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I: Western Central Pacific

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1. TOPOGRAPHY

As defined here the northern boundary runs from the southern tip of Korea to 130°E, 20°S, thence eastward. The western and southern boundaries are the mainland coast of Asia and the Malay Peninsula to 100°E long., thence south to Sumatra, and along the Sumatra–Java–Sunda island chain to 130°E long., the northern coast of Australia to the Torres Strait, the coast of New Guinea, and east to 180° long. (A revised northern boundary running to the south of Taiwan is being used in future FAO statistical tabulations.)

The region includes wide areas of continental shelf. From the north these are given in Table I1 (with approximate areas in km², and n.mi² (in brackets) to the 200 m contour):

The North Equatorial Current flows westward, generally north of 5°N lat., and upon approaching the Philippines separates into two branches, one directed in a general northward direction and the other in a southerly direction. The northern branch moves northward along the Philippine Islands, then along the coast of Formosa where it becomes known as the Kuroshio Current.

The southern branch, depending on the time of year, provides Pacific water into southeast Asia and also forms the basis of the Equatorial Countercurrent.

The Kuroshio moves in a northeasterly direction past the Ryukyu Islands then veers eastward, then northeastward along the coast of Japan up to approximately 35°N lat. Here the Kuroshio leaves the Japan coast and moves eastward as the Kuroshio Extension. In the Ryukyu area the Kuroshio Current sends a branch northward as the Tsushima Current. The major flow of the Tsushima Current enters the Japan Sea, while a part of the flow is deflected north-westward by the tip of Korea into central East China Sea and the Yellow Sea.

The Yellow Sea and East China Sea are characterized by pronounced seasonal changes. During the winter season, cold air moves from the Asiatic continent over these two bodies of water at an average wind speed of 2.5 m/sec. The overall cooling of surface water and the following convection allows an equalization of the temperature of sea water from the surface to the bottom, and the strong successive blowing of cold winds by the continental high atmospheric pressure accelerates the

TABLE I1. AREAS OF SHALLOW WATER IN THE WESTERN CENTRAL PACIFIC (UNDER 200 M)

Area	*n.mi²*	*km²*
Yellow Sea and East China Sea (to the north end of Taiwan)	(275,000)	950,000
Formosa Strait and Chinese south coast	(82,000)	280,000
Gulf of Tongking (to 15°N)	(58,000)	200,000
Gulf of Thailand (from Cape Cambodia to Malaysia–Thailand border)	(89,000)	305,000
South China Sea (from 15°N to the Equator)	(280,000)	970,000
Java Sea (from the Equator south and east to Bali)	(170,000)	580,000
Gulf of Carpentaria and the eastern Arafura Sea	(280,000)	960,000
There are also narrower areas of continental shelf and shallow waters round the oceanic islands; the approximate areas are:		
Southwest coast of Japan	(16,000)	50,000
Ryukyu Islands	(3,000)	10,000
Philippines	(63,000)	215,000
Eastern New Guinea, Solomon Islands, etc. (north of 10°N)	(27,000)	90,000

Note: Those areas are only approximate, particularly for the areas surrounding islands with narrow shelves. They have been estimated from the charts in Philip's Mercantile Marine Atlas (14th edition, 1952) which gives the 100 fm contour. There does not seem to be detailed presentation of the size of the shelf in the region. Menard and Smith (1966) give the following areas within the 200 m contour:

Yellow Sea and East China Sea	977,000 km²
"Asiatic Mediterranean"	4,715,000 km²

The former figure agrees well with the figure used here, but the "Asiatic Mediterranean" figure (apparently not defined precisely) is rather greater than the total of the areas above (omitting Yellow Sea and East China Sea) (=4.17 million km²). Moiseev (1969) gives a figure of 4.5 million km² for the whole region.

2. HYDROGRAPHY

The Western Central Pacific is dominated by the Equatorial Current system and even in southeast Asia the area is under greater influence of Pacific than Indian Ocean waters (Wyrtki 1961). A general view shows a striking difference between the northern and southern sections. In the north, the circulatory pattern is relatively constant with the strong Kuroshio Current the dominant feature; to the south the surface currents are greatly influenced by the prevailing monsoons. Many of the currents in the southern waters alternate in flow direction in response to changes in wind direction, i.e. during one part of the year the surface water flow is in one direction and during the other part of the year the flow is in the reverse direction (see figures).

southward advection of cooled water mass from the Yellow Sea to the East China Sea. That is to say, the enlarging of the "Yellow Sea Cold Water Mass" is recognizable. Sea surface temperatures are low, ranging from about 1°C in the north end of the Yellow Sea to 15°C at 30°N lat., 127°E long. in January. The circulation of surface water during the winter season is in a counter-clockwise direction. Water of Kuroshio origin moves northward along the eastern side of the East China Sea into the Yellow Sea. Cold surface water from the northern sector of the Yellow Sea is carried southward along the western side and leaves the East China Sea through the Formosa Strait.

During the summer season, the winds blow from the southeast at an intensity comparable to the winter period. The sea surface temperatures are relatively high, ranging from 25°C in the northern Yellow Sea to 28°C in the southern sector at about 30°N lat., 127°E long. in August. The circulatory pattern in summer is not as well defined as in the winter season. Warm water of Kuroshio origin is still deflected northward along the eastern part of the East China Sea and Yellow Sea. Along the western side, rather than a strong southerly flow as noted during the winter period, there is a general northward flow and a considerable amount of South China Sea water moves into the East China Sea.

Besides the current system just mentioned above, another important aspect of the hydrography of these seas is the remarkable tide which is particularly strong at the western coast of Korea—the range between the high and low tides is about 9 m in some places.

As indicated earlier, the circulation of surface waters in southeast Asia is complex with a complete reversal in direction of many of the currents. It is beyond the scope of this paper to describe in detail the complex nature and dynamics of this circulation. Rather it should suffice to describe the prevailing conditions during the peak of the two periods, the north monsoon in February and the south monsoon in August.

In February, the high pressure system located over the Asiatic continent is fully developed. North of the Equator the northeast monsoon prevails (Fig. I1); at the Equator the winds blow from a northerly direction and from south of the Equator to 10°S lat. the winds originate from a northwest direction. The southeast trades blow south of 10°S lat. Since the axes of the bodies of water in southeast Asia generally follow the direction of the wind system, the currents tend to flow in the same

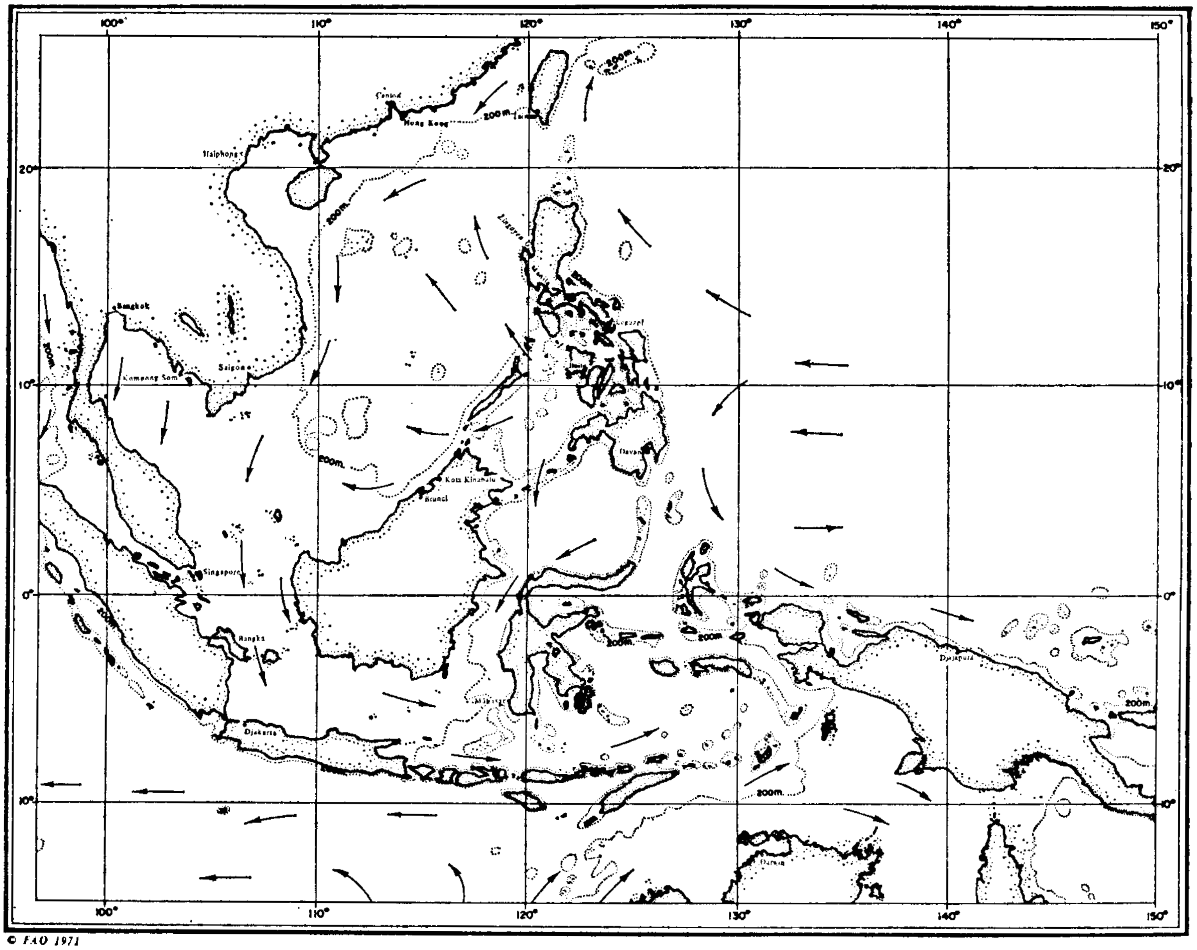

Fig. I.1. Surface currents in the Eastern Central Pacific in February

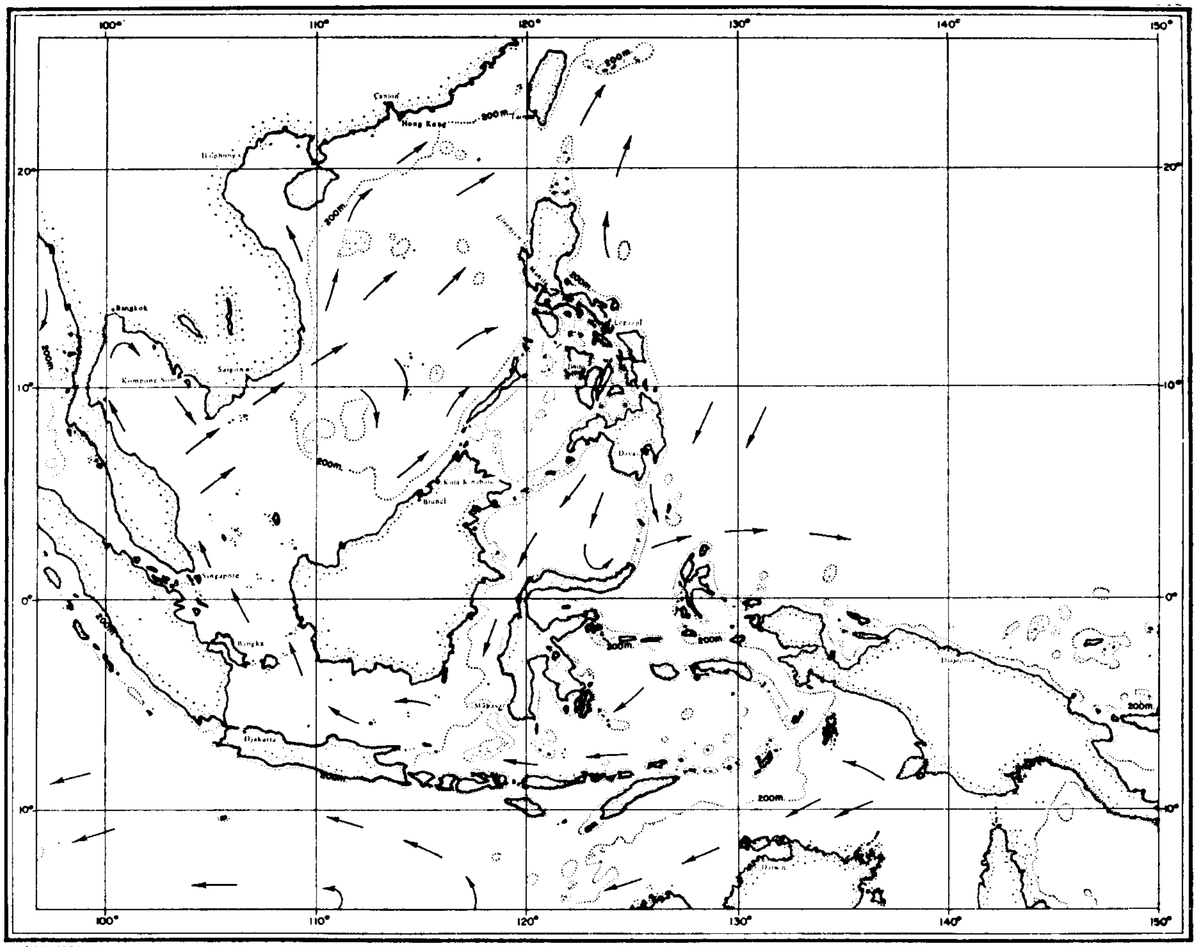

Fig. I.2. Surface currents in the Eastern Central Pacific in August

direction as the prevailing winds. Figure I1 shows the general surface water circulation in February. North Equatorial water moves into southeast Asia through the south of the Philippine Islands. Along the Asiatic mainland, the currents in the South China Sea area move along the coast in a southerly direction and much of this surface water enters the Java Sea. In the Java Sea the winds are from the northwest and the currents also move in this direction with the flow moving from the Java Sea into the Flores Sea and then the Banda Sea. Part of this water enters the Indian Ocean primarily as southwesterly current in the Timor Sea just south of the Timor Islands; lesser amounts enter the Indian Ocean through the Strait of Malacca and the Sunda Strait.

In August, the South Equatorial Current is strongly developed (Fig. I2) and inflow of Pacific water into southeast Asia occurs south of Mindanao in the Philippines and south of Halmahera Island. A very strong current flows in a northwest direction north of New Guinea and forms the principal water source of the Equatorial Countercurrent. The general surface circulation in the southern seas is from the Banda Sea into the Flores Sea and then into the Java Sea. The Banda Sea receives mostly Pacific water from the northeast. In the South China Sea the flow of water is northward along the continental shelf. During this period there is considerable flow of Pacific Ocean water into the Indian Ocean through the Timor Sea.

2.1 Upwelling

Undoubtedly much of the productive fisheries along the continental shelf of the Asiatic mainland result from nutrients brought up to the surface by the alternating shift in currents and localized regions of upwelling. Available oceanographic data from the western side of the South China Sea indicate localized areas of upwelling off the coast of Vietnam in June and July (Wyrtki 1961). Other areas of possible upwelling include off the coast of Macassar during the southeast monsoon and localized upwelling along the coast of China near Hong Kong during the northeast monsoon and also off the coast of Sarawak.

On the basis of upwelling, the area with the greatest potential of enrichment in southeast Asia is the Banda Sea—Arafura Sea area. Wyrtki (1961) indicated that this was an area of alternating upwelling and sinking and that during the upwelling period, which reaches a peak in July and August, the flow of upwelling water is approximately 5 million m^3/sec.

3. ZOOPLANKTON

In the northern sector, the waters in and south of the Kuroshio are rather barren. The biomass (measured by the net weight of the upper 100 m) is usually less than 25 mg/m^3, with a maximum of 50 mg/m^3 in summer, and in the winter the biomass is usually 25–50 mg/m^3, with a maximum of 100 mg/m^3.

The main species south of the Kuroshio are *Undinula darwini*, *Calanus minor* and *Eucalanus subtenuis*; north of the Kuroshio, *Calanus helgolandicus* is one of the dominant species. (By Motoda and Marimo, Proceedings of Symposium on the Kuroshio 1965).

In the southern sector, studies of zooplankton in Australian waters showed a relatively high standing crop, averaging about 100 mg/m^3, over the Australian continental shelf. In the open ocean the standing crop was considerably lower with values no greater than 50 mg/m^3, usually less than 25 mg/m^3 (Tranter 1962).

4. BENTHOS

The dominant groups in the Yellow Sea and East China Sea are as follows: Holothuridae, Macrura, Brachyura and Cephalopoda in the central part of the East China Sea, with Ophiuroidea in the northern part; Macrura, Ophiuroidea, Brachyura and Asteroidea in the southern part of the East China Sea.

Ophiuroidea are distributed in depths between 60–85 m; Asteroidea in 50–80 m and 100–150 m; Macrura in 50–110 m; Gastropoda and Cephalopoda in about 50 m. In general the peak of the distribution lies about 70 m deep.

Studies of benthos biomass in two bays in the Philippines showed considerable differences in composition and magnitude (FAO, 1959). In Manila Bay the standing crop of benthos biomass was found to be only 0.741 g/0.1 m^2 compared to the 7.957 g/0.1 m^2 for San Miguel Bay. In the Manila Bay samples the dominant groups included errantian polychaetes, macrurans and brachyurans. The major groups in San Miguel Bay were sedentarian polychaetes, errantian polychaetes and ophiuroids. The benthos standing crop of Manila Bay (area of 1,350 km^2) was estimated to be 10,000 metric tons (74.1 kg/ha) and the San Miguel Bay (area of 520 km^2) 40,000 metric tons (795.7 kg/ha).

5. FISH STOCKS AND FISHERIES

5.1 The fisheries

The region is one of the more productive areas of the world, though the large scale industrial fisheries with big ships, concentrating on a few species, characteristic of temperate waters, are absent. Instead the fisheries in the region are typically carried on by a very large number of small vessels, using a wide range of gears, and catching a great variety of species, which are usually not identified (at least down to a species level) on the fish market.

Little or no long range fishing is done in the area, except for tuna fishing in the open Pacific, but all countries in the area have a more or less vigorous local fishery supplying a strong home demand. The most striking recent development has been the growth of trawl fishery by Thai vessels, triggered off by the introduction of single-boat trawling instead of the former pair-trawling. The larger Thai trawlers are now becoming engaged in medium range fishing in the southern part of the Gulf of Thailand and beyond. Medium range vessels also operate from Japan, in the Yellow Sea and East China Sea, and from China (Taiwan) and Hong Kong in the South China Sea.

5.2 Statistics

Recent catches by countries in the area, as available to FAO, are summarized in Appendix Table I8. Except for Japan, the statistics are of total marine fish catch, which in some cases (e.g. Thailand Malaysia and Indonesia) include catches taken outside the present area.

(a) Japan

Statistics are generally good, and much detailed data are published in various forms. Detailed breakdown of landings is available from home landings, of which two areas—southern Pacific coast, and East China Sea—come within the region considered here. There is a good breakdown by species and type of gear and fair statistics of effort.

(b) South Korea

Statistics are now good (large annual Yearbook of Fishery Statistics published), with the probable exception of coastal subsistence fishing. Area breakdown is available by province of landing; those on west and south coasts come within this region. Breakdown is given by species and type of gear. Effort statistics are not very complete.

(c) North Korea

No figures are available since 1957 (then 291,000 tons). Before the war, rather more than half the total Korean catch (925,000 tons out of 1.769 million tons in 1936) came from the present North Korea. Much of this catch was sardine and this stock has very greatly declined. It is probable that the North Korean catch has increased since 1957. There are no details of species breakdown, or of area of capture (especially division between east and west coasts).

(d) China (Mainland)

There are no good statistics available. The most recent statistics given in FAO Yearbook are a total of 5.8 million tons in 1960, without detailed breakdown. Shindo (1964) gives a good description of Chinese fishing; of the 5.8 million tons reported, only 1.8 million tons was from normal sea fisheries; the rest being inland fisheries (2.8 million tons) and fish culture (1.2 million tons). These figures are far from being entirely reliable, but the value of marine fish catch seems reasonable in comparison with the length of coastline, and the catches of adjacent countries, such as China (Taiwan) and Korea. Shindo also gives some details of the expansion of marine fishing from 1949 to 1960, as well as the species and area breakdown in 1960. In a later study, in 1966, Shindo re-estimated the marine catch as 1.6 million tons, 1.2 million tons in the Yellow Sea and East China Sea, and 400,000 tons in the South China Sea. It is not known how the Chinese fishery has developed since 1960, but the marine catch is believed not to have increased much.

(e) **China** (Taiwan)

Statistics for this region are generally good; detailed breakdown by species is available.

(f) **Hong Kong**

Good statistics are available for landings in Hong Kong, but much of the fleet land part of their catch (for licensing purposes) in China (Mainland), and this part is not recorded. Detailed breakdown by species is given. Effort and some data are available for some of the large vessels.

(g) **Democratic Republic of Vietnam**

Latest statistics in FAO are for 1962, and their reliability is unknown. The total fish catch is only broken down into marine and freshwater. Between 1955 and 1962, the reported catch increased from 94,000 to 289,000 tons.

(h) **Republic of South Vietnam**

Up-to-date statistics of total catch are available, broken down into freshwater fish, marine fish and crustaceans, in the FAO Yearbook of Fishery Statistics (YFS). The reported totals increase steadily from 120,000 tons in 1955 to 375,000 tons in 1965, but it is not certain to what extent this represents a real increase in catch, or merely greater completeness in the collection of statistics. Probably there are still very incomplete data as small-scale subsistence fisheries are prevalent in both fresh and coastal waters.

(i) **Khmer Republic (Cambodia)**

Catch statistics are given in the FAO Yearbook for 1961/5 with sub-totals for freshwater fish, marine fish, crustaceans, molluscs and various. The totals show a very slight increase (from 148,000 to 166,000 tons) but it is not known how reliable these figures are. There is probably a great deal of under-reporting of subsistence fishing.

(j) **Thailand**

Detailed statistics are available, though the figures include a very large proportion of unsorted and unidentified fishes (probably mostly from the rapidly developing trawl fishery). It is known that part of the rapid increase in the total reported catch since 1961 is due to improvement in the collection of statistics. Probably the most recent figures are reasonably reliable.

(k) **Malaysia and Singapore**

Detailed statistics by species are available. These are probably reasonably reliable. Some effort data are available for major fisheries.

(l) **Indonesia**

The reliability of the figures (1.176 million tons of marine and freshwater fish reported in 1968) is probably very low. The figures are more likely to be too low than too high because of non-reporting of subsistence fishing. Of the 1967 total (1.18 million tons) approximately 640,000 tons were believed to be marine fish. Nearly all the catch is taken by small boats in depths less than 25 m, not more than 25 mi from shore.

(m) **Australia**

There is very little fishing in the region. A shrimp fishery is developing in the Gulf of Carpentaria for which good statistics should be available.

(n) **New Guinea, Solomon Islands, other island groups**

There are very little data available, most of which are of export figures only. The latter are probably reliable, and the total catch is probably small.

(o) **Philippines**

The FAO Yearbook gives detailed figures, broken down by species; much of these data have been derived from information which might be used for tax purposes, adjusted by a factor believed to correct for misrepresentation. The factor used may be too large or too small. The proportions of different species may be a reasonably reliable estimate for the commercial fisheries, but these proportions may not be the same in the so-called municipal fisheries, which account for about half the total reported catch. Probably demersal fish are commoner and pelagic fish rarer in the municipal catches than the published statistics suggest.

(p) **Long-range fishing**

Fortunately, in view of the deficiencies in the statistics of local fishing, there is not much long-range vessel fishing in the region far from the home bases. Japanese trawlers have occasionally worked in the South China Sea and the Gulf of Tongking, and there may be developments in long distance trawling and fishing for shrimps in the South China Sea by Korea, Hong Kong, Thailand and Singapore, but this is likely to remain on a small scale. High seas fishing for tuna is considered separately in the section on oceanic resources. The main statistical problems are, therefore, confined to the countries adjacent to each area concerned.

5.3 Stock assessments for exploited stocks

(a) Yellow Sea and East China Sea

Demersal

Assessments for the major stocks have been carried out by Japanese scientists. These studies have shown some degree of separation of discrete stocks within the area. However, the degree of exploitation of different stocks of the same species seems much the same. There is not much information of the degree of mixing with stocks outside the region; however, the demersal fish do not seem to migrate far. The analysis for demersal fish covers the area of the Japanese trawl fishery; this extends south to about 26°N, and therefore covers nearly the whole of the East China Sea areas as used here.

The present demersal catch from the area is uncertain; from Shindo (1964) the catch of marine fish by Mainland China in 1960 was 1.8 million tons; of this, two-thirds came from the area considered, and the great majority of this total was demersal fish. Allowing for a slight increase since 1960, the 1965 catch of demersal fish may be estimated as 1.2 thousand tons. The Taiwan catch in 1965 consisted of 84,000 tons of specified demersal fish, and 61,000 tons of unspecified fish, probably nearly all demersal, i.e. a total of 145,000 tons; the proportion of this that came from the East China Sea is not known, perhaps it is as much as one-third, say 50,000 tons. The Japanese and South Korean catches are known reasonably well. It is not known what proportion of the North Korean catch is demersal fish, nor how the total is divided between the East (Japan Sea) and the West (Yellow Sea) coasts, but probably most of the catch is taken in the Japan Sea. The best estimate of the total demersal catch in the Yellow Sea and the East China Sea is as follows:

TABLE 12. DEMERSAL CATCHES IN THE YELLOW SEA AND THE EAST CHINA SEA

Area	*Estimated catch 1965 (in metric tons)*
Mainland China	1,200,000?
Japan	330,000
South Korea	130,000
Ryukyu	1,000
Taiwan	50,000
North Korea	100,000?
Total	1,810,000

A major uncertainty remains concerning the share of the total taken by Mainland China (Shindo 1964). The evidence of decline in catch per unit effort, smaller sizes of fish, and increased mortality show clearly that the demersal fisheries are approaching or beyond the level at which no further increase in average catch can be achieved. (See Anon. 1963, Mako 1961, Murakami *et al.* 1964 for demersal stocks generally; Misu 1965 for ribbon fish (hairtail), *Trichiurus lepturus*; Ikeda 1964 for yellow croaker, *Pseudosciaena manchurica*; Otaki 1964 for sharp toothed eel, *Muraenesox cinereus*; Shindo 1964 for yellow sea bream, *Taius tumifrons*). The trends since 1953 in catch and catch per unit effort for different species have been different; some tending to increase, e.g. ribbon fish and shrimp, at least up to 1961, while others have decreased sharply, e.g. lizard fish (Murakami *et al.* 1964). Most recently the catch per unit effort even of those species which had been increasing have tended to flatten out or decrease. These differences are probably due to several causes, including:

(a) changes in the balance of species in the sea, independent of fishing;
(b) relative decreases of species most vulnerable to fishing;
(c) switching of the main fishing concentration from the initially preferred species;
(d) development of new fisheries, e.g. for shrimp.

Because of these differences, it is most unlikely that the intensity of fishing is the same for all stocks, and while all the demersal stocks included in the above analysis are at least moderately heavily fished, it is likely that the yield of some could be increased by heavier fishing, while the yield of others could be increased by reduced fishing. In addition, the yield of several species might be increased by the use of larger trawl meshes. Potentially, therefore, the yield of the presently exploited demersal fish could be increased (perhaps by 10–30%), but much of this increase would require rather detailed control of fishing. It is probably unrealistic to expect much change from the present total. A potential yield of 2 to 2.4 million tons corresponds to a yield per unit area of *c.* 25 kg/ha.

Pelagic

Estimates of the present yields of pelagic fishes from the Yellow Sea and the East China Sea are provided in the following table. The figures for Mainland China and North Korea are both very rough, assuming about one-third of the Korean catch are pelagic fish, but, following Shindo (1964), that the pelagic catch by China is small, say 10% of the total.

TABLE 13. PELAGIC CATCHES IN THE YELLOW SEA AND THE EAST CHINA SEA

Area	*Estimated catch 1965 (in metric tons)*
China (Mainland)	100,000?
Japan*	350,000
South Korea	100,000
China (Taiwan)†	20,000
North Korea	100,000?
Total	*c.* 600,000?

* Jack mackerel and mackerel
† Assuming East China Sea catch is one-third of total

Studies have been made by Japanese scientists of the major species. The two species of mackerels (*Scomber japonicus* and *S. tapeinocephalus*) are mixed in the statistical records. While catches have recently increased very greatly in other parts of Japan, the catches in the present area have not changed much. Effort and catch per unit effort data also show little change, but the effort figures do not take into account improvements in the gear efficiency. Size and age distributions show a dominance of small, young fish. It is, therefore, believed that the stock is heavily fished (Tsujita 1965), though the evidence is not as conclusive as for the demersal fish.

Catches of jack mackerel (*Trachurus japonicus*) increased in 1958/60 due to an expansion of Japanese fishing in the East China Sea, and probably also a greater availability of the stock. Since then, catches and catches/effort have been more stable, but efficiency of the unit of effort may have increased. Average age and size is low (Mitani and Shojima 1966) and may be decreasing. There is some indication of the existence of different stocks.

Though the situation is not as clear as for demersal fish, it is the belief of Japanese scientists that these stocks are heavily exploited and catches from them cannot be substantially increased by greater fishing. Pelagic catches in Japanese waters have fluctuated very greatly, probably largely independent of fishing.

Japanese scientists have data on larval abundance of several pelagic species. It is hoped to examine these to obtain estimates of relative (and perhaps absolute) abundance of these species.

The food items of a species forming the base of large fisheries often provide clues to potential resources of unexploited species. Stomach contents of ribbon fish (*Trichiurus lepturus*) contained the following relative numbers of different species of fish (in brackets catch in tons from the area by Japanese and South Korean vessels) (Misu 1964).

Engraulis japonica	118	(95,000)
Trichiurus lepturus	60	(70,000)
Pseudosciaena manchurica	50	(70,000)
Argyrosomus argentatus	11	(25,000)
Other identified fish	42	

It is interesting that anchovy is the only pelagic fish taken by ribbon fish. These studies do not suggest the existence of any substantial unexploited stocks. The potential yield is probably not much more than the present total catch, perhaps 25–50% above it, i.e. three-quarters to one million tons.

(b) **Other areas on continental shelf**

Little stock assessment work has been carried out and in many areas even the basic data on catches, effort, sizes, etc. are lacking. Some data are being collected in Taiwan, Hong Kong, Thailand, Malaysia and Philippines and assessments are now available for some of these fisheries.

Demersal

South of the East China Sea area, trawling takes plac along the Asiatic continent, with increased effort noted in waters around Hong Kong, Gulf of Thailand and the Philippines. More recently trawling has increased in the Strait of Malacca by Malaysia and exploratory work is being intensified in the southern sectors of the South China Sea by various countries, e.g. Taiwan and Thailand. The present fish catch from these southern waters is given below:

In the area off the south coast of China, between Taiwan and Hainan, there have not been detailed stock assessments, but experience from Hong Kong suggests that there has been an appreciable falling off in the catch rates, at least of the preferred species. This suggests that the potential yield of demersal fish in the area is being approached, i.e. that the potential is probably in the range of 800,000 to 1.5 million tons.

In the Gulf of Thailand, the recent rapid increase in trawling has been followed by a substantial fall in catch per unit effort (Isarankura and Kühlmorgen-Hille 1967, Tiews *et al.* 1967). Some further increase in catch may be possible. It appears that a large variety of species is caught and landed, though only half the catch is of fish used for human consumption (Tiews 1966). Probably all species easily taken by the present gear are exploited, if not to precisely the same extent.

An assessment of the demersal stock in the Gulf of Thailand has been made by Gulland (in press), using data on total catches, number of vessels and catch per unit effort of survey vessels given by Menasveta (1968). The last has decreased from just under 300 kg/hour in 1960 to 115 kg/hour in 1967. Making some allowance for the spread of fishing into more distant waters, so that only a proportion of the total catch in recent years comes from the survey areas in the northern part of the Gulf, there appears to be a clear and approximately linear relation between the survey catch per unit effort and the total effort. The corresponding relation between total catch and effort gives a maximum yield of 400–500,000 tons per year at a level of fishing rather less than that in 1966. Since 1967 the total catch by Thai trawlers has increased above half a million tons, but this increase has come from trawlers moving into more distant areas. An estimate of 500,000 tons as the potential of the area directly off the Thai coast still appears the most reasonable, if some allowance is made for a small increase in catch from more selective methods of fishing.

This analysis did not take into account the changes in species composition that have taken place (Tiews *et al.* 1967). Some of these changes are the direct effect of fishing, e.g. the greater decline of the larger or more valuable species; others can be ascribed to the indirect effects, e.g. the increase in squids due to the reduction in their predators. Other changes, e.g. the increase in *Lutjanus*, which being a large valuable fish might have been expected to decrease greatly, are less easily explained. They may be due to complex fishery-induced causes, or

TABLE I4. ESTIMATED DEMERSAL CATCHES BY AREAS (IN 1966)

Area	*Catch by countries*		*Total (in metric tons)*
Formosa Strait and Chinese South Coast	China (Mainland)	550,000	
	China (Taiwan)	100,000	
	Hong Kong	50,000	700,000
Gulf of Tongking	China (Mainland)	50,000?	
	Vietnam Dem. Rep.	200,000?	250,000
South China Sea	Republic of S. Vietnam	250,000?	
		(total marine fish 290,000)	
	Malaysia	75,000	
	Singapore	10,000	
	Indonesia	10,000	400,000?
Gulf of Thailand	Thailand	337,000	
	Khmer Republic	30,000	
		(total marine fish 40,000)	370,000
Java Sea	Indonesia	500,000?	500,000?
Gulf of Carpentaria and Arafura Sea	Australia	negligible	
	Indonesia	?	probably very small

may be completely independent of fishing. Any full analysis of the changes in the demersal fish community must, therefore, be a rather involved study. It may well be that short of an extremely detailed study, the simple study above, in which the total catch per unit effort of the survey vessels may be taken as a synthesis of all the direct and indirect effects of fishing, gives a rather better assessment of the state of the stocks generally than a species-by-species analysis.

This is only the sustainable yield from the part of the survey area fished by Thai trawlers, which is not the same as the whole of the Gulf of Thailand. Tiews stated that fishing is not carried out below 50 m, and considered the catches at that time came from an area of 24,400 n.mi^2 (= 84,000 km^2). This is not much more than a quarter of the total area of the Gulf less than 200 m as estimated in the first section (=89,000 n.mi^2 = 305,000 km^2). Use of one or other of these areas gives values of yield per ha of 60 and 17 kg/ha respectively (6.0 and 1.7 tons/km^2 respectively). Though high, a figure of 60 kg/ha may be compared with annual catches of 20–25,000 tons from Manila Bay (150–180 kg/ha) (Tiews 1959). This figure includes some pelagic fish, and also includes fish caught inside the Bay which have grown up outside the Bay. It may therefore be an over-estimate of the harvested production of demersal fish per unit area, though some studies by the FAO/UNDP(SF) project suggest that the true demersal catches in Manila Bay may be as high as 30–40,000 tons, and suggest that this production can be quite high.

As an estimate of the productivity from all waters, the latter figure (17 kg/ha) will certainly tend to be an under-estimate because much of the fish in deeper waters, or in the south-eastern part of the Gulf (off Cambodia), will not move into the area fished by Thai trawlers; equally the former figure (60 kg/ha) may be an over-estimate of the productivity in waters shallower than 50 m, because the catches may include fish which have moved into the fished area, and therefore represent the production over a bigger area than considered by Tiews. There are no good data for productivity in waters deeper than 50 m. Data from several areas (Tiews 1966, Pathansali *et al.* 1967, etc.) show that trawl catches are much less in deeper waters, at least in some areas. Exploratory fishing data from the FAO/UNDP project in the Philippines, provided by J. Magnusson, show little difference in catch rate—*c.* 200 kg/hour—in 50–100 m, and in less than 50 m. However, the deeper water is at present little exploited, and the similar catch rates may reflect lower productivity, plus lower exploitation.

Therefore, it is best to follow Tiews in assessing the possible catches in waters less than 50 m deep separately; for this the higher figure above is probably closer to the value for the Gulf of Thailand. A likely range may be between 30 and 50 kg/ha (3–5 tons/km^2). If the other tropical and sub-tropical areas in the Indo-Pacific region shallower than 50 m, which, according to Tiews (1966), cover 465,000 n.mi^2 (= 1.6 million km^2), were as productive as the Gulf of Thailand, the total potential catch of demersal fish would be between 4.8 and 8 million tons. However, if the waters of the Gulf of Thailand shallower than 50 m are more productive than other parts of the region, this may be an over-estimate. There is evidence that this is so, e.g. Ichiye (in Fairbridge 1966) quotes figures of primary production of 6 gC/m^2/day at the head of the Gulf, 1–2 gC/m^2 in the central part, compared with 0.5 gC/m^2 in Philippine off-shore waters and the Celebes Sea. However, productivity round the Phillippines appears to increase towards the shore and to be exceptionally high in Manila Bay.

The relative potential of demersal fish in different areas may also be estimated from a comparison of actual trawl catches, by commercial, exploratory, or research vessels. This has to be done with some caution, since trawl catches depend very much on the size and power of the vessel, type and rigging of the net, time of day etc. However, an increasing number of observations are now becoming available for the region. Besides covering an increasing proportion of the potential trawling area, there should be an increasing overlap in which more than one ship has fished in the same area at the same time of year, thus providing a proper opportunity for inter-ship calibration.

Lester (1967) and Menasveta (1968) have reviewed most of the published data in the Sunda Shelf area, the most important of which are the surveys carried out from Taiwan (Tsung 1962; Yee 1961, 1963; Tseng (1967), though other surveys have been made from Malaya (Ommanney 1961), Hong Kong and Thailand (Tiews 1966). Four areas produced good catches; in the Taiwan surveys the highest catches were on the east side of the Gulf of Thailand, and South Vietnam (15 boxes, or *c.* 400 kg/haul), followed by the area off the Mekong (12 boxes, or *c.* 300 kg/haul), and the northern part of the Gulf of Thailand (7 boxes, or *c.* 200 kg/haul); other vessels also took good catches round Natuna Island, in the centre of the Sunda Shelf. These results confirm the higher potential of the inner Gulf of Thailand, especially since this area was, at the time of the surveys (1960/4), more heavily exploited than others.

However, the surveys also showed that demersal fish were present over the whole of the Sunda Shelf. Blank hauls occurred, as they do in all fishing operations, but there was no large area of consistently zero or very low catch. Excluding the richer areas noted above, the average catch per haul in the Taiwan surveys was 4 to 5 boxes (100–125 kg). This is perhaps half the value that would have been obtained in the inner Gulf before fishing started; probably the potential yield is in proportion to the standing crop. Reasonable estimates for the potential yield are, as extrapolated from experience in the Gulf of Thailand, therefore, 20–30 kg/ha in the richer parts, and 15–25/ha, elsewhere. These figures may be compared with the fairly good estimate of *c.* 25 kg/ha in the East China Sea, and the much rougher estimate of 800,000–1.5 million tons total, or 30–50 kg/ha for the Chinese south coast. The agreement is reasonably good, and using these figures, estimates of demersal potential may be summarized as shown in Table 15.

The total demersal potential as estimated in this table is 9.1–13.3 million tons. This is about double the present catches, though the immediate prospects for expansion are not quite as good as this two-fold difference implies, since some of the areas where the unexploited potential is greatest are the open areas of the South China Sea, some distance from suitable markets, and where the

TABLE 15. ESTIMATED DEMERSAL RESOURCES OF THE WESTERN CENTRAL PACIFIC BY AREAS

	Area ('000 km²)	*Present catches ('000 tons)*	*Catch, kg/ha*		*Total potential ('000 tons)*
			Present	*Potential*	
Yellow Sea—East China Sea	950	1,800	20	25	2,000–2,400
Chinese south coast	280	700	25	30–50	800–1,500
Gulf of Tongking	200	250	12	30–50(a)	600–1,000
Gulf of Thailand					
Thailand coast	84	337	40	60	500
Southeast coast	50	50?	10?	60(a)	300
Central	170	—	—	15–25(a)	250–400
South China Sea					
Richer areas (b)	50	?	?	30–50(a)	150–250
Others	920	?	?	15–25(a)	1,400–2,300
Java Sea	580	500?	9?	15–25(a)	900–1,500
Gulf of Carpentaria	960	—	—	15–25(a)	1,500–2,500
Philippines (c)	215	200(400?)	10	30–50(a)	600–1,000
New Guinea, etc.	90	?	?	15–25(a)	135–225

Notes: (a) Extrapolated from Gulf of Thailand.
(b) Off the Mekong Delta and Natuna Island. Other areas may later be shown to be rich, so the figures for the whole South China Sea may be an under-estimate.
(c) Studies by the FAO/UNDP(SF) project suggest that the true demersal catch may be as high as 400,000 tons, and the pelagic catch rather less than reported.

catch rates are low, and consist of a large proportion of low-valued fish.

Pelagic

Estimates of the present yield of pelagic fish from the southern waters are provided in the following table. As indicated earlier, the lack of data from many localities in this area subjects the estimates of present catches to considerable error.

The best studied area is probably again the Gulf of Thailand and virtually all the Thai catch (of some 70,000 tons) came from north of 9°N (statistical areas I, II and III). The stock has been studied in detail in a report by Kurogane *et al.* given to the 1970 session of the Indo-Pacific Fisheries Council. This concluded on the basis of a careful analysis of catch and effort data, size composition information and tagging results that no great increase in catch could be achieved either by an increase in effort, or by a change in size at first capture. Allowing for additional catches from the southern part of the Gulf of Thailand, if the fish there are a separate stock, it seems that the potential catch of pelagic fish from the Gulf is probably 100,000 tons, and may well be as much as 200,000 tons and might even be greater.

The pelagic resources in the Gulf are, therefore, probably rather less than the demersal resources, but probably rather more than a quarter of the demersal fish. Lacking better data, it is reasonable to assume this is also true of other areas in waters less than 50 m, which would give a total pelagic resource in the shallow water zone of from 1 million tons, as a conservative lower limit, up to perhaps 5 million tons.

In deeper waters (between 50 and 200 m), the pelagic fish are probably relatively more abundant; the large area concerned implies that the total demersal stock may be quite large, even if too widely scattered to be at present commercially exploitable; and the pelagic resources are probably as large or larger. A total resource of 1 million tons from this zone would imply a value of only 4 kg/ha (0.4 tons/km²), about one third of the lower

TABLE 16. ESTIMATED PELAGIC CATCHES, BY AREAS IN 1966 (IN TONS)

Area	*Catches by countries*		*Total*
Formosa Strait and China south coast	China (Mainland)	100,000?	
	China (Taiwan)	50,000	
	Hong Kong	10,000	160,000?
Gulf of Tongking	China (Mainland)	10,000?	
	Dem. Rep. of Vietnam	100,000?	100,000?
South China Sea	Rep. of S. Vietnam	70,000?	
	Malaysia	20,000(a)	
	Singapore		
	Indonesia	10,000?	100,000?
Gulf of Thailand	Thailand	70,000	
	Khmer Republic	10,000	80,000
Java Sea	Indonesia	300,000?	300,000?
Gulf of Carpentaria	Australia	negligible	
	Indonesia	?	?
Philippines	Philippines (b)	300,000	300,000
Total—all southern waters			*c.* 1,000,000

Notes: (a) Most of the Malaysian pelagic catch is taken on the west coast, outside the present region.
(b) True catch may be rather smaller.

estimate of the yield per unit area of demersal fish in the shallow zone. This is not unreasonable.

Island resources

One of the most notable features of the Western Central Pacific area is the presence of numerous islands of volcanic and coral origin. With the exception of relatively fair-sized commercial fishing carried out in the Ryukyu Islands and the Philippines, much of the fishing effort in the island areas is of a subsistence type and directed to fish and shellfish in the immediate coastal waters; primarily in the reef zone. The pelagic waters are presently fished for tunas and billfishes by Japanese, Chinese and other far-ranging fishing fleets. Another group of resources has been recently exploited by Russian trawlers which have taken good catches of bottom and near bottom fishes near some of the mid-ocean islands. While some data are available from these long range fisheries, data are almost completely lacking on the magnitude of the catch resulting from the subsistence type fishing around the islands. Although stock assessment estimates are not available for the fish species around the island waters, there are indications that much of the reef areas are presently over-fished, especially those located close to large communities.

Undoubtedly with proper management the yields of the over-fished reef areas can be increased; however, the total yield cannot be expected to be too great since the reef areas are relatively limited. In island waters, the resources which have not been explored or exploited to a great degree are the fishery resources in deeper waters beyond the reef zones. These waters contain demersal species such as snappers and groupers, and pelagic species of schooling fish such as scads and mackerel. To date these resources have not been fully harvested principally because of inadequate gear and marketing problems.

The estimate of the potential yield of the island waters (excluding the open sea fish species, e.g. tunas and billfishes) provided in the following table were obtained on a basis of comparability with a nearly fully exploited area, the Hawaiian Islands:

TABLE 17. POTENTIAL YIELD FOR ROUND OCEANIC ISLANDS IN THE WESTERN PACIFIC

Area	*Length of coastline (mi)*	*Potential yield (a) (metric tons)*
Nampo Shoto group	153	612
Trust territory of the Pacific Islands	3,561	14,244
Gilbert Islands	626	2,504
Ellice Islands	135	540
Solomon Islands	2,464	9,856
Islands southeast of New Guinea	3,943	15,772
Total	10,882	43,528

Note: (a) Based on yield of 4.0 metric tons per mi of coastline.

The fish fauna of the Hawaiian Islands is similar to the fauna of the Western Central Pacific Islands. The Island of Oahu has a general coastline length of 112 mi and the waters of Oahu are the most intensively fished of the major islands in the Hawaiian chain. The present catch of neritic pelagial fish species around Oahu has been estimated to be 4.0 metric tons per mi of coastline per year. Applying this rate to the island waters (excluding Ryukyu Islands, Taiwan, Philippine Islands, New Guinea and islands to the west of these areas) in the Western Central Pacific provides a rough minimum potential yield of 43,500 metric tons of fish. It is very likely that the true potential yield of fish from the island waters of the Western Central Pacific is some multiple of the 43,500 tons provided here. A three- to five-fold increase is not unrealistic, especially since the fauna of the Western Central Pacific is considered richer than the Hawaiian fauna and there is some evidence that fishing in Hawaii has not reached it full potential. As indicated in the above table, the total coastline of the islands in the Western Central Pacific considered here is estimated to be about 11,000 mi.

6. SUMMARY AND DISCUSSION

6.1 Summary

The estimates of potential in the region are of around 9–13 million tons of demersal fish, and of 2–6 million tons, or quite possibly more, of pelagic fish. These figures are extremely rough, and the range of estimates, though wide, are certainly no wider than the inadequacy of the data. However, the information is good enough to show that there are ample opportunities for expanding fish catches in the region, with the exception of certain heavily fished areas (e.g. the Yellow Sea, and the northern part of the Gulf of Thailand). The estimates also suggest that, especially for demersal fish, the region is potentially one of the most productive in the world, exceeding for example the total potential of the rich but less extensive areas of the Northwest Atlantic by some four-fold.

This is perhaps surprising in view of the fact that the region has not attracted the long distance fleets which exploit such areas as the Northwest Atlantic, Southwest Africa, etc., but may be explained by several factors. First, the shelf area is very large, so that the actual potential per unit area is not estimated to be very high. Secondly, the presumed faster turn-over and shorter life-span of most fishes in these warmer seas prevent the accumulation of large unexploited standing stocks and, under conditions of steady fishing, result in lower mean abundance from a given annual production. Also the wide variety of species in tropical areas is less attractive to industrial operations than the single-species fisheries of higher latitudes.

6.2 Requirements for further study

Although the available data have enabled estimates of potential to be obtained which are useful as first rough guides to the possible developments of fisheries in the area, it is obvious that much improved estimates are desirable.

The primary requirement is clearly an improvement in many of the basic statistics. It is impossible to make any useful estimate of the potential yield if the present yield is not known with any accuracy, and this accuracy is lacking in the available statistics of several countries. For nearly all fisheries there is an absence of any data of fishing effort in any form.

There are very few detailed assessments of the state of stocks and until the basic data, especially the statistics, have been improved, the number of stocks for which good assessments are available must remain small.

For most parts of the area, therefore, estimates of potential yield will have to be by comparison with other, better studied areas. It is, therefore, important to check how valid such comparisons are. This is best done as a comparison of the stock of commercial fish, e.g. as catch per hour of a standard unit of gear, but standardization is not too easy. Any other measure of biological productivity, from primary production onwards, would therefore be most useful, especially from the waters round Indonesia, in which data are very sparse.

Information on pelagic resources and of fish resources generally beyond 50 m depth is also sparse and urgently needs improving. Surveys with modern sonar and echo sounder gear to check on the presence or absence of shoals of pelagic fish (especially if accompanied by an efficient fishing vessel/purse seiner, or mid water trawler) would be particularly useful.

Appendix

TABLE I8. CATCHES FROM THE WESTERN CENTRAL PACIFIC ('000 TONS)

Country	1962	1963	1964	1965	1966	1967	1968	1969
Vietnam (North) (a)	222	214	(215)	(215)	(215)	(215)	(215)	(215)
Vietnam (South)	200	329	345	318	316	351	359	400
Cambodia	31	36	40	43	39	45	46	45
Thailand	249	303	472	513	591	648	842	(1,070)
Malaysia (b)	(170)	(200)	210	220	259	334	372	...
Singapore	11	12	10	11	18	18	17	17
Philippines	429	486	606	668	708	752	878	906
Brunei	2	4	3	4	3	1	2	2
Indonesia	436	447	(450)	(500)	(540)	(508)	534	566
New Guinea	(7)	(10)	(10)	(13)	(13)	(13)	(14)	(14)
Australia	*	*	*	*	*	*	*	1

Notes: (a) Catch of Vietnam (North) is very rough estimate
... No data
Brackets denote estimation
The precise figures of the catches of several other countries should be treated with some caution (see text)
(b) Malaysia excludes Sarawak
* Denotes catches less than 50 tons

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