All fishing took place between 0500 and 1900 hours, the stations generally following each other on a "station line" of 4-7 hauls (our few oceanographic stations were placed at the

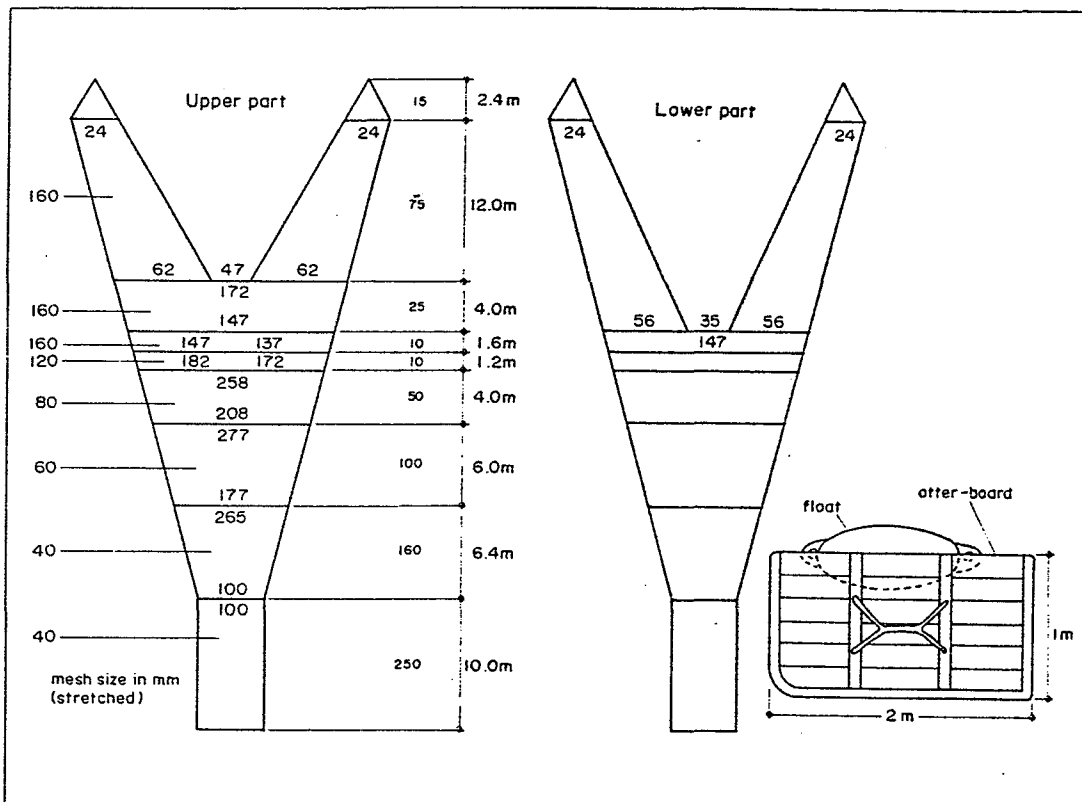


Fig. 3. The "Thailand trawl" and the otter boards used by *Mutiara 4*.

[Gambar 3. Diagram "Thailand trawl" dan otter board yang dipakai *Mutiara 4*.]

Box 3. Species identification and sorting.

[Boks 3. Identifikasi dan sortasi jenis ikan.]

The practice of sorting scientific trawl catches to the family level only was inherited from the previous Thai-German Trawl Fisheries Development Project (see e.g., Ritrgasa 1976) which served as model for the project reported upon here. Actually, sorting to species would have been possible - even for what at first appeared a bewildering number of species - given adequate (self)training of all participating biologists.

Available identification tools for shipborne identification included the book of Munro (1967), the FAO identification sheets of Fischer and Whitehead (1974) and an array of family-specific keys, e.g., that of Kühlmorgen-Hille (1968) for the Leiognathidae.

In the second phase of this project, from about mid-1976 on, sorting was done to species level, which greatly increased the value of the survey results for stock assessment and biodiversity studies (see also Pauly, this vol. and Bianchi et al., this vol.).

end of such lines). Steaming between the different station lines occurred in the first night hours, after which the ship was anchored until the beginning of the next line.

The station lines were parallel to the predominant current, and similar numbers of trawl stations were carried out with and against that current.

The method for estimating standing stock size is based on the assumption that there is a direct relationship between catch per unit of effort (i.e., catch/hour trawling) and stock density. Here, the area in km² (A) swept by the net in one hour is given by

$$A = 2/3 (HR)(2.8)(1.85)(10^{-3}) \quad \dots 1)$$

where HR is the length of the net's head rope in m (here 36 m), 2.8 is the mean trawling speed of the boat in knots and 1.85 converts nautical miles to kilometers.

Assuming a catchability of 0.5 (Shindo 1973), later confirmed by Pauly (1980) the stock density (D, in t·km⁻²) was determined by

$$D = \frac{\text{kg} \cdot \text{hour}^{-1} (10^{-3})}{A(x_1)} \quad \dots 2)$$

Stations were considered successful when trawling proceeded for one hour without incidents, or when the net was only slightly damaged when retrieved. When trawling had to

Box 4. Observations on zooplankton.

[Boks 4. Pengamatan zooplankton.]

Some zooplankton sampling was done in Area 5, first through vertical tows of a Hansen (fish) larval net: this was not effective, so new collectors were built which could be towed obliquely. Our zooplankton biomass estimates were as follows:

Station ^a	38	44	50	56	62	68	75	82	88	94	100	104
Depth (m) ^b	30	40	38	26	22	16	30	20	32	46	20	20
Water filtered (m ³) ^c	179	327	251	187	200	90	46	60	103	72	64	50
Zooplankton biomass (g·m ⁻³) ^d	0.27	0.14	0.10	0.10	0.08	0.15	0.17	0.15	0.06	0.05	0.13	0.08

^aArea 5 only; see Fig. 4 for locations.

^bLowest depth of oblique tow, as estimated from simultaneous BT records.

^cBased on a calibration experiment conducted in Tanjung Pinang Harbour.

^dWet weight.

These data match closely previous biomass estimates (Anon. 1973) which give values of 0.1 g·m⁻³ for the Java Sea. We also noted large concentrations of jellyfish, when surveying Area 4.

Box 5. Observation on zoobenthos.

[Boks 5. Pengamatan zoobenthos.]

Some benthos samples were taken in Areas 4 and 5 with a van Veen grab whose open jaws covered a surface area of 0.1 m². Generally, 50 % of each bottom sample was kept and preserved in 4% formaldehyde in seawater, and later sorted after sieving over 500 micron meshes. Mollusc shells, found to be regularly empty, were discarded, leaving the polychaetes, mainly errantian, and small crustaceans. Large forms, such as echinoderms or decapod crustaceans never occurred in our grab and are therefore discussed below on the basis of their appearance as trawl by-catch. The results thus obtained were as follows:

Area/ Station ^a	Depth (m)	Biomass (wet weight; g·m ⁻²)		Total *
		Polychaetes	Crustaceans	
4/15	24	1.0	0.2	1.2
4/23	35	0.8	-	0.8
4/31	20	1.0	-	1.0
4/42	35	-	-	-
4/47	34	6.4	0.4	6.8
4/54	13	5.4	0.2	5.6
4/59	35	1.4	0.4	1.8
4/62	32	1.6	0.2	1.8
5/38	36	5.6	0.8	6.4
5/56	42	3.2	-	3.2
5/62	44	2.8	1.6	4.4
5/68	27	5.6	1.0	6.6
5/82	40	1.0	1.4	2.4
5/102	52	5.0	0.4	5.4

^aSee database in Torres et al. (this vol.) for positions, times, etc.

The following observations were made on the macrobenthic bycatch:

Crustaceans: Penaeid shrimps, palinurids, *Thenus orientalis*, and other crustaceans such as brachiurans (crabs) and stomatopods (mantis shrimp) never occurred in commercially relevant concentrations. This is most probably due to the gear used, the depths, and the areas surveyed but it may also indicate an overall scarcity of these resources in the area of the survey. The following penaeid shrimp were found and identified: *Penaeus merguensis*, *P. semisulcatus*, *Metapenaeus monoceros*, *Parapenaeopsis* spp., *Solenocera* spp.

Echinoderms: except for a tendency for large sea-stars to become entangled in the net, and for ophiuroids and echinoidea to make the deck sticky and slippery, the animals of this phylum seem to represent neither a nuisance nor a resource.

Porifera: During coverage of Areas 4 and 5, large mushroom-shaped sponges (tentatively identified as *Poterion nautilus*) occurred in almost every haul; they were counted, and some of them weighed; a rough average of 40 kg per sponge was estimated.

be interrupted, but the haul was nevertheless considered successful, the catch was made comparable to an hourly catch by application of a multiplicative factor. Stations were considered unsuccessful when the net was badly damaged, torn, or when the otter boards (Fig. 2) were not properly set. The position and details on all stations, including the time (Western Indonesian time), the depth, the catch and/or remarks in the case of unsuccessful stations are given in the database documented in Torres et al. (this vol.).

Sorting of the Catch

The catch of each haul was generally sorted to families, or to genus or species in some cases (Box 3). This work was done by the biologists, who were herein kindly assisted by the ship's crew. The catch of each group was weighed with the precision of 0.1 kg. Weighings were done with an arm balance, not very sensitive to the movements of the boat.

Fish specimens were gathered throughout the survey area for the reference collection of the MFRI, and included in mid-1976, over 750 specimens distributed in 80 families, 146 genera and 231 species (Widodo 1976). The corresponding occurrence records will be part of FishBase 97 (see Froese et al., this vol.).

Length-frequency Measurement

A total of over 40,000 fish, belonging to 40 species were measured during the surveys presented here. Most of these measurements are documented in Martosubroto and Pauly (1976) and Pauly and Martosubroto (1980). Pauly et al. (this vol.) present the analyses based on these data, which are also included in the database documented in Torres et al. (this vol.).

Results and Discussion

The measurements of temperature, O₂ and transparency performed in the course of the survey are too scattered to warrant presentation here; they may be found, however, in the database documented in Torres et al. (this vol.). Box 4 documents our observations on the zooplankton in survey area 5, while Box 5 documents the zoobenthos.

Catch Rates, Stock Densities and Standing Stocks

Table 2 shows the numbers of successful hauls in each area and depth horizon (excluding the Malacca Strait, discussed in Martosubroto et al., this vol.). These numbers vary greatly between areas (see also Fig. 4), due to several breakdowns of

Box 6. Back and forth fishing experiment.

[Boks 6. Percobaan penangkapan "maju-mundur."]

During the coverage of Area 5, an experimental depletion of the fish stock by means of repeatedly fishing on the same station was conducted, based on a suggestion by Captain P. Jarchau, whose help largely contributed to its relative success. This was to provide information on:

- i) how fast an area swept by the trawl is "resetled", hence on how close two trawlers might follow each other when operating; and
- ii) the possibility of separating fish groups into "sedentary" and "motile", hence on whether the thinning out of certain fish groups in a given area will affect the nearby areas.

Nine hauls were made by trawling back and forth between two buoys anchored with a distance of approximately 2.3 nm from each other. The average trawling time was 49 minutes, and all catches were adjusted to the standard of one hour's trawling. The experiment was carried out at the geographical position of Station 110, in Area 5 (i.e., 0°47.6'N; 104°27.0'E).

Six groups, assumed to represent the main behavioral type of "sedentary" and "motile" fishes were selected. Of these, only two showed a decreasing trend over the nine hauls: the sharks, and the rays; the latter of these can safely be assumed to represent the most sedentary of the group below:

Group	Successive densities (kg-hour ⁻¹)								
	Haul number								
	1	2	3	4	5	6	7	8	9
Sharks	10.1	17.5	7.5	10.1	4.1	4.7	2.0	4.8	3.9
Rays	45.9	48.8	13.2	44.1	20.9	22.7	29.7	20.8	14.3
Clupeidae/Engraulidae	1.5	5.0	0.1	0.8	0.1	0.4	0.2	0.4	2.4
<i>Chirocentrus dorab</i>	0.5	9.1	6.0	1.1	1.4	1.4	0.9	12.0	4.5
Ariidae	0.9	2.0	1.8	2.1	0.2	0.3	0.9	0.7	1.4
Leiognathidae I	61.7	94.1	32.2	6.0	-	-	-	-	-
Leiognathidae II	-	-	-	-	45.3	249.2	50.0	73.1	26.0

The pelagics (Engraulidae/Clupeidae, *Chirocentrus dorab*) were not affected by the back and forth fishing. The Ariidae, surprisingly, also appeared to be very "motile" although they are benthic fishes.

The catch data for the Leiognathidae (*Leiognathus splendens* for more than 90%) first decreased markedly, then rapidly increased, suggesting that a large school entered the fished zone. This school was then depleted by subsequent fishing.

the ship's main engine. Still, these hauls allowed mapping the catch rates over most of Areas 1-5 (Fig. 5).

The estimates of overall stock density obtained by the swept area method are given in Table 3, by area and depth range. The highest stock density of 5.2 t·km⁻² occurred in Area 1, between 50 and 59 m, while the lowest density of 0.8 t·km⁻² occurred, as expected, in the heavily exploited shallow waters off Western Java, i.e., in Area 2 (see also Martosubroto, this vol.).

Table 2. Number of successful hauls by Mutiara 4, November 1974 to July 1976^a.

[Tabel 2. Jumlah tarikan trawl yang sukses dari Mutiara 4, November 1974 hingga Juli 1976.]

Depth (m)	Area	Area	Area	Area	Area
	1	2	3	4	5
10-19	-	1	17	5	13
20-29	-	29	22	25	24
30-39	-	11	11	30	48
40-49	3	24	14	1	50
50-59	17	35	15	-	9
60-69	30	4	6	-	3
70+	-	1	-	-	-
Total	50	105	85	61	147

^aExcluding Area 6 (Malacca Strait, treated in Martosubroto et al., this vol.).

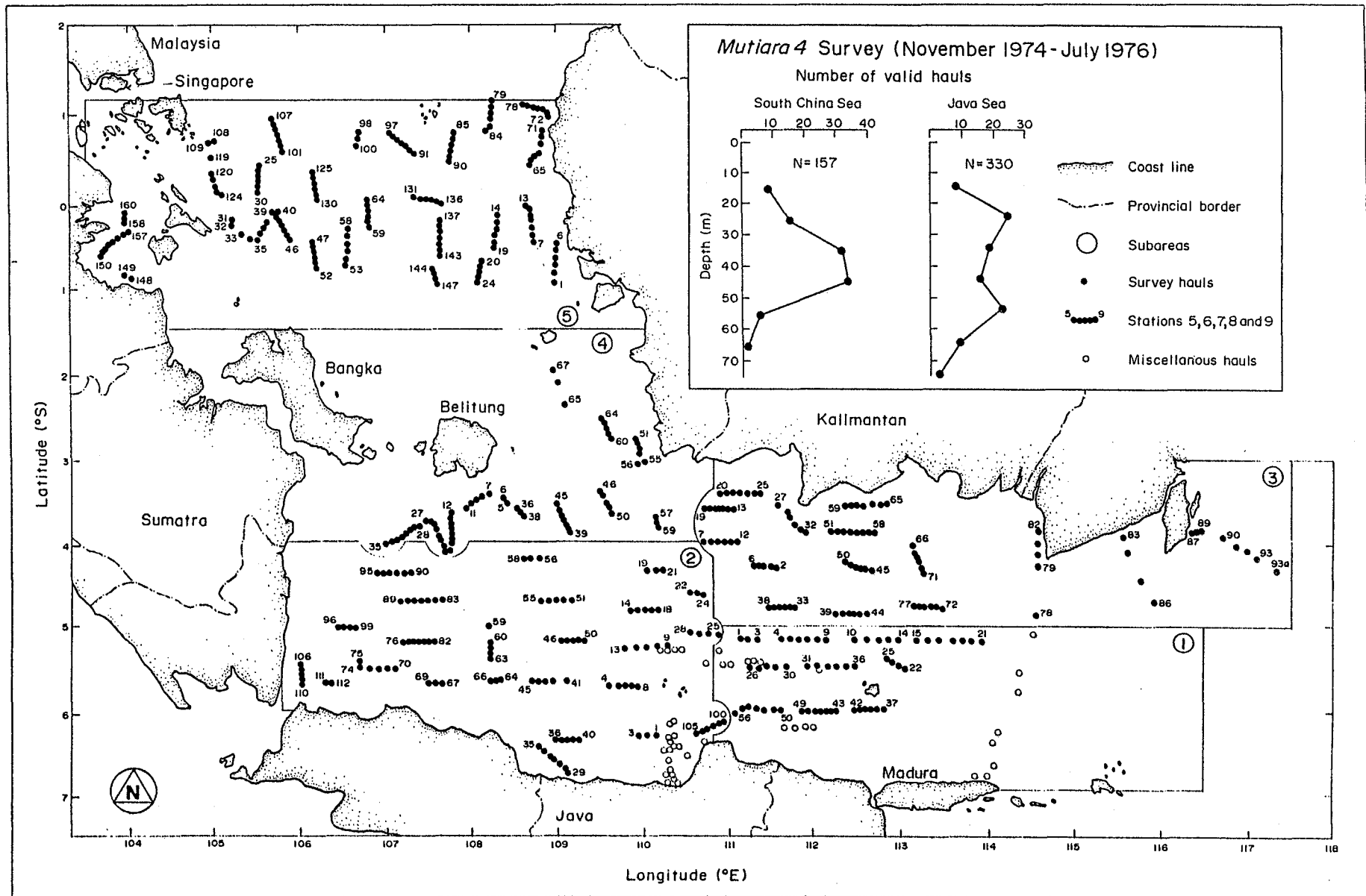


Fig. 4. The station grid of *Mutiara 4*, November 1974 to July 1976 (excluding the Malacca Strait, treated by Martosubroto et al., this vol.).

[Gambar 4. Stasiun pengambilan contoh kapal *Mutiara 4*, November 1974 hingga Juli 1976 (tidak termasuk Selat Malaka, dibahas dalam Martosubroto et al., pada volume ini).]

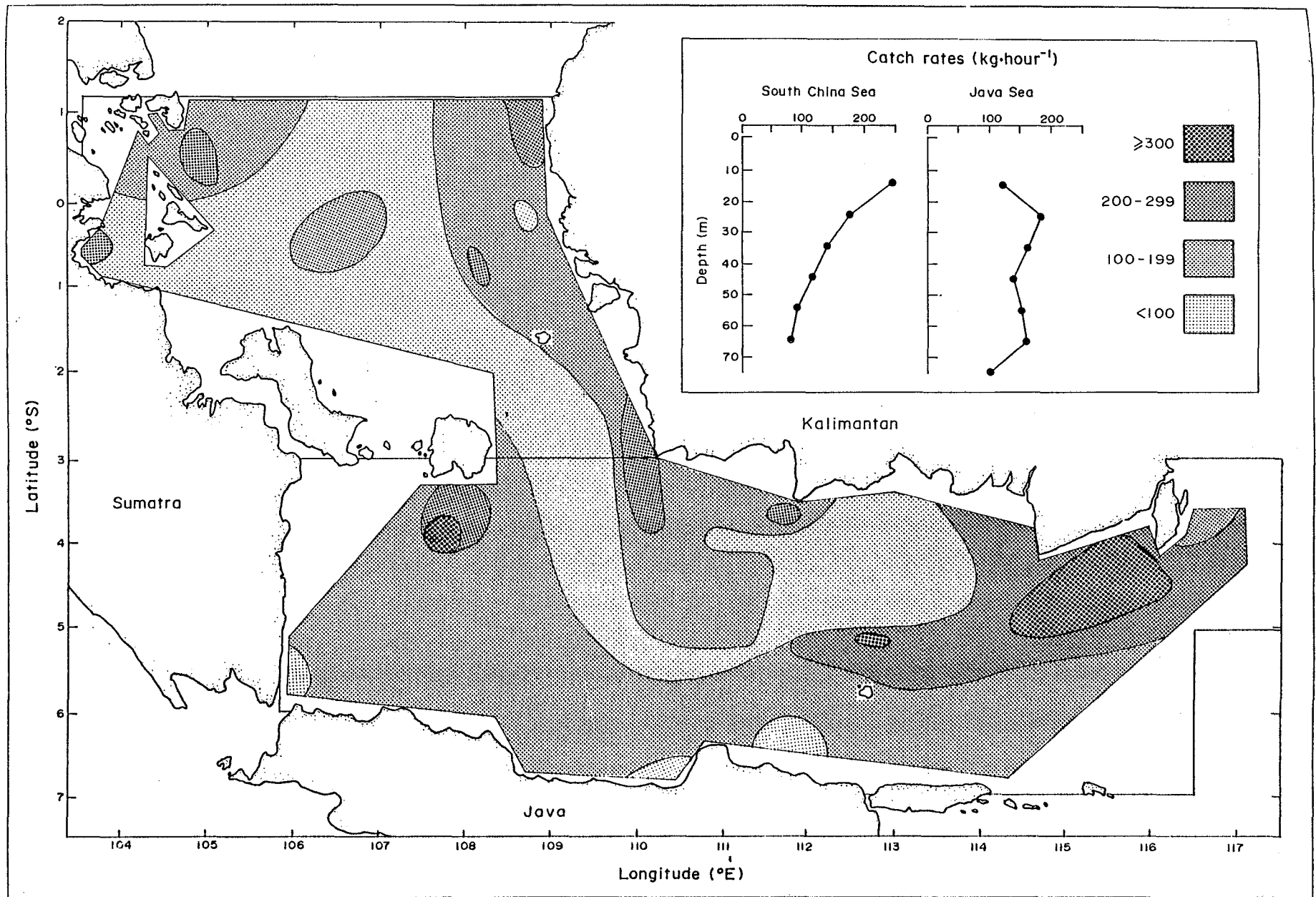


Fig. 5. Distribution of catch rates (kg-hour⁻¹ of Mutiara 4 November 1974 to July 1976 (excluding the Malacca Strait, treated by Martosubroto et al., this vol.).

[Gambar 5. Sebaran rata-rata hasil tangkapan per jam larikan trawl dari Mutiara 4, November 1974 hingga Juli 1976 (tidak termasuk Selat Malaka, dibahas dalam Martosubroto et al., pada volume ini).]

Table 3. Mean density (in t·km⁻²) of demersal fish as estimated by the swept area method for the period from November 1974 to July 1976^a.

[Tabel 3. Estimasi kepadatan rata-rata (dalam km²) sumberdaya ikan demersal berdasarkan metode dalam kurun waktu November 1974 hingga Juli 1976^a.]

Depth (m)	Area 1	Area 2	Area 3	Area 4	Area 5
10-19	(3.0)	0.8	2.1	4.8	3.4
20-29	(2.5)	2.7	2.4	4.3	2.8
30-39	(1.9)	2.4	2.5	2.1	2.3
40-49	3.2	2.2	2.2	1.4	1.8
50-59	5.2	1.9	1.6	-	1.4
60-69	3.4	1.9	1.5	-	1.2
70+	(1.5)	1.5	-	-	(1.5)
Biomass ^b	362	272	259	388	389

^aExcluding Area 6 (Malacca Strait, treated in Martosubroto et al., this vol.).

^bIn t·10³.

From the density data, the standing stock (biomass) for each area and depth range was calculated, based on the surface area of the various depth ranges in Table 1. We abstain here from presenting more than the sum of these estimates, by area (Table 3, last row).

In Saeger et al. (1976), "Gulland's equation" i.e., (Potential yield = 0.5·M· unexploited biomass; Gulland 1971) was used to derive potential yield estimates from the biomasses in Table 2, and $\bar{M} = 1 \text{ year}^{-1}$. Then, the number of trawlers was estimated which would be required to harvest this yield, and rough estimates of the value of their potential catch were presented - the point being to assemble all the elements required for assessing the prospects for the development of trawl fisheries.

The demersal fisheries did develop - so fast, indeed, that trawling was banned a few years later (Sardjono 1980). Pauly (this vol.) discusses this, and the new uses to which the data we gathered (documented in Torres et al., this vol.) can be put; Pauly et al. (this vol.) discuss the biology of some of the fish species surveyed by *Mutiara 4* and other research vessels, while Martosubroto (this vol.) and Bianchi et al. (this vol.) discuss the structure of the assemblages formed by these fishes.

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