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Chapter 13

Fisheries research and the demersal fisheries of Southeast Asia

Daniel Pauly

INTRODUCTION

Southeast Asia is one of the most diverse regions of the world, both in terms of its people and natural resources. At the core of the region surrounding the Sunda Shelf are the six members of the Association of Southeast Asian Nations (Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand). To these should be added—for a number of historical and cultural reasons—Burma to the west, the Indo-Chinese states of Vietnam and Kampuchea (landlocked Laos need not concern us here) and the southern Chinese coast up to Hong Kong and Taiwan in the northeast, and Papua New Guinea in the southeast, the latter of these peripheral countries linking up with the Northern Australian Shelf (see Figure 13.1 and Chapter 14). Except for the two small states of Brunei and Singapore, all Southeast Asian countries considered here have long, indented coastlines and two of them—Indonesia and the Philippines—are the largest archipelagic countries in the world.

Historically, this has resulted in Southeast Asian people having a close relationship to the sea, be it as seafarers or fishermen (Ruddle and Johannes, 1985). Yet at least until the turn of the century, exploitation of the region's abundant marine fish resources was light for a number of factors, such as:

- populations, and hence markets, much smaller than at present;
- relatively abundant freshwater fish resources (except possibly in the Philippines);
- lack of gears capable of catching demersal fish except near the coast.

Attempts to introduce trawling to the region were made under various colonial administrations: by the Dutch in Indonesia; by the English in what are now Malaysia, Singapore and Brunei; and by the French in Vietnam. At least in the latter case these efforts failed because the heavy gear used tended to get stuck in

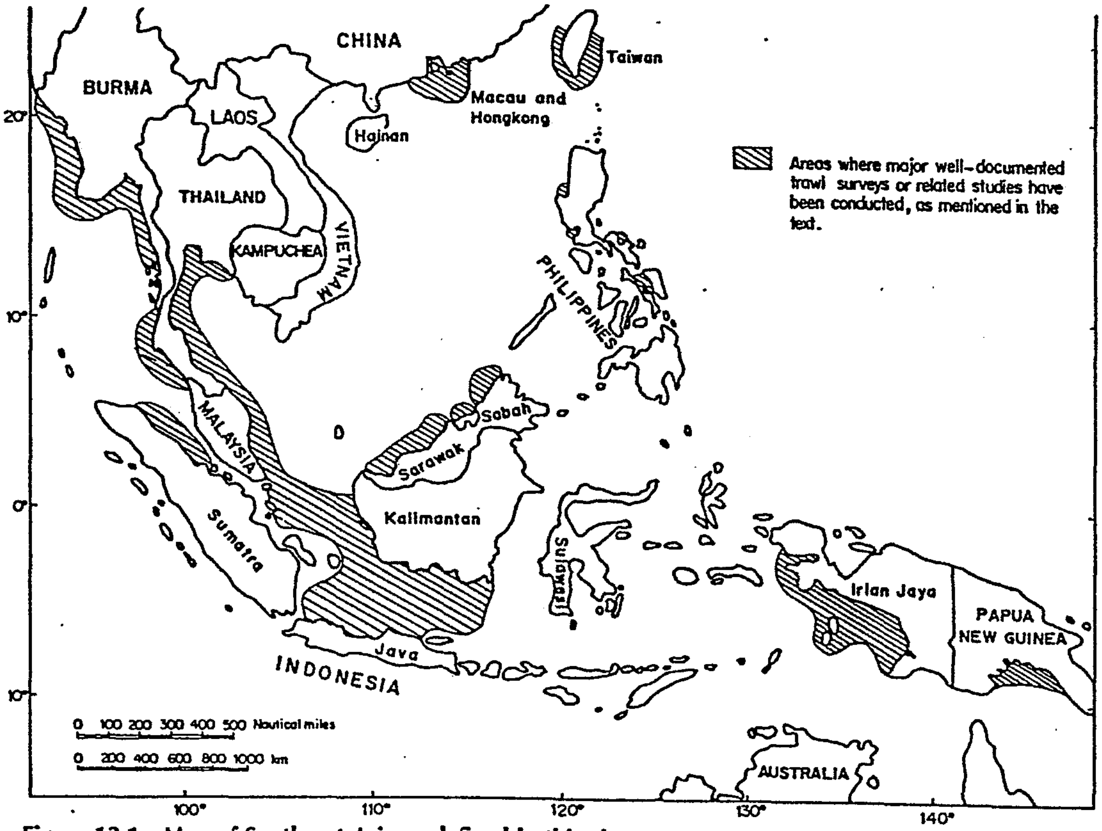

Figure 13.1 Map of Southeast Asia as defined in this chapter

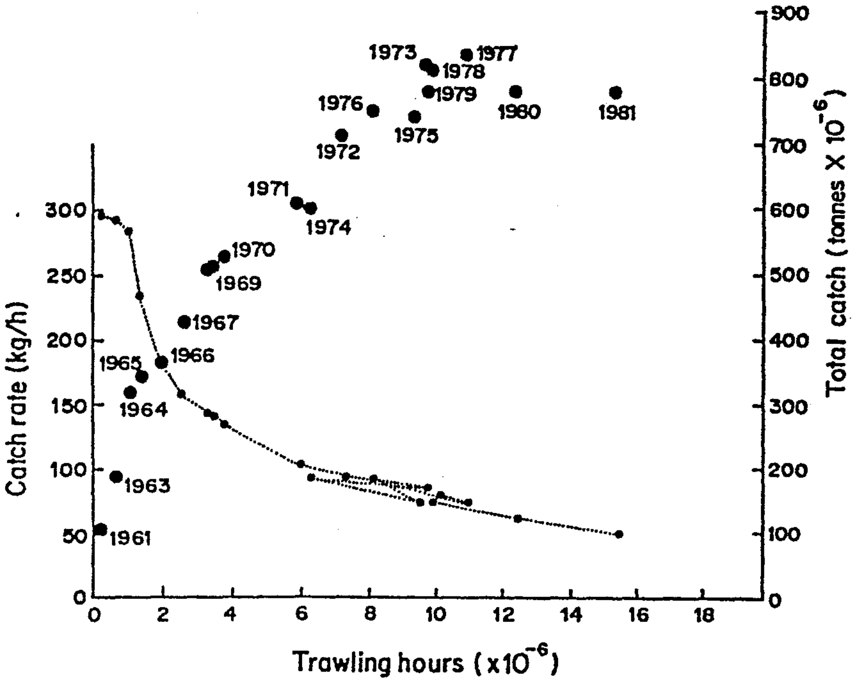

Figure 13.2 **Evolution of the total catch and catch per effort in the Thai demersal trawl fishery, 1961 to 1981 (from Boonyubol and Pramokchutima, 1984) (Reproduced by permission of ICLARM)**

the large mud 'hills' characteristic of the deeper parts of the Sunda Shelf areas.

More successful were the Japanese, who in the late 1920s introduced trawling to the Gulf of Tonkin and the coast of southern China and beam trawling to the Philippines.

Immediately after the Second World War and the destruction it entailed, conditions in Southeast Asia allowed for a rapid redevelopment of the trawl fisheries in the Philippines only, where an abundance of engines and crafts were abandoned by the US forces and a vigorous programme of reconstruction involving trawl and pelagic surveys, fish processing and other aspects of the fishery development was conducted. These efforts led to an early upsurge of demersal catches in the Philippines, especially in Manila Bay. This began to show signs of overfishing as early as in the late 1950s, partly masked by a transition to larger engines and high-opening trawls catching larger quantities of pelagic fish.

The 'take-off' of demersal trawl fisheries in other parts of Southeast Asia began later, and was initially focused in the Gulf of Thailand, to which the experience gained in the Philippines was transferred via a bilateral assistance project. This project, in addition to introducing trawling as a highly successful commercial operation, initiated a series of regular trawl surveys, which have been continued ever since, as well as other research work (Tiews, 1962, 1965, 1972).

Table 13.1 Time series of catches from three important Southeast Asian fisheries, 1960–80, in thousands of tonnes per year*

	Thai demersal fisheries		
Year	Gulf of Thailand	Andaman Sea and international waters	Philippine demersal fisheries
1960	58.9	7.5	71.8
1961	106.7	4.2	65.0
1962	129.7	6.6	67.2
1963	198.2	6.7	85.8
1964	320.6	13.9	104.4
1965	343.1	10.3	104.8
1966	363.8	23.8	112.8
1967	437.4	59.1	126.9
1968	513.4	152.5	178.1
1969	518.6	296.0	122.3
1970	530.9	336.9	115.0
1971	608.6	101.2	111.5
1972	737.9	295.7	141.7
1973	830.9	317.7	136.7
1974	604.9	431.3	157.8
1975	752.1	221.9	190.8
1976	787.9	156.5	169.4
1977	848.1	325.6	156.3
1978	814.1	384.2	155.1
1979	832.4	211.0	154.4
1980	798.0	241.8	139.7

* From Boonyubol and Pramokchutima (1984) and Silvestre *et al.* (1986).

The meteoric rise of the Gulf of Thailand demersal trawl fishery, and the consequent decline of its resource base (see Figure 13.2, Tables 13.1 and 13.2) have since become a classic story in tropical fishery science and there is here little need to belabour the economic and political implication of such overcapitalization. Rather, a brief account will be given of some of the scientific issues concerning the resource base of that fishery; this account will serve to introduce issues discussed in the subsequent section of this chapter.

THE GULF OF THAILAND TRAWL FISHERY: A BRIEF REVIEW

Early developments

The earliest estimate of potential yield of demersal fish in the Gulf of Thailand—or more precisely its shallower part, since most of the fishery is largely conducted within a coastal strip not deeper than 50 m—was of 75 000 tons per annum

Table 13.2 **Mean catch composition (in kg per trawling hour) during surveys conducted by R/V Pramong 2 and R/V Pramong 9 in the coastal areas of the Gulf of Thailand. (Adapted from Tiews 1965, 1972 and M. Boonyubol, Demersal Fish Division, Dept. of Fisheries, Bangkok, personal communication.))**

Groups identified	1963	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Leiognathidae	71.50	20.02	10.87	14.37	10.59	10.25	2.98	4.86	6.00	2.70	2.53	–	–	–	–	–	–	3.32
Carangidae	19.70	9.89	9.11	9.90	9.25	9.08	3.89	3.83	2.85	2.62	2.34	1.91	2.22	2.32	2.52	2.35	1.15	1.30
Nemipterus spp.	18.40	15.31	11.78	7.46	7.40	8.61	7.31	4.73	3.20	3.07	5.89	5.75	5.34	3.99	4.98	4.73	4.39	3.77
Sciaenidae	18.30	2.60	4.54	2.68	0.63	1.46	0.61	0.70	0.17	0.15	0.12	0.16	0.30	2.55	0.06	0.40	0.14	0.07
Mullidae	16.10	5.90	9.74	7.24	6.14	3.77	2.74	1.91	1.96	0.89	1.60	1.54	1.07	1.22	0.65	0.78	0.51	0.37
Rays	14.80	9.63	4.77	2.17	2.99	2.86	1.35	1.22	1.54	0.91	1.14	0.63	0.61	1.15	0.31	0.17	0.31	0.10
Saurida spp.	11.30	5.34	4.52	5.42	5.29	6.64	3.07	3.32	1.87	2.29	1.65	2.91	3.02	2.76	2.79	3.39	2.70	2.67
Tachysuridae	7.40	3.59	2.14	1.79	1.31	1.44	0.98	0.45	0.61	0.41	0.33	0.29	0.24	0.34	0.27	0.24	0.14	0.00
Loligo spp.	6.10	8.04	9.13	10.60	11.61	8.55	11.03	14.23	9.94	14.28	6.42	9.27	8.31	8.99	6.79	6.98	7.28	8.61
Scolopsis spp.	7.60	4.74	3.28	2.65	3.91	2.62	1.91	1.38	0.98	0.71	0.74	0.87	0.72	0.65	0.37	0.55	0.55	0.48
Priacanthus spp.	5.60	4.08	7.17	6.22	7.45	7.38	5.21	1.89	2.43	5.44	2.10	2.87	2.33	3.11	3.87	4.09	4.41	3.78
Sharks	2.10	1.86	1.64	1.04	0.60	0.75	0.60	0.54	0.45	0.28	0.14	0.21	0.30	0.15	0.19	0.05	0.21	0.12
Sphyraena spp.	2.10	1.74	1.37	0.74	1.14	1.43	0.35	0.31	0.15	0.22	0.16	0.15	0.17	0.36	0.52	0.29	0.34	0.30
Thenus spp.	2.00	0.72	0.34	0.35	0.29	0.19	0.13	0.11	0.05	0.04	0.03	0.04	0.06	0.03	0.02	0.01	0.01	0.12
Lutjanidae	1.50	4.76	4.02	3.83	3.01	2.25	0.99	0.56	0.54	0.41	0.43	0.75	0.20	0.50	0.77	0.47	0.49	0.89
Plectorhynchidae	1.30	1.17	1.37	0.95	1.09	0.63	0.23	0.14	0.09	0.14	0.11	0.09	0.07	0.09	0.06	0.20	0.05	0.02
Trichiruidae	0.90	1.01	1.24	1.46	0.74	0.94	0.69	0.85	1.02	0.84	2.87	1.86	1.25	0.98	2.10	0.39	0.29	0.75
Serranidae	0.80	1.23	1.37	1.05	0.95	0.86	0.51	0.33	0.33	0.21	0.45	0.51	0.59	0.41	0.66	0.63	0.47	0.45
Rastrelliger neglectus	0.80	0.19	0.37	0.52	1.03	1.54	0.40	0.16	0.22	0.08	0.14	0.09	0.08	0.19	0.41	0.17	0.14	0.25
Crabs	0.70	0.92	0.61	0.70	0.86	1.32	1.15	1.61	0.91	1.60	1.00	0.75	0.85	0.87	1.12	1.05	0.66	0.57
Lactarius lactarius	0.60	0.59	0.19	0.23	0.10	0.02	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Shrimps	0.60	0.27	0.12	0.09	0.11	0.15	0.26	0.22	0.10	0.09	0.16	0.24	0.31	0.24	0.24	0.42	0.29	0.37
Ponadasys spp.	0.40	0.41	0.32	0.21	0.30	0.16	0.05	0.06	0.08	0.05	0.01	0.01	0.01	0.02,	0.01	0.02	0.00	0.02
Scomberomorus spp.	0.40	0.61	0.47	0.82	0.08	0.56	0.33	0.38	0.55	0.44	0.30	0.30	0.27	0.28	0.35	0.52	0.18	0.41
Penaeus spp.	0.40	0.27	0.16	0.19	0.13	0.09	0.05	0.05	0.04	0.17	0.03	0.01	0.03	0.03	0.01	0.02	0.00	0.02
Psettodes erumel	0.40	0.99	0.63	0.58	0.65	0.56	0.71	0.51	0.30	0.25	0.36	0.24	0.24	0.22	0.16	0.20	0.17	0.09
Chirocentrus spp.	0.20	0.19	0.13	0.30	0.17	0.23	0.15	0.10	0.14	0.22	0.13	0.17	0.21	0.23	0.43	0.24	0.22	0.20
Rachycentron canadus	0.20	0.24	0.33	0.23	0.21	0.22	0.09	0.13	0.08	0.17	0.02	0.10	0.10	0.06	0.12	0.07	0.05	0.07
Lethrinidae	0.20	0.47	0.86	0.33	0.28	0.25	0.11	0.16	0.05	0.05	0.04	0.16	0.11	0.05	0.09	0.13	0.11	0.04
Muraenesox spp.	0.10	0.24	0.16	0.21	0.66	0.26	0.29	0.21	0.12	0.14	0.30	0.18	0.17	0.18	0.08	0.14	0.12	0.12
Rhinobatidae	–	0.62	0.65	0.84	0.43	0.40	0.48	0.06	0.11	0.01	0.09	0.02	0.09	0.02	0.01	0.01	0.00	0.00
Anadontostoma spp.	–	0.24	0.15	0.30	0.36	0.21	0.11	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.03
Gerridae	–	–	5.93	3.13	3.06	2.55	1.49	0.85	0.49	1.41	0.69	1.11	0.80	0.54	0.05	0.09	0.06	0.04
Rastrelliger kanagurta	–	0.42	0.66	0.63	0.96	0.86	0.47	0.36	0.26	0.26	0.18	0.20	0.28	0.45	0.40	0.25	0.20	0.22
Bothidae	–	0.63	0.33	0.38	0.35	0.32	0.52	0.58	0.26	0.16	0.35	0.18	0.14	0.00	0.00	0.00	0.00	0.00
Cynoglossidae	–	0.12	0.06	0.04	0.14	0.07	0.24	0.31	0.13	0.06	0.37	0.09	0.10	0.09	0.11	0.14	0.10	0.04
Sepia spp.	–	2.80	1.87	2.10	2.33	2.62	2.28	2.97	1.87	3.10	2.31	2.41	2.39	2.43	2.36	1.84	1.71	1.27
Misc. fish	–	–	12.44	13.79	14.77	15.14	12.52	13.01	12.02	13.80	11.45	–	–	–	–	–	–	12.45
Total catch (including misc. fish)	248.95	130.98	114.84	105.54	102.37	97.24	66.31	63.12	51.92	57.68	46.99	57.22	46.98	52.12	51.66	48.14	38.77	43.36
No. of hauls	200	713	713	719	720	718	720	720	718	540	480	261	579	436	235	245	159	215

(Tiews, 1962). In this fishery some 150 species make a significant contribution. At the time this estimate of potential was produced—which in retrospect appears very low, see Figure 13.2—the theory of fishing as developed by R.J.H. Beverton, S.J. Holt, M.B. Schaefer and W.E. Ricker for single-species stocks was still being resisted in the region where it originated. Moreover, none of the rules of thumb suggested by J.A. Gulland, such as 'potential yield = half $M \times$ virgin stock', or the procedure of treating the whole multispecies biomass as if it were a single species, were then available. Still less were there models which explicitly considered interactions between a large number of species.

Based on his rules of thumb, Gulland (1972) derived an alternative estimate of potential yield of 500 000 tons per annum, still less than the plateau now apparent at about 800 000 per annum (see Figure 13.2).

Species changes

Evidence for massive changes in the species composition of the Gulf of Thailand demersal resources was first presented by Tiews *et al.* (1967), based on two of the early trawl surveys conducted in 1963/64 and 1966.

These changes consisted of a massive decrease of some of the previously abundant groups, such as the croakers (Sciaenidae) and the slipmouths (Leiognathidae), and a marked increase of the snappers (Lutjanidae) and squid (predominantly *Loligo duvaucelí*) (see Table 13.2), and were attributed by Tiews *et al.* (1967) entirely to the effect of fishing. However, Gulland (1972) noted that:

> The biggest effect of fishing would be expected among the fish most attractive to the fishermen, through being abundant or of high value, or the fish with potentially long lives (probably the bigger fish); on these grounds, one might well expect *Lutjanus* to show an above-average decline, not an increase.

Pauly (1979), in a later analysis based on data for 1963–72, noted among others, the following changes:

- virtual disappearance of rays and sawfish (i.e. very large, long-lived fish);
- increase in numbers of squid;
- faster than average decrease in the Leiognathidae and some other small fishes.

He then raised the question of the degrees to which the simple models, developed in temperate waters, could be used in the tropics. Table 13.2 may be consulted for further trends, notably the disappearance of fish such as *Lactarius lactarius* and the continuation of the above-mentioned trends from 1972 to 1982.

The disappearance of the large zoobenthos feeders (given large trawler effort), such as certain groups of rays, is not surprising, and has been demonstrated also to occur elsewhere, e.g. in San Miguel Bay, Philippines. The vulnerability of rays to heavy fishing has also been noted in temperate waters (see Chapter 12).

The increase in numbers of squid has been examined in some details by Pauly

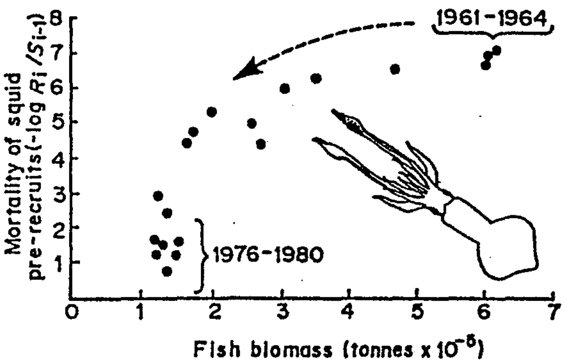

Figure 13.3 **Relationship between the estimated mortality of squid pre-recruits ($-\ln R_i/S_{i-1}$) and the biomass of their potential predators (mostly fish) in the Gulf of Thailand, 1962–80 (From Pauly 1985, with permission)**

(1985). Based on catch-per-effort data such as in Table 13.2, effort data such as in Figure 13.2 and the assumption of a constant catchability, squid biomass was estimated using the swept area method (see Gulland, 1983). This biomass was then converted into an estimate of annual squid egg production in (S_i) using available information on the fecundity of loliginid squid and on the size at first maturity and growth parameters of *Loligo duvauceli*, which, being the most abundant species of squid in the Gulf of Thailand, was taken as representative of the group.

Annual recruitment (R_i) into the squid stock was estimated by dividing annual yield per recruit of *L. duvauceli* (recruitment being measured at the time the squid weighed 2 g) into the annual catch of squids from the Gulf, a procedure which is legitimate given the very short lives of squid such as *L. duvauceli*. Then an index of egg to recruit mortality was computed, for each year, as $-\ln (R_i/S_{i-1})$. This index was finally plotted against the estimated fish biomass in the Gulf of Thailand (Figure 13.3). As might be seen, the mortality of squid pre-recruit diminished with the biomass of fish in the Gulf of Thailand. Because of the procedures used, and the possible existence of common trends with time, it is impossible to test the statistical significance of this result. However, it agrees with previous suggestions by various authors that when a demersal fish stock is reduced, the demersal eggs of squid and their newly hatched young suffer less predation, and that their stock may increase in spite of a strong fishing pressure.

Other changes have been more difficult to explain biologically, and a number of competing hypotheses relative to the dynamics of groups such as the *Leiognathidae*, the flatfish *Psettodes erumei* or the penaeid shrimp may be found in the literature (see e.g. Murphy, 1982; Pauly, 1984; Pauly and Murphy, 1982).

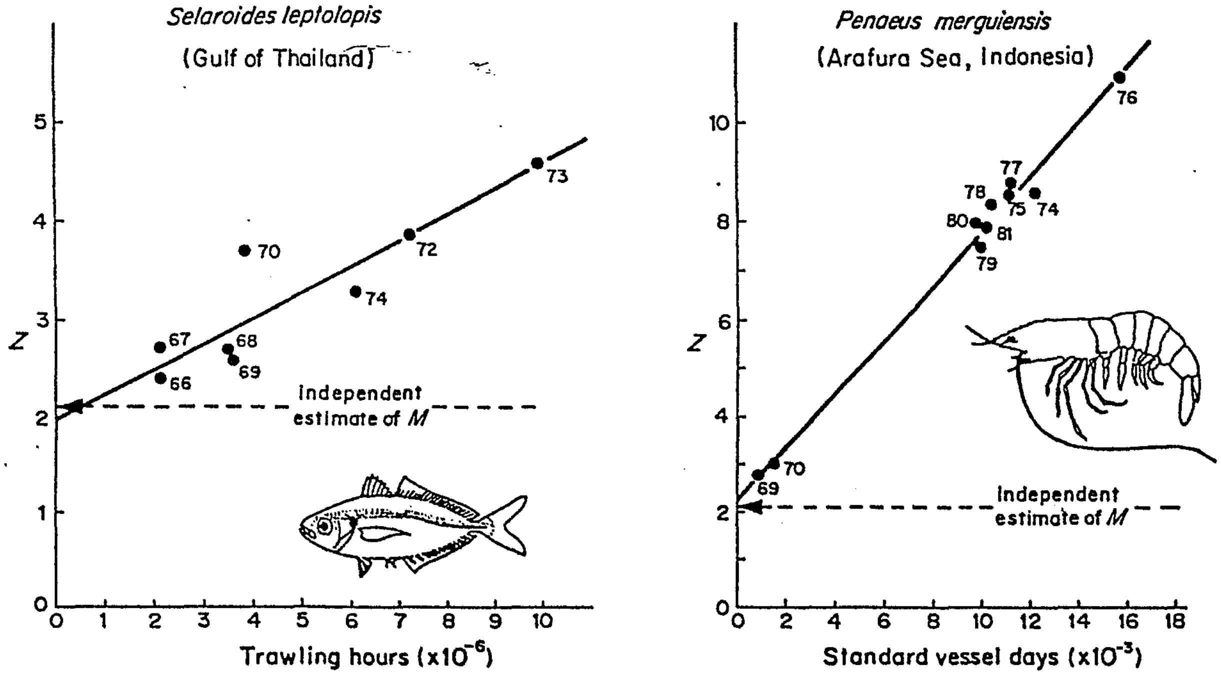

Figure 13.4 Relationship between total mortality (Z) and fishing effort in yellowstripe trevally (left) and banana prawn (right) from two major fishing grounds in Southeast Asia (from Pauly 1980a, and Naamin 1984). (Reproduced by permission of the Food and Agriculture Organization of the United Nations, and N. Naamin)

Technological interactions

Pope (1979) in his comprehensive analysis of the Gulf of Thailand trawl fishery emphasized technological interactions (i.e. changes due to species differences in vulnerability to the fishing gear) and, based on a principal component analysis of *c/f* data similar to those in Table 13.2, was able to show that species changes could be largely explained by the steady increase of effort, thus vindicating Tiews et *al.* (1967).

Indeed, it now seems that some earlier questions as to the applicability of the theory of fishing to tropical stocks such as occur in the Gulf of Thailand have been resolved, and standard approaches shown to apply. This is exemplified here by Figure 13.4 (left), representing a plot of total mortality in yellowstripe trevally *Selaroides leptolepis* (estimated from the mean length in survey trawl catches and growth parameter estimates) on standardized trawling effort.

This plot produces (at zero effort) an estimate of $Z = M$ which is extremely close to the estimate of M obtained using the empirical equation of Pauly (1980b).

Other questions, related to the decline of the formerly very abundant Leiognathidae to extremely low levels of apparent abundance at a rate higher than the demersal stock as a whole, now seems to be resolvable without recourse to exotic mechanisms. These fish, like the rest of the Gulf of Thailand demersal stock, were exploited by commercial trawlers with cod-end mesh sizes of 2 cm (stretched) but had been monitored by a research trawler using 4 cm cod-end mesh.

Hence the decline of leiognathid catch per effort in research surveys relates only to the larger individuals, and exaggerates the actual decline of the population as a whole. That this effect should have been stronger in the Leiognathidae than in other fishes can then be explained by their overall small size (only one representative of this family reaches more than 20 cm, while the majority of the species reach 12 cm at most).

SOME ISSUES IN POPULATION DYNAMICS

Stock definition and community analyses

The bulk of the biomass of demersal fishes in Southeast Asia occur—at least when the stocks are unexploited—at depths of less than 50 m. Trawl surveys of the little-exploited stocks off Burma showed that, as elsewhere in Southeast Asia, certain species and families occur predominantly in distinct depth ranges. Important fish species characteristic of shallower waters (10–50 m) were *Pomadasys hasta, Lutjanus johni, Dasyatis* spp., *Arius caelatus, Osteogeniosus militaris, Polynemus indicus, Carangoides malabaricus* and *Leiognathus splendens*.

At depths exceeding 100 m, the most important species are *Priacanthus macracanthus* and *Saurida undosquamis*, which are common throughout Southeast Asia, as well as crocodile fishes *(Peristedion weberi, P. adeni)*, which, unlike all previously named species, occur rarely in other Southeast Asian countries (Pauly et *al.*, 1984).

However, rigorous community analyses of demersal fish have until recently not been conducted either in Burma or elsewhere in Southeast Asia. In this, the region differs markedly from, say, west Africa, where the results of the Guinean Trawling Survey have provided a solid database from which generalizations about community structure, e.g. the differences between communities on hard or soft bottoms, or above or below the thermocline, could be derived 20 years ago which now still hold (Fager and Longhurst, 1968).

This lack implies that work on the dynamics of Southeast Asian demersal stocks is usually conducted using data (e.g. catch per effort, catch, species and size composition data) which may stem from different communities.

One recent analysis by McManus (1986) and based on extensive trawl survey data from the Samar Sea, central Philippines, led however, to the following two key findings:

– all ordination and classification analyses indicated that depth is the primary gradient affecting the distribution of demersal fish species. Other factors (e.g. bottom type, temperature, etc.) only caused variability in the effects of depth as the primary structuring force;

– the change with depth is particularly sharp at around 30 m, leading to the marked differences between the communities above and below 30 m.

This suggests that commercial fishing pressure in the waters below 30 m may have little influence on many of the species important to the shallow water artisanal fishery.

These findings have the obvious implication that legislation aiming at reducing the impact of the growing commercial trawl fisheries on the small-scale non-trawl fisheries by a physical separation should use 30 m (or 15 fathoms) as the dividing line, rather than the current 7 fathom limits.

Further studies of this type will reveal whether these findings can be generalized to the other parts of Southeast Asia, where 7 fathom or even lesser limits are commonly used to separate artisanal from commercial fishermen.

Surplus production models

Surplus production models (e.g. the model proposed by Schaefer, 1954) have been widely applied to tropical fisheries throughout the world. Some of the applications have widened the assumptions of these models, which treat the population of a given species as a single biomass, regardless of size or age composition, and treat the demersal population as a single biomass, regardless of species composition.

Examination of a number of plots of catch v. effort for multispecies stocks revealed that often they do not display a declining trend at very high levels of effort (see Marten and Polovina, 1982, and Figure 13.2).

The flat-topped nature of such plots is due to changes in relative species composition; i.e. to faster growing, smaller fish (or by invertebrates such as squid) making up a higher proportion of the stock at high levels of fishing effort. It must be stressed that the ordinate scale of such a plot (i.e. the 'annual catch' scale) involves the combination of quantities, e.g. catches of rays, large groupers (important in the early years of a fishery), and squids and/or small fishes (important in the later years of that 'same' fishery) which are not exactly comparable, and which should be combined only with caution. This has the practical implication that there is no unique level of effort corresponding to MSY (i.e. there is no f_{MSY}) and hence the health of the fishery cannot be measured in terms of how much actual effort differs from f_{MSY}.

This implies that economic considerations (e.g. 'which level of effort allows the fishery to break even while still landing as much fish as possible?') should become paramount when fishery biologists formulate management options. Thus in the case of Figure 13.2, it is readily apparent that the level of effort prevailing in the mid-1970s was more than sufficient to extract the potential yield of the Gulf of Thailand. The further increase of effort, which involved considerable extra economic costs, produced no additional tonnage, and involved changes in species composition that, in general, reduced the value of the catch (see Table 13.2).

Analysis of length–frequency data

Age studies of fish based on otoliths, scales or other hard parts of fish have been rare to non-existent in most Southeast Asian countries, both in terms of annual or seasonal rings, and in terms of daily otolith rings, the only exception to this being the numerous studies off Taiwan, Hong Kong and the Gulf of Tonkin, where the strong summer/winter water temperature differences (6–10 °C) induce marked annuli on the scales and otoliths of fish (Eggleston, 1972). Thus the fishery biologists in this region have been unable to use the many age-based techniques which are standard in temperate waters.

Analyses of length–frequency data, on the other hand, have been conducted on a large number of stocks and species. These studies have relied on the fact that recruitment of the fish composing the Southeast Asian demersal resources is not 'continuous'. Rather, length–frequency data collected over a sufficiently long period, and over a wide range of sizes, using a gear that is reasonably non-selective (e.g. a trawl) will generally exhibit seasonal 'pulses' of recruitment which can be followed over time. This can provide a general idea of the growth of the fish of a given stock similar to the 'Petersen method' in temperature waters (D'Arcy Thompson, 1942).

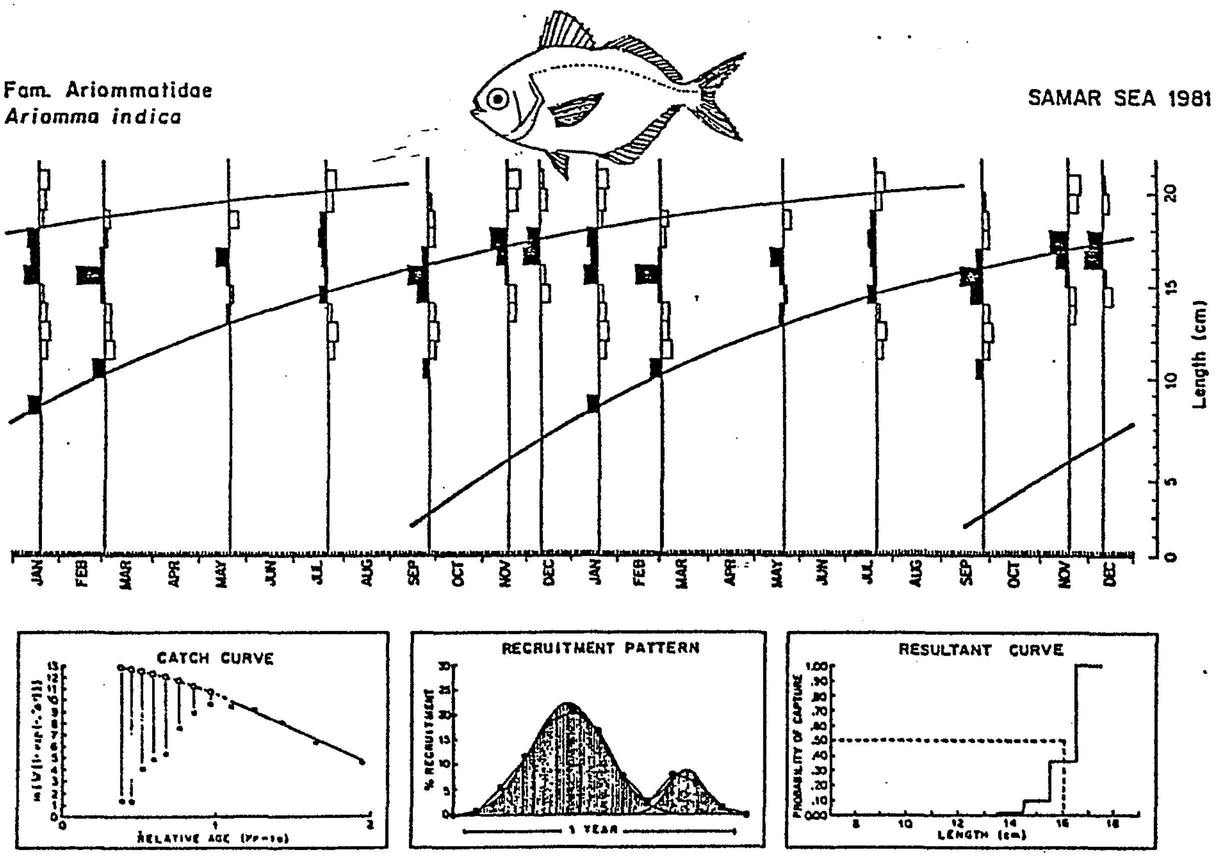

Figure 13.5 Results of an analysis of length–frequency data on Indian driftfish from the Southern Samar Sea, Philippines, using ELEFAN I and II (modified from Corpuz et al., 1985) See text for details (Reproduced by permission of the Department of Marine Fisheries, University of the Philippines in the Visayas)

Various methods—some computer-based, some not—exist which allow for identifying and/or emphasizing such 'pulses'. Figure 13.5 (upper panel) shows how a set of length–frequency data on Indian driftfish, *Ariomma indica*, was analysed with one of these methods (see Pauly, 1982). The top part of the figure shows the length composition after a smoothing process has been applied, and indicates peaks in the length groups, above the mean curve (in black) and troughs below the mean curve (open).

Combinations of the von Bertalanffy growth formula (VBGF) parameters were examined to find the curves (shown in the figure) that best fit the observed peaks. Note that the data have been repeated for a second year to simplify the work of fitting the curves. The estimated parameter values of the VBGF were $L_\infty = 22.5$ cm and $K = 1.13$ (year^{-1}).

Once these parameters have been estimated, the length–frequency data used for the estimation of growth parameters can be summed up to obtain an approximation of the average size composition of the catch, which can be then used to derive, given the estimates of L_∞ and K, a length-converted catch curve (Gulland, 1983; Pauly, 1982). An example of such a curve is presented here in the lower left panel of Figure 13.5. It provides an estimate of $Z = 6.1$ year^{-1}, which is rather high and might be due to the assumption of steady state implicit in catch curve analysis not having been met in this case. The right descending arm of a length-converted catch curve can, moreover, be projected backward to obtain an estimate of the (relative) number of fish that would have been caught, had it not been for size-specific selection and recruitment to the fishery. This leads to a 'resultant selection curve', as illustrated in the lower right panel of Figure 13.5, where the ratio of the numbers of fish caught to the numbers of fish that would have been caught, had it not been for the effects of incomplete selection and recruitment, is plotted as a function of length.

Finally, using length–frequency data, one can also infer the seasonal structure of recruitment into a stock. The result of this analysis, which is a feature of the ELEFAN II program, is illustrated in the lower panel, middle graph of Figure 13.5. In this example, recruitment apparently consisted of two unequal pulses separated by approx. 6 months.

Thus, length–frequency data, properly sampled and analysed, can in a large number of cases provide estimates of key parameters used in the assessment of single-species stocks (see Chapter 4).

Combined with data related to a given fishery (e.g. catch, effort), vital statistics derived from length–frequency data can be used to estimate derived parameters such as natural mortality (Figure 13.4) needed for yield-per-recruit analyses or in combination with estimates of length at first capture (e.g. $L_{0.5} = 16$ cm in Figure 13.5) can be used to make inferences on optimum mesh sizes, as discussed in the following section.

Table 13.3 Optimum mesh size for the cod-end of Southeast Asian trawlers as estimated using various methods (present mesh size is usually 2 cm or less)*

Area/Country	No. of species (groups) incl. in analysis	Optimum cod-end mesh size (cm)	Sources and remarks
Southern South China Sea	44	4.5–5.5	Sinoda *et al.* (1979), based on original method derived from considerations in Jones (1976). Results apply to landed weights and values
Malacca Strait	38	4.5–5.5	
Inner Gulf of Thailand	51	4.5–5.5	Meemeskul (1979), based on method of Sinoda *et al.* (1979)
Brunei	Numerous, but emphasis on 4 spp. of Leiognathidae	≥4	Lindley (1982), based on an approach suggested by Jones (1976)
Northwest Shelf of Australia*	35	5.5–7.0	Sainsbury (1984), using original method
San Miguel Bay, Philippines†	16	5.4	Based on landed weight, Smith *et al.* (1983), using method of Sinoda *et al.* (1979)
San Miguel Bay, Philippines†	16	5.3	Based on landed value, Smith *et al.* (1983), using method of Sinoda *et al.* (1979)
Southern Samar Sea, Philippines	10	3.5	Silvestre (1986), assuming knife-edge selection

* Taiwanese trawlers operating off northern Australia have a larger mesh size than trawlers operating in Southeast Asia (i.e. 6 cm).

† One of the 16 groups explicitly included was penaeid shrimp.

Optimum multispecies mesh sizes

Exploiting with a trawl a multispecies resource as diverse as that represented by the data in Table 13.2 (where each family may consist of two to twenty individual species) raises problems. Yield-per-recruit analyses, e.g. as developed by Beverton and Holt (1957), provide a straightforward method for the estimation of optimum mesh size in single species and mesh assessments can also be made directly from length data (Gulland, 1961). The optimum mesh size for a given species will depend on its size and shape, as well as on the balance between growth and natural mortality, and on the fishing effort to which it is exposed.

The species listed in Table 13.2 reach maximum sizes ranging from a few centimetres (in penaeid shrimps, or in Leiognathidae) to over 1 or 2 m (e.g. in sawfish) and have very different shapes. There is therefore no single mesh size which is optimum for all species, even though they belong to the same biological community.

A number of authors working on Southeast Asian and similar demersal stocks have attempted to estimate the optimum mesh size to use in such multispecies fisheries. This usually involves making a number of assumptions, among other things:

– that a given set of growth parameters (usually L_∞ and K of the VBGF) can be used to represent the growth of a group of species reaching similar sizes;

– that a given set (or range) of M values (or M/K values) can be used to express the natural mortality of fish of similar size occurring in the same environment;

– that the recruitments of different species groups remain in the same ratio over a wide range of fishing mortality.

Given these assumptions—of which only the latter is highly questionable, but is used for lack of a better alternative—optimum mesh sizes can be computed for different groups using yield-per-recruit analyses. These can then be used to calculate an overall 'best' mesh size, e.g. based on an averaging of single-species optimum sizes using a simple weighting scheme derived from the third assumption, as suggested by Sinoda *et al.* (1979).

Alternatively, a summation function can be formulated such that aggregate yields per recruit for all species is maximized for a given overall mesh size (Sainsbury, 1984; Silvestre, 1986). This is probably preferable because the yield per recruit is not a linear function of mesh size, and because such an approach allows explicit consideration of wide selection ogives (Table 13.3).

As might be seen in Table 13.3, the analyses based on these two basic approaches and variants thereof all tend to suggest the same result, i.e. that the optimum trawl cod-end mesh size in Southeast Asia is about 4–5 cm. The meshes of about 2 cm currently utilized are far too small, and should be at least doubled in size.

One reason why increased mesh sizes are difficult to achieve is that demersal trawlers in Southeast Asia actually have small-sized penaeid shrimp as their target species, an issue briefly covered in the following section.

The shrimp problem in Southeast Asian fisheries

In 1980, the price to fishermen of medium-quality penaeid shrimp in the Philippines was about 56 pesos per kg (live weight) (8 Philippine pesos = 1 US$ in 1980). During the same period, the price of medium-quality demersal fish was about 7 pesos per kg. The 8 : 1 ratio between these two prices, which is typical of Southeast Asia, is one of the root causes of a number of biological, technological and social problems besetting the demersal fisheries of this region (Pauly and Neal, 1985). These problems, although they form a continuum, may be split into three sets, as follows:

– problems in assessing the shrimp and associated fish stocks, especially with regard to the biological interactions between fish and shrimp;

– technological problems related to attempts to catch only one part of the exploited shrimp/fish complex (e.g. catching shrimp but no fish, or vice versa);

– social problems arising from trawlers aiming at shrimp concentrations close to the shore, on ground utilized by small-scale fishermen (see also Chapter 9).

All of these problems occur because shrimp occur in commercially exploitable quantities in Southeast Asia only in habitats which are also the habitats of a large number of fish, and often in which the fish occur predominantly as juveniles. Thus, Unar and Naamin (1984) stated that,

> The ratio of shrimp to fish caught [. . .] depends upon the distance of the fishing ground. The closer the ground is to the shore, estuarine and lagoon, the more shrimps [are] caught. The ratio could be 1 : 1 or 1 : 3 and the further the ground from the shore, estuarine and lagoon, the fewer shrimps [are] caught, the ratio falling to 1 : 20 or 1 : 30.

Or, put differently: shrimp concentrations rapidly decrease with distance offshore. The problem is that absolute fish densities also decrease offshore, while the shrimp : fish ratio decreases even faster. This implies that in Southeast Asia, at least, attempts to 'disentangle' the artisanal inshore fisheries from the trawl fisheries using traditional legislative or administrative means (exclusive zones, bans on inshore fishing for trawlers, and others) usually fail to work because the offshore stocks simply cannot support lucrative commercial trawl fisheries.

Some radical approaches to resolving this issue have been attempted, e.g. in Indonesia. One has involved the introduction of a selective gear which catches shrimp and releases fish, and which is used mainly in the Arafura Sea area, eastern Indonesia, where a heavily exploited stock of *Penaeus merguensis* occurs (Figure 13.1), but where markets for the fish by-catch are presently absent. Another rather radical approach to 'disentangling' artisanal inshore and commercial trawl fisheries has been to ban trawling totally, as in certain areas of the Philippines, and especially in western Indonesian waters (Sardjono, 1980).

DISCUSSION

The previous brief review of some aspects of the demersal fisheries of Southeast Asia was presented to illustrate the contention that, over the last two decades, a gradual evolution of existing concepts, and the development of new methods, have greatly improved the ability of fishery scientists working in Southeast Asia and in other tropical demersal fisheries to perform stock assessments.

Crucial developments in this context have been, among others:

– the decoupling of surplus production models from the constraining assumptions upon which they were originally based, and their evolution toward exploratory plots of catch v. effort for describing the evolution of multispecies fisheries;

– the development of length-based methodologies, either as extensions of older, age-based approaches, or as new techniques for estimation of statistics expressing the growth, mortality and other processes in exploited fish populations;

– the extension of single-species models such as yield-per-recruit and mesh-size analyses to deal with multispecies situations.

Together, these developments, and others not presented here for lack of space, have created an environment that is extremely conducive to stock assessment and related research, and which allows—at least as far as formulation of practical fishing management advice is concerned—to a large extent earlier constraints to be overcome: lack of detailed catch statistics, multiplicity of species and the absence of clear annual rings on scales or otoliths.

These developments, furthermore, have laid bare the real problems of fisheries such as the demersal fisheries of Southeast Asia: these are not necessarily related to the precise estimation of biological statistics of fish, or the technical aspects of fishing management. Rather, it is a number of allocation and enforcement problems which prevent these fisheries from providing to society as many benefits as they could if they were well managed.

Although fisheries utilizing a variety of gears have existed since time immemorial, the recent introduction to Southeast Asia of otter trawls and the larger vessels used to fish them brought about a major transition. To understand the impact of this introduction fully it must be kept in mind that the numbers of small-scale fishermen utilizing other small gears for fish and shrimp were also increasing at the same time. Trawling has created a 'trash fish' industry; as trawling has increased, landings of by-catch and its usage for industrial purposes (production of meal, duck food, etc.) have also increased (Sinoda et *al.*, 1978). Boonyubol and Pramokchutima (1984) observed that total catch of food fish has increased only slightly since 1963 in Thailand; however, the 'trash fish' catch has increased dramatically, as is demonstrated by the increased number of fish-meal factories, from six in 1967 to 95 in 1980. The high value of the shrimp taken by trawlers 'subsidizes' the harvesting of fish populations at densities lower than would be economical if only the fish were taken.

The effect is a serious conflict between trawl fishermen and small-scale fishermen using traditional gears. It is not surprising that there are fewer fish as a result of shrimp trawling, or that small-scale fishermen catch less than previously, or that the small-scale fishermen recognize the trawlers as one of the causes of their problems. Outside of total bans as in Indonesia, efforts to restrict trawling on traditional small-scale fishing grounds near shore are largely ineffective, because these grounds yield the best shrimp catches. The small-scale fishermen have no tenure rights to the resources or the areas fished and thus tension mounts between the many poor fishermen and small number of well-equipped trawl owners and operators. Traditional fishing and management systems have eroded and few viable alternative systems are in sight, short of radical measures such as implemented in Indonesia.

These appear to date to be the real issues concerning fisheries in Southeast Asia, and it is apparent that while fishery biologists can contribute toward rational allocation and management decisions, these will ultimately be *political.*

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