Coastal Fisheries and Mollusk and Seaweed Culture in Southeast Asia: Integrated Planning and Precautions

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Abstract

Capture fisheries in Southeast Asia are characterized by rampant overfishing, made worse in many areas by problems of overpopulation and by inappropriate management strategies based on misconceptions about tropical fisheries. Mollusk culture and seaweed culture are frequently cited as means to alleviate fishing pressure and to provide substitute protein. There is great potential for expansion of these types of mariculture in terms of area used, species employed, and products generated. However, large-scale mariculture rarely provides significant employment, and the provision of low-cost protein in markets does not alleviate poverty in countries where food production is the primary means of employment. In cases where conflicts have arisen between mariculture development and ecosystem maintenance, mariculture has been favored by inappropriate economic valuations. Small-scale mariculture designed to provide alternative livelihood for fishers is worth developing, although limited by larval supplies and suitable farming areas. Mariculture should be approached as a species-diverse, small-scale enterprise within the framework of integrated coastal management.

Introduction

The increasing awareness of the fact that most capture fisheries in Southeast Asia are overexploited has focused attention on the mariculture of invertebrates and seaweeds to provide alternative protein and incomes. This paper briefly considers the overfishing problem, the prospects for mollusk and seaweed mariculture, the potential benefits of integrated mariculture systems, and the need for caution and proper perspective in planning such enterprises.

Coastal Marine Fisheries

The analysis and management of tropical fish stocks has traditionally been based on temperate Fishery paradigms. This has led to a history of misconception and faulty advice in the management of Southeast Asian fishery systems (Smith 1981, Pauly in press). A simple, fixed-price bioeconomic model (Gordon 1954; Fig. 1) illustrates the tendency for unemployed people in a relatively open-access fishery to enter the fishery until no substantial profit is left to share. In most temperate, developed countries, the equilibrium based on the actual cost of fishing is rarely approached, because of enforcement of regulations, or because alternative employment and welfare funds allow an effective equilibrium further to the left on the production curve (Smith 1979). However, in countries such as Indonesia and the Philippines (as well as many countries in Africa and the Caribbean), there is a large excess labor force, which is not provided alternative livelihood and not protected by a welfare system. National budget restrictions do not allow full enforcement of regulations and fisheries are left open to access. Thus, fisheries in these countries tend to be overharvested to a greater extreme.

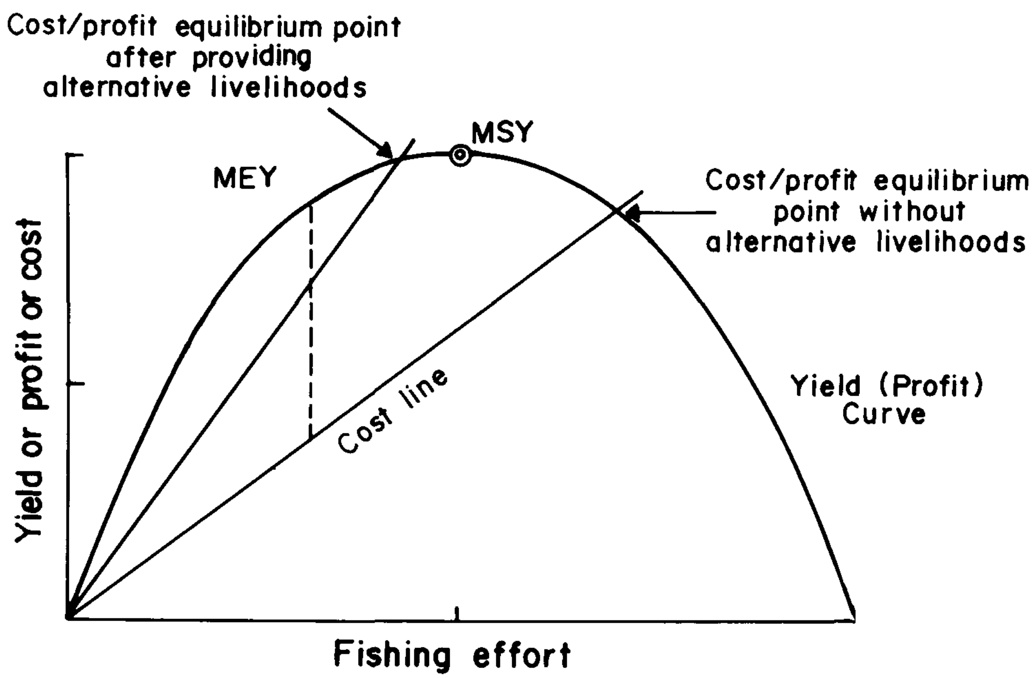

Fig. 1. Fixed-price model for profit and cost in an open-access fishery. In a society with open-access fisheries and an excess labor force willing to work for marginal profits, fishers tend to enter the fishery until virtually no net profit is to be made. MSY (maximum sustainable yield) coincides with the point of maximum gross profit. However, the maximum net profit occurs at the MEY (maximum economic yield), the point at which the difference is greatest between the cost of fishing and the gross profit. MEY is often attainable only after a 60% reduction in the fishery labor force or in the fishing intensity through provision of alternative livelihood. Efforts to lower the cost of fishing, such as providing fishers more efficient gear or low-interest loans, generally only drive the cost-profit equilibrium lower and result in severe depletion of the fishery. After McManus et al. (1992).

When complaints have arisen from fishers about the lack of fish, the typical response of governments, as well as international funding agencies, has been to provide low-interest loans for better gear. This has often been supported by the misconception that there are large, untapped stocks of fish in deep waters. However, unlike temperate seas, most tropical seas have a permanent thermocline that limits biological productivity primarily to upper waters. There are very few fish below 100 meters, and the bulk of the biomass is generally above 40 meters (Fig. 2; Pauly 1987). The improved gears have then merely worsened the overfishing problem in shallow waters. The fact that most such loan programs involved widespread defaulting produced an effective lowering of the cost of fishing and an increase in fishing effort to a new no-profit equilibrium point. Studies have clearly shown that both pelagic and demersal fisheries in the Philippines are overfished (Figs. 3 and 4), and so are those of most of southeast Asia.

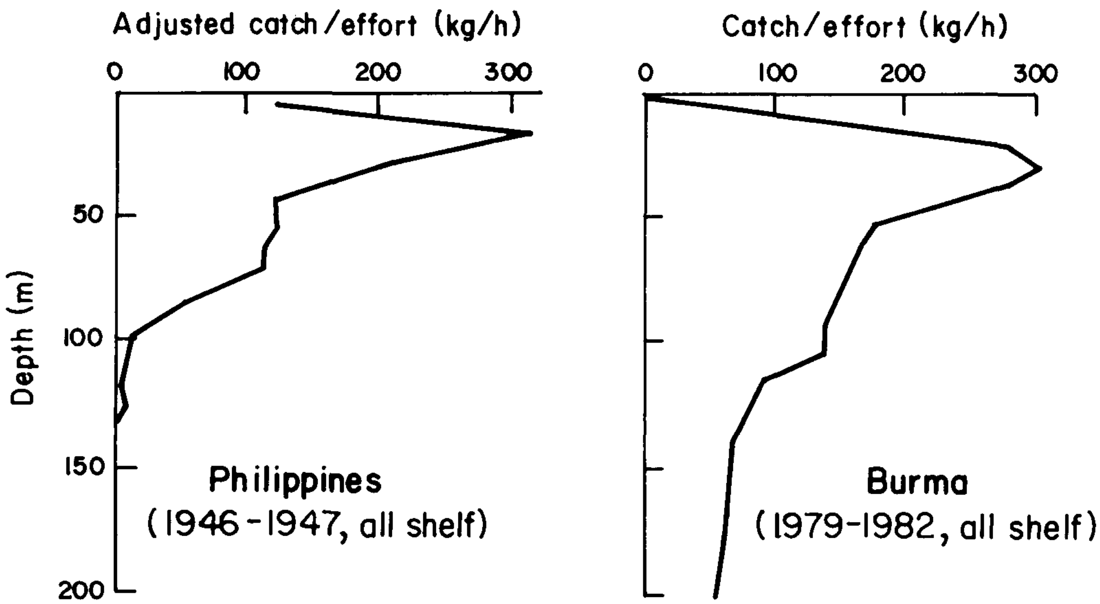

Fig. 2. Variation in abundances of demersal fish with depth prior to major exploitation in the Philippines and Burma. After Pauly (1987).

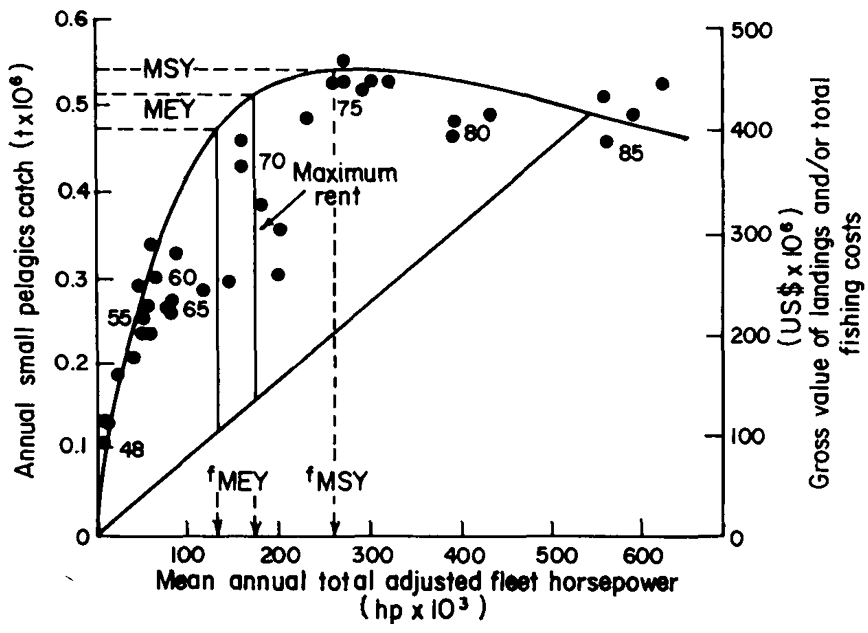

Fig. 3. Fixed-price bioeconomic model of Philippine pelagic fisheries, showing approximate levels of overfishing vs. maximum economic yield ranges. Points are yearly catches; numbers indicate years from 1948 to 1985. From Dalzell et al. (1987).

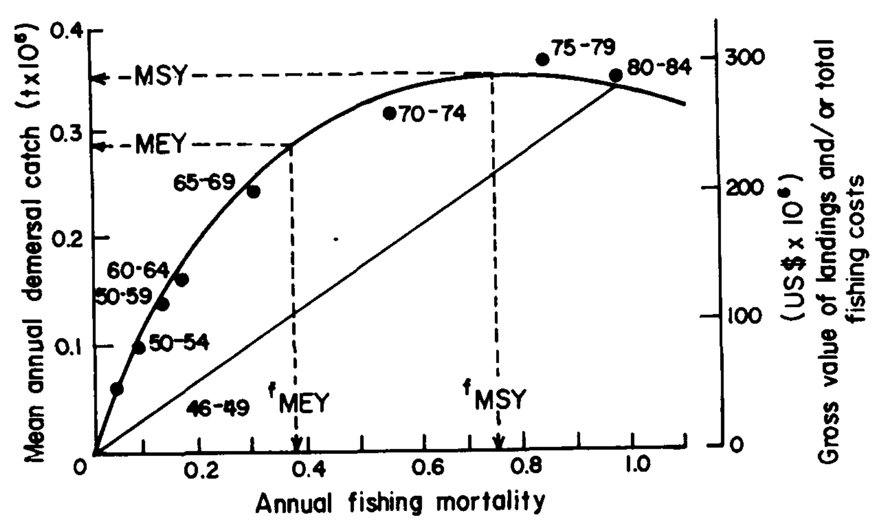

Fig. 4. Fixed-price bioeconomic model of Philippine demersal fisheries, showing approximate levels of overfishing vs. maximum economic yield ranges. Points are mean catches for 5-year periods. From Silvestre G, Pauly D. Estimate of yield and economic rent from Philippine demersal stocks. Paper presented at the IOC-WESTPAC Symposium on Marine Science in the Western Pacific, 1-6 Dec 1986, Townsville, Australia.

The ideal level of fishing is generally believed to be at the point where the vertical distance between the cost and profit lines is maximal, i.e. the point of greatest aggregate profit or maximum economic yield (MEY). A rule-of-thumb approximation indicates that normally, a work force operating at the cost-profit equilibrium should be reduced by about 60% to achieve MEY (McManus 1992). It is reasonable to assume that throughout the Philippines and much of Indonesia, there are more than twice as many fishers as there should be. An appropriate reduction in the work force may not result in an increase in total catches, as can be seen in the small difference between the production levels at the cost-profit equilibrium and at the MEY point in most graphs. However, the catches *per fisher* would roughly double, incomes would increase, and the ecosystem would be harvested at a more benign and presumably more resilient level.

A final misconception pertains to the interpretation of the production curve itself. The so-called Schaefer model on which it is based was originally justified in terms of the population dynamics of a single fish stock in relative isolation from other species both ecologically and in the fishery (Pauly 1979). These assumptions are quite reasonable when dealing with certain temperate fish stocks with little predation on adults and with very specific fisheries, such as for cod. However, most tropical fisheries involve hundreds of fish species with complex interactions captured in diverse groups. The distribution of individuals among species is such that most species are, in fact, uncommon or rare in a given assemblage (McManus 1986). Thus, the optimal fishing effort for the average species in a tropical fishery is likely to be dangerously too intense for many other species. This fact and the habitat modification caused by fishing gears raise concerns about sustainability with respect to biodiversity.

The overfishing situation is compounded greatly by the high population growth and inequitable distribution of resources. These all lead to the state of desperation known as Malthusian overfishing, which fosters the use of habitat- and self-endangering gear such as blasting devices and crude aircompressors for diving and spearfishing. A comprehensive solution must involve a reduction in the human population growth rate. However, some symptomatic relief can be achieved by providing alternative livelihood and reducing the fishing force. One important, though possibly overemphasized means of producing such livelihood is through coastal mariculture.

Mollusk Culture

There are hundreds of species of edible mollusks in Southeast Asia and several hundreds that are valuable for their shells. However, local abundances, established markets, local food preferences, traditions, and technology currently limit mariculture to a few well-known species:

	Reference
• Mussels *Perna viridis* and *P. indica*	Vakily (1989)
• Cockles *Anadara granosa* and *A. antiquata*	Broom (1985)
• Pearl oysters *Pinctada maxima* and *P. margaritifera*	Gervis & Sims (1992)
• Slipper oyster *Crassostrea iredalei*	Glude (1984)
• Top shell *Trochus niloticus*	Heslinga(1981)
• Green snail *Turbo marmoratus*	Murakoshi et al. (1993)

- Giant clams *Tridacna derasa. T. gigas, T. squamosa, T. crocea, T. maxima* and *Hippopus hippopus* — Lucas (1986), John Munro (personal communication)

All these species are edible. Pearl oysters are valuable not only for their pearls, but also for their shells as a source of mother-of-pearl. The shells of green snails and topshells are similarly valuable, the latter being particularly suitable for the production of buttons. The shells of giant clams are widely sold for decorations, and young giant clams are in great demand as aquarium species. Cockles are often used in shellcraft. Some idea of the potential for expansion in the range of species cultured may be found in the study of Guzman (1990) who found 27 species of mollusks gathered from the reef flats in Bolinao, Pangasinan (western Luzon), primarily for the shellcraft industry. Similarly, Amornjaruchit (1988) found 39 species of commercial mollusks and 13 others locally consumed across Thailand.

A major constraint in mollusk culture is the supply and abundance of larvae. Generally, culture is limited to areas with natural spatfalls. Efforts are underway to develop hatchery systems to enhance and disperse production. This includes work to increase the production of pearl oysters, which are valued at over US$60 million per year for the Indo-Paciftc region excluding Australia. Current research on giant clams includes collaborative efforts in the Solomon Islands, Palau, the Philippines, Fiji, Tonga, and the Cook Islands to develop hatchery, rearing, and marketing techniques. This does involve some reintroductions of species to sites where they have become locally extinct from overharvesting. The significance of such reintroductions for local wild populations will be limited, as the original cause of the local extinctions, overharvesting, has not been reduced, and in general will have increased. Efforts to repopulate marine protected areas are the most promising.

All the species listed above can be grown on reef flats. The mussels, cockles, and slipper oysters can also be grown in semi-enclosed or estuarine coastal areas where the currents, tidal range, plankton abundance, and water quality are appropriate.

Seaweed Culture

Seaweed culture is an attractive source of alternative livelihood for several reasons. Seaweeds are primary producers (low on the food chain), are minimally disruptive of the environment, and provide a rapidly growing list of money-making products. Species that are currently farmed in the Philippines and nearby countries include *Eucheuma denticulatum, Kappaphycus alvarezii, Caulerpa lentillifera, Enteromorpha clathrata, E. compressa* and *E. intestinalis* (Liana 1991). Japanese cultivation techniques may be adapted for the local varieties of *Porphyra.* Other species that are widely utilized but not extensively farmed include *Codium edule, Sargassum cristaefolium, S. granuliferum, S. nigrifolium, S. polycystum, S. siliquosum, Gracilaria verrucosa* and *Gelidiella acerosa* (Liana 1991). The total number of economically important seaweeds is about 150, mostly used directly as human food or livestock feed. The fanned species are primarily for the production of phycocolloids, but *Caulerpa* is grown in ponds for direct human consumption.

There are three classes of commercial phycocolloids derived from seaweeds. Carrageenan in lambda, kappa and iota forms depending on gel characteristics, comes from various species of red algae such as *Eucheuma* (Critchley 1993). Carrageenan is used in a wide variety of foods (ice creams, cakes, gel desserts, beer, macaroni, etc.) and for non-food products such as toothpaste, mineral oils, and paints. Agar is extracted from red algae such as *Gracilaria* and *Gelidiella* and comes in three grades: bacteriological, sugar-reactive and food-grade (Critchley 1993). Alginate comes primarily from brown algae such as *Sargassum* and is used in textiles and food. The uses of carrageenan, agar, and alginate are very diverse and constantly growing more so.

Seaweed culture in Southeast Asia is principally confined to reef flats. The production in most cases involves tying vegetative propagules of algae to lines suspended from wooden or bamboo frames which are either anchored or staked to the bottom. The effects of seaweed culture on the ecology of the reef flat are presumably minimal. However, increases in the abundance of rabbitfish (*Siganus* spp.) have been noted. These herbivorous fishes are a problem for small seaweed farms, but because they are limited by other factors, they do not increase proportionately as farms become larger (Doty 1981). Fishes are only some of the potential pests to be reckoned with. Exposure to storms is another critical factor that severely limits the range of seaweed farm sites.

Seaweed production is generally on the increase. However, both production and price vary widely from year to year depending on import restrictions, investment climates, catastrophes, and bottlenecks in processing plants overseas.

Integrated Planning and Precautions

Mariculture operations are sharply divided between large-scale commercial operations and those involving ownership by truly artisanal operators (Newkirk 1993). Large farms do very little to alleviate the Fishing pressure in the coastal zone. A typical operation involves only a few personnel for a farm of 30 hectares. Most post-harvest processing occurs far from the farm or in distant countries. Most of the income goes to a few investors who most likely spend it outside the local communities. Often, such large farms effectively redistribute local resources from the local coastal people to outsiders and distantly based concerns. At best, large seaweed farms contribute to the growth of the economy at the national level.

Artisanal mariculture specifically channel local resources into local economies. The localized benefit can be greatly enhanced by also localizing the processing of the harvested seaweed. For example, *Sargassum* and other seaweeds can be processed with very little equipment into liquid fertilizer before being sold outside the communities (McManus et al. 1992). The production of semi-refined carrageenan (Liana 1991) might be practical at the local level, whereas that of refined carrageenan is not feasible. Similarly, it is often better to locally produce shellcraft from cockles and giant clams rather than to export the shells for this purpose. Innovative ways that further localize the processing of mariculture products can increasingly provide alternative employment along crowded coastlines.

Artisanal mariculture systems lend themselves to the integration of multiple products in a single farm (Newkirk 1993). Some examples of integration were outlined by Doty (1981), who listed 35 species that could be grown in various combinations on reef flats: arthropods, corals, echinoderms, mollusks, seaweeds, and vertebrates. Given the wide range of mollusks and seaweeds that are widely used but not currently farmed, some well-focused research could greatly extend the list of organisms that could be grown in integrated mariculture farms.

Mariculture operations that involve habitat destruction are particularly problematic. Often in the past, pond development in mangrove areas has been justified in terms of incomplete or flawed valuations of the mangroves. Dixon (1989) divides mangrove products and benefits into four classes. He showed that marketed products from on-site (wood products, etc.) are usually considered in economic analyses. Marketed products from off-site (e.g., adjacent fish stocks) are sometimes included. Unmarketed benefits on-site (fish nursery, biodiversity) are seldom included, and unmarketed benefits off-site (nutrient support for adjacent ecosystems, storm buffering) are usually ignored.

Resource economists valuating ecosystems have often applied substantial rates of discounting to the future value of the ecosystem. Recently, a large number of economists and ecologists have shown that the assumptions behind such discounting have been flawed and ignore such principles as the increased value of a resource as it becomes scarce, and the responsibility for intergenerational transfer of resources (from parents to the children and grandchildren). These arguments are summarized in the volume *Ecological Economics* (Costanza 1991) and have been further developed in a regular journal of the same title. Recent work underlines the importance of carefully evaluating the potential impacts of any mariculture development on the environment, be it a direct conflict such as deciding between building fishponds or rejuvenating damaged mangrove areas, or more subtle effects such as widespread shading of reef flat areas.

Finally, it is important to maintain a reasonable perspective on the future. The evaluation of mariculture potential extends far beyond the practice of totalling areas of coastal water of a given depth range. Even with the introduction of hatcheries, most mollusk culture will still be restricted to areas with favorable tides and currents. Seaweed culture will be favored only in reef flats protected from excessive waves. All types of mariculture will continue to be severely limited by storm paths. The continued growth of large-scale mariculture will do little to alleviate the excessive fishing pressure on the coastlines of Southeast Asia. The provision of low-cost protein to markets is no solution to the poverty in areas where most of the employment comes from food production. In such a situation, the production of protein with high market value is most helpful. Moreover, mariculture could not in the foreseeable future make up more than a small portion of the total fishery production in Southeast Asia. Thus, mariculture could not be made an excuse for allowing coastal ecosystems and fisheries to decline from improper management. There is reason to be enthusiastic about the future prospects of mariculture, but only when it is viewed as a part of a larger program of coastal and national development.

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References

Amornjaruchit S. 1988. Economically important molluscan shellfish of Thailand, pp.1-8. In: McCoy EW, Chongpeepien T (eds) Bivalve Mollusc Culture Research in Thailand. ICLARM Technical Reports 19, 170 pp. Department of Fisheries Thailand, Bangkok; International Center for Living Aquatic Resources Management, Manila; Deutsche Gesselschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn.

Broom MJ. 1985. The Biology and Culture of Marine Bivalve Molluscs of the Genus *Anadara.* ICLARM Studies and Reviews 12, 37 pp. International Center for Living Aquatic Resources Management, Manila.

Costanza R (ed). 1991. Ecological Economics: the Science and Management of Sustainability. Columbia University Press, New York, 525 pp.

Critchley AT. 1993. Introduction — Seaweed resources, pp. 1-6. In: Ohno M, Critchley AT (eds) Seaweed Cultivation and Marine Ranching. Kanagawa International Fisheries Training Center and Japan International Cooperation Agency, Yokosuka, Japan.

Dalzell P, Corpuz P, Ganaden R, Pauly D. 1987. Estimation of maximum sustainable yield and maximum economic rent from the Philippine small pelagic fisheries. Bureau of Fisheries and Aquatic Resources Technical Paper Series 10(3): 1-23.

Dixon JA. 1989. Valuation of mangroves. Tropical Coastal Area Management 4(3): 1-6.

Doty MS. 1981. The diversified farming of coral reefs. Harold L. Lyon Arboretum Lecture 11, University of Hawaii, Honolulu.

Gervis MH, Sims NA. 1992. The Biology and Culture of Pearl Oysters (Bivalvia: Pteriidae). ICLARM Studies and Reviews 21, 49 pp. International Center for Living Aquatic Resources Management, Manila; Overseas Development Administration of the United Kingdom, London.

Glude JB. 1984. The applicability of recent innovations to mollusc culture in the Western Pacific Islands. Aquaculture 39: 29-43.

Gordon HS. 1954. The economic theory of a common property resource. J. Polit. Econ. 62: 124-142.

Guzman AB de. 1990. Community structure of macrobenthic invertebrates on exploited reef flats of Santiago Island, Bolinao, Pangasinan. M.Sc. Thesis, Marine Science Institute, University of the Philippines, 141 pp.

Heslinga GA. 1981. Larval development, settlement and metamophosis of the tropical gastropod *Trochus niloticus.* Malacologia 20: 349-357.

Liana EG. 1991. Production and utilization of seaweeds in the Philippines. Infofish International (1/91): 12-17.

Lucas JS. 1986. Developments in giant clam mariculture related to fringing reefs, pp. 137-156. In: Baldwin CL (ed) Proceedings of the Fringing Reef Workshop. Great Barrier Reef Marine Park Authority, Townsville, Australia, 280 pp.

McManus JW. 1986. Depth zonation in a demersal fishery in the Samar Sea, Philippines, pp. 483-486. In: Maclean JL, Dizon LB, Hosillos LV (eds) The First Asian Fisheries Forum. Asian Fisheries Society, Manila.

McManus JW. 1992. How much effort should there be?, pp. 52-56. In: McManus et al (1992) below.

McManus JW, Nanola CL, Reyes RB, Kesner KN. 1992. Resource Ecology of the Bolinao Coral Reef System. ICLARM Studies and Reviews 22, 117 pp. International Center for Living Aquatic Resources Management, Manila.

Munro JL. In Press. Prospects for aquaculture in coral reef environments, pp. 97-98. In: Munro JL, Munro PE (eds) The Management of Coral Reef Resource Systems. ICLARM Conference Proceedings 44. International Center for Living Aquatic Resources Management, Manila.

Murakoshi M, Komatsu T, Nakamura R. 1993. Development of mass seed production techniques for green snail, *Turbo marmoratus* in Okinawan water. Suisanzoshoku 41: 299-309.

Newkirk G. 1993. Do aquaculture projects fail by design? World Aquacult. 24(3): 12-18.

Pauly D. 1979. Theory and Management of Tropical Multispecies Stocks: a Review, with Emphasis on Southeast Asian Demersal Fisheries. ICLARM Studies and Reviews 1, 35 pp. International Center for Living Aquatic Resources Management, Manila.

Pauly D. 1987. Theory and practice of overfishing: a Southeast Asian perspective, pp. 146-163. In: Hancock D (ed) Papers Presented at the Symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia, 22nd Session, Indo-Pacific Fishery Commission, Darwin, Australia, 16-17 Feb 1987. RAPA Report 1987/10, 552 pp.

Pauly D. In Press. Small scale fisheries in the tropics: marginality, marginalization and some implications for fisheries resources. In: Proceedings International Symposium on Fisheries Management: Global Trends. University of Washington, Seattle.

Smith IR. 1979. A Research Framework for Traditional Fisheries. ICLARM Studies and Reviews 2, 45 pp. International Center for Living Aquatic Resources Management, Manila.

Smith IR. 1981. Improving fishing incomes when resources are overfished. Mar. Pol. 5: 17-22.

Vakily JM. 1989. The Biology and Culture of Mussels of the Genus *Perna.* ICLARM Studies and Reviews 17, 63 pp. International Center for Living Aquatic Resources Management, Manila; Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), GmbH, Eschborn.