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WHERE THE LAND MEETS THE SEA:
INTEGRATED SUSTAINABLE FISHERIES DEVELOPMENT
AND ARTISANAL FISHING

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ABSTRACT

Artisanal fishing communities include some of the "poorest of the poor". In the past 40 years, strategies that have targeted the harvesting sector of such communities have often failed to address their chronic problems of poverty. Using data from gill net fishers in Malaysia, the paper presents the first technical efficiency study of an artisanal fishery and finds that artisanal fishers are poor but technically efficient. The results from the study and the experiences of other artisanal fisheries are used to advance a development strategy for artisanal fisheries called integrated sustainable fisheries development (ISFD).

"...there is little doubt that the problems facing small-scale fishermen in developing countries are among the most intractable ones in the field of development assistance,..."

Francis T. Christy (1986; p. 121)

1. Introduction

Where the land meets the sea, over 200 million artisanal fishers worldwide live and exploit a complex and varied ecosystem.¹ Dispersed and isolated by geography, artisanal fishing communities are socially, politically, and culturally marginal to their society.² Indeed, artisanal fishers and their families form some of the "poorest of the poor". Many face difficult conditions for economic growth and development due to their isolation and poor infrastructure and have only limited access to public health, education, and other such services.

In contrast to large-scale commercial fisheries, artisanal fisheries are owner-operated and labor-intensive, employing rudimentary technologies. Artisanal fishers harvest the sea from comparatively small vessels, powered by sail, paddles, or outboard motors of limited power, have limited fishing range, and generally deploy passive fishing gears that are set and later retrieved. As with large-scale fisheries, the resources and ecosystems utilized by artisanal fishers are increasingly over-exploited and degraded from destructive fishing practices, pollution, and changes in land use.³ Artisanal fisheries are often overcapitalized, and fishing capacity is far in excess of that required to take the maximum sustainable yield, and even further in excess of that required for economic efficiency. These problems are compounded by incomplete property rights and conflicts with large-scale, industrial vessels.⁴

The earliest fisheries development strategies focused almost exclusively on large-scale fisheries, presumably in the belief that artisanal fisheries would expand their scale of production and adopt the technologies of large-scale fisheries and fish further offshore or otherwise provide labor to the operation of large-scale fisheries (Panayotou, 1982; Platteau 1989). Artisanal fishers were expected

to move from their isolated coastal villages and hamlets to find employment inland and in cities, and little attention was given to the growing environmental and resource problems associated with fishing.

Since the mid-1980s, fisheries development strategies began to focus on artisanal fishers. Assistance directed to the harvesting sector aimed to increase the efficiency of traditional fishing methods, and included aid to introduce or upgrade the motors for traditional craft and to use monofilament nylon in place of traditional fishing gear (Lawson, 1984; Ishak, 1994; Vincent et al., 1997). This approach often involved credit assistance, subsidies for vessels, motors, and gear, and aid in marketing fish. Despite some successes, a focus on the harvesting sector helped to create a dependency on the state (Lawson, 1984; Ishak, 1994), contributed to overexploitation of certain fish stocks, and largely failed to solve the problems of endemic poverty and poor infrastructure in fishing communities (Panayotou, 1982).

Given the lessons from the past, what is the preferred approach to promote the development of artisanal fishing communities?⁵ Should the current focus on the harvesting sector be continued or a strategy for the future be recast? The answer, in part, hinges upon whether artisanal fishers are technically efficient. Substantive scope for improving efficiency would favor a continued focus on the harvesting sector. If, however, the existing harvesting practices are largely efficient, a recast development strategy must look elsewhere.

Using a unique data set of the Malaysian gill net fisheries (MGF), the paper provides the first technical efficiency study of an artisanal fishery.⁶ The results indicate little scope to increase technical efficiency and that the effect of human and physical capital variables on technical efficiency differs across regions. Using the results and past experiences in artisanal fisheries, the paper presents a broad-based approach to help resolve the problems of artisanal fishing communities. The approach, called integrated sustainable fisheries development, makes explicit the interdependence of artisanal fisheries

and coastal resource management; refocuses the emphasis from the harvesting sector to onshore and community development, the coastal zone, and the broad ecosystem in general; and stresses the importance of environmental factors and sustainable renewable resource use and management.

2. The Malaysian gill net fishery

The artisanal fishing communities examined in this paper are the gill net (*pukat hanyut, pukat hijau, pukat tansi*) fisheries on the west and east coasts of the Malaysian peninsula.⁷ The gear type employed in these fisheries is common in Southeast Asia and accounts for over half of all the gear used in all fisheries in Malaysia (Alam, 1991). Throughout Southeast Asia, gill net fishers employ small boats, often of wood construction, powered by comparatively small motors, usually outboard, deploy nets usually made of monofilament nylon, and catch a wide variety of species.

Typically in these fisheries, and elsewhere in Southeast Asia, vessels set out from the port, village, or hamlet on what are generally day fishing trips with a limited operating radius. A captain (*Taikong*) commands the vessel during the fishing trip and is most often the vessel's owner. The captain remains in charge of the fishing vessel, selects, organizes and manages the crew, is responsible for the security and maintenance of all fishing equipment, provides overall leadership (Firth, 1975; Alam, 1991) and is often the most knowledgeable and experienced person on board.

Fishers employ surface, mid-water and bottom gill nets, depending on the species they are seeking.⁸ Gill nets are set around coastal areas, river mouths or traditional resource-rich fishing grounds and "soak" for some time, during which fish or prawns swim or are carried by tides and currents into the net where they become entangled. After "soaking", the nets are retrieved and the fish entangled in the mesh are extracted and hauled on board. Upon arrival on shore, the fish and prawns are sold fresh to a variety of local outlets, such as petty traders, beach markets, and local "open-air" markets; state-

sponsored buyers and cooperatives; and middlemen or brokers. Some fish are retained for home consumption and others may be dried and subsequently sold.

Much of the sea off the west coast is comparatively shallow with a muddy and flat sea floor and is fringed by mangrove swamps and estuaries. The fishing grounds are bounded by the island of Sumatra on the opposite side of the Straits, and have been subject to biological and economic over-fishing (Ishak, 1994; Vincent et al., 1997). The east coast fishing grounds along the South China Sea are larger in area, face a more severe monsoon, have deeper and rougher waters, more reefs, fewer prawns, and a coastline more fringed by sandy beaches and coconut palms than the west coast. West coast fishers exploit the pelagic (migratory), demersal (bottom-dwelling), and prawn resources while east coast fishers are more likely to harvest pelagic fish (Ooi, 1990).

Social and economic conditions and traditions vary substantially between the east and west coasts of Peninsular Malaysia. The majority of the manufacturing industries, plantations, tin reserves, and population are concentrated in the west. By contrast, the east coast states are more sparsely populated and relatively underdeveloped. On both coasts, the widely dispersed fishing villages are typically located along rivers, estuaries, or at river mouths, which can be isolated and lacking in physical, social, and public amenities and infrastructure, and where many fishers and their families live below the poverty line. Some fishing communities earn almost all of their income from marine fishing, while others make their livelihood by combining fishing, farming, aquaculture, gathering from mangrove forests and coral reefs, and working on plantations or rice farms.

3. Model and data

Each vessel's performance in the MGF is measured relative to its ability to produce on the fleet's best-practice frontier, the maximum output possible from a given set of inputs and production technology (Aigner et al., 1977). Technical inefficiency is measured as the deviation of an individual

vessel's production from the best-practice frontier, which is stochastic because fishing is sensitive to random factors such as weather, resource availability, and environmental influences. Due to differences in resource abundance and availability, species composition, ecosystems, weather, and socioeconomic conditions between the two coasts in the MGF, two separate stochastic production frontiers are specified:

$$\begin{aligned} \ln Y = & \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 \ln T + \alpha_4 \ln N + \alpha_5 \ln OD + \alpha_6 \ln K^2 + \alpha_7 \ln L^2 + \alpha_8 \ln T^2 \quad (1) \\ & + \alpha_9 \ln N^2 + \alpha_{10} \ln K \ln L + \alpha_{11} \ln K \ln T + \alpha_{12} \ln K \ln N + \alpha_{13} \ln L \ln T + \alpha_{14} \ln L \ln N \\ & + \alpha_{15} \ln T \ln N + \epsilon, \end{aligned}$$

where symmetry has been imposed by $\alpha_{ij} = \alpha_{ji}$ and $i, j = K, L, N, T$. Total output (catch) in kilograms is denoted by Y and is the geometric mean of fifteen species of fish plus prawns (where revenue shares serve as weights). The inputs are specified as service flows by multiplying the stocks of capital and labor by days at sea.⁹ The vessel capital stock (K) is a volumetric measure given by vessel gross registered tons (GRT); labor (L) is the number of crew employed per vessel for the month, including the captain; and the gill net capital stock (N) is measured by its length in meters multiplied by the number of hauls of the gill net per day.¹⁰ The number of trips per month (T) represents variable input usage (e.g., diesel and/or gasoline, lubricant and/or oil, ice, container/polythene, and miscellaneous variable inputs). Distance from shore to the fishing ground is specified in nautical miles (OD) and is an environmental variable beyond the control of fishers, providing for differences in resource conditions that vary by distance from shore and by water depth.¹¹

The error term ϵ in Equation (1), comprised of two independent components, is defined as $\epsilon = V - U$. The V is a two-sided error term captures exogenous stochastic shocks and is assumed to be symmetrical and independently and identically distributed as $N(0, \sigma_v^2)$. U is a non-negative term which captures differences in technical inefficiency and is assumed to be an independently distributed non-

negative random variable, such that U is the truncation of a normal distribution at zero, with mean $\mu = Z\delta$ and variance σ_U^2 , $N(Z\delta, \sigma_U^2)$ (Stevenson, 1980). Z defines a $(1 \times M)$ vector of explanatory variables associated with the technical inefficiency function, and δ is an $(M \times 1)$ vector of unknown parameters to be estimated (Battese and Coelli, 1995). Technical efficiency for each vessel is defined as $TE = \exp(-U)$, where \exp is the exponential operator (Battese and Coelli, 1988).

The technical inefficiency function, comprised of the vector of variables Z which are hypothesized to affect the technical efficiency of vessels, is specified by:

$$U = \delta_0 + \delta_1 EXLIH + \delta_2 EXLIE + \delta_3 EXLIN + \delta_4 FEXP + \delta_5 MESH + \delta_6 FSIZE \quad (2)$$

$$+ \delta_7 D_{CH} + \delta_8 D_{CT} + \delta_9 D_{NOP} + \delta_{10} D_{SM} + \delta_{11} D_P + \delta_{12} D_S + \delta_{13} D_B.$$

U is the vessel-level technical inefficiency measure; $EXLIH$, $EXLIE$, and $EXLIN$ are the remaining economic life, in years, of the vessel hull, engine, and gill net as estimated by respondents; $FEXP$ is years of fishing experience for the captain; $MESH$ is mesh size in meters; and $FSIZE$ is the family size of the captain. The seven D terms are dummy variables and are equal to one when: the vessel has a Chinese captain (CH); the captain has participated in a Malaysian fisher training program (CT); the captain is not the owner of the vessel (NOP); the vessel is small (SM)--defined as less than 5 and 10 GRT, respectively, for the west and east coasts; the captain has a primary education (P); the captain has a secondary education (S) (none of the captains of the east coast vessels received a secondary education); and on the west coast, if the engine brand is any other than Yanmar (B).¹² The intercept δ_0 captures the case of a Malay captain, who own and operates the vessel, did not participate in the training program, does not have a formal education, and has a Yanmar engine.¹³ A random error term was added to Equation (2) for estimation. The stochastic frontier, Equation (1), and the technical inefficiency function, Equation (2), were jointly estimated by maximum likelihood using Frontier 4.1

(Coelli, 1996), under the behavioural hypothesis that fishers maximize expected profits (Zellner, Kmenta, and Dreze, 1966).¹⁴

The cross-sectional data used in the study were collected in 1988 using a multi-stage sampling procedure. The first stage of the sampling selected the states where the fishers would be sampled and the second stage selected gill net fisheries within states where the sampling took place. In the second stage, vessels were randomly selected from lists of licensed gill net vessels obtained from the Department of Fisheries and the fisher cooperative associations. After pretesting the questionnaire, vessel owners were interviewed and provided information on one month's fishing activity.¹⁵ The 40 west coast fishers came from the states of Perak (15 fishers), Kedah (10 fishers), and Perlis (15 fishers) while the 42 east coast fishers came from the states of Terengganu (23 fishers), East Johor (10 fishers), and Pahang (9 fishers).

Summary statistics of the data, reported in Table 1, indicate that the vessels used in the fishery are relatively small, with mean lengths of 10-12 meters, and that the captains on both coasts have considerable fishing experience. Compared to west coast vessels, east coast vessels are longer with larger GRTs and engine power, possess larger nets, operate further from shore, have larger crews, catch more fish, have larger revenues, and are more capital-intensive as measured by a larger capital-labor (GRT/fisher) ratio. This larger scale of operation reflects the larger and deeper South China Sea, the existence of fewer estuaries and coastal wetlands and sandier ocean bottom in comparison to the Straits of Malacca, and greater severity of monsoons. East coast vessel hulls, engines, and nets also have longer expected remaining economic lives than those of the west coast. West coast vessels make more frequent hauls of their shorter nets per day than do east coast vessels and tend to fish closer to shore and use smaller mesh sizes, thereby catching smaller fish. Both east and west coast vessels, however, fish about the same number of days per month. A greater proportion of east coast skippers are Chinese,

rather than Malay, have larger families, have more years of fishing experience, but have fewer years of formal education. About the same proportion of captains are owner-operators on the west and east coasts.

4. Empirical results

Several hypotheses about the model can be tested using generalized likelihood ratio tests, whose results are summarized in Table 2.¹⁶ The hypothesis tests indicate that for both coasts with the truncated normal error term, at the one percent level of significance: (1) the stochastic production frontier is appropriate ($H_0: \gamma = 0$ is rejected)¹⁷; (2) the translog functional form is suitable for the stochastic production frontier ($H_0: \alpha_6 = \alpha_7 = \dots = \alpha_{15} = 0$ is rejected); and (3), the technical inefficiency function depends on the vector of explanatory variables ($H_0: \delta_1 = \delta_2 = \dots = \delta_M = 0$ is rejected).¹⁸ Parameter estimates of the final form of the stochastic production frontier, Equation (1), are reported in Table 3.

The distribution of technical efficiency scores, relative to the best practice frontier scores and reported in Table 4, is similar for both coasts. Technical efficiency scores are skewed towards higher levels of efficiency, where a score of 1.0 lies on the frontier, with concentrations in the 80th and 90th percentiles for both east and west coast vessels. Only a limited number of vessels display substantially lower levels of technical efficiency. The arithmetic means of the individual technical efficiency scores are 0.84 and 0.88 for the east and west coasts, and are somewhat higher than those generally found from stochastic frontiers for developing country agriculture (Bravo-Ureta and Pinheiro, 1994; Table 1). The comparatively high level of technical efficiency is consistent with Schultz's (1964) thesis of "poor and efficient" smallholders and peasants in developing country agriculture. In sum, the vast majority of the artisanal fishers have high levels of technical efficiency and face limited scope for technical efficiency gains, given the state of their technology and resource conditions.

The factors affecting technical inefficiency can be analyzed by the magnitude, algebraic sign, and significance of the estimated coefficients in Equation (2), the technical inefficiency function, which are reported in Table 5. The dependent variable is technical inefficiency as opposed to technical efficiency, so that a negative sign indicates a *decrease* in technical inefficiency or an *increase* in technical efficiency. These results are summarized into three broad areas: the expected life or vintage of the vessel, the characteristics of the captain, and vessel ownership.

4.1. Vintage of capital stock

A vessel of an older vintage, embodying an older state of technology, (construction material, hull design, size, configuration for sail or engine) may preclude that vessel from employing best-practice techniques of production, determined in part by the best-practice technology. To capture the effects of capital vintage for the hull, the estimated remaining economic life, in years, for the hull (EXLIH) was introduced in Equation (2), where a longer remaining economic life is taken to represent a newer capital vintage.¹⁹ Similar "vintage" variables were included for the engine (EXLIE) and net (EXLIN).²⁰

EXLIH and EXLIN are statistically significant on the west coast but only EXLIE is significant for the east coast (Table 5). The positive sign for the EXLIH on the west coast is contrary to expectations and suggests that an increase in economic life of the vessel hulls *decreases* efficiency.²¹ One possible explanation is that in the artisanal gill net fisheries, a learning period may be required to master a new vessel and utilize its capabilities to its fullest extent. All coefficient values are, however, comparatively small, suggesting that those variables which are significant, minimally affect efficiency.

4.2. Technical inefficiency and captains

The captain's fishing skill is often considered to be an important determinant of a vessel's catch and efficiency. Technical inefficiency can be related to characteristics of captains, which comprises the components of a captain's human capital in Equation (2).

4.2.1. *Ethnicity of captain:* Ethnicity of captains may explain different fishing practices and variations in efficiency across vessels. Each ethnic group is more likely to have crews of its own ethnic group. The dummy variable for Chinese ethnicity (D_{CH}) in Equation (2) was not significant for the east coast, but was negative and significant for the west coast, indicating that Chinese skippers *increase* efficiency on west coast but not east coast vessels (Table 5).²²

4.2.2. *Fishing experience of captains:* Fishing experience of captains often provides better knowledge about the location of fish, weather patterns, currents and tides, bottom conditions, and how to best catch the fish. The variable for years of fishing experience (FEXP) was insignificant on the west coast but negative and significant on the east coast (Table 5) – indicating greater experience *increases* efficiency. East coast fishers travel further out to sea in more difficult conditions and in larger boats, so that the captain's expertise may play a more important role than in the west coast, where most fishing is much more confined to estuaries, river mouths, and nearshore fishing grounds.

4.2.3. *Formal education of the captain:* Additional schooling can improve literacy and cognitive skills which may reduce technical inefficiency by increasing the ability of captains to adopt technical innovations. Dummy variables for a captain's formal primary (D_p) and secondary (D_s) education were, however, both insignificant on the west coast but D_p for the east coast (no fishers in the sample had secondary education on the east coast) was negative and significant (Table 5). Thus, education appears not to affect efficiency of fishers on the west coast but does *increase* technical efficiency on the east coast.²³ The differences may be explained by the relative isolation and lack of infrastructure

on the east coast, where primary schooling may offer one of the few opportunities to learn skills that may be more readily learnt by fishers on the west coast outside of formal schooling.

4.2.4. Participation of captains in training programs: The Malaysian government has implemented a number of training programs for fishers to improve efficiency and increase incomes (Ishak, 1994). The dummy variable for captain's training (D_{CT}) is insignificant for the east coast but is positive, comparatively large, and significant on the west coast (Table 5), indicating a *reduction* in efficiency. The contrary result on the west coast may be due to the lack of participation of the most successful captains in training programs, and thus the real impact of fisher training may be disguised. Whatever the reason, the results do not provide evidence that participation in training programs by captains increases technical efficiency.

4.2.5. Captains' family size: The size of a fisher's family may provide information on an individual fisher's characteristics, including income and access to family labor. Family size (FSIZE) does not significantly affect efficiency on the west coast but is negative and significant on the east coast, suggesting that an increase in family size *increases* efficiency (Table 5). On the more isolated east coast, a larger family may provide fishing captains with greater flexibility as to when to fish, while crew who are family members may work more cooperatively and exert greater effort when fishing.

4.3. Technical inefficiency and vessel ownership

Both owning and operating a vessel can affect incentives. The non-owner-operator dummy variable (D_{NOP}) is insignificant in explaining differences in technical inefficiency for both coasts (Table 5). Thus, Marshallian disincentives sometimes attributed to share contracts in agriculture do not appear to exist in the MGF.²⁴

4.4. Technical inefficiency and vessel size

The relationship between inefficiency and farm size has received considerable attention in the agricultural and development economics literature (Barrett, 1996 and Bravo-Ureta and Pinheiro, 1993 give recent surveys), but the comparable relationship between inefficiency and vessel size in the fisheries and development economics literature remains unexamined. The results indicate that in the MGF the small vessel dummy variable (D_{SM}) was insignificant for the west coast but was significant and negative for the east coast (Table 5). Thus on the east coast, smaller vessels are more technically efficient than larger vessels. The result may, in part, be attributed to differences in the fuel used, crew and mesh sizes, and resource abundance across vessel-size classes. Operating larger vessels, but with the same gear, may also impose coordination costs which may reduce technical efficiency. The results do not, however, suggest that efficiency changes with the level of capitalization, as defined by the capital/labor (GRT/fisher) ratio. Although the capital-labor ratio is higher on the east than the west coast, it is lower on both coasts for the small vessel size class (Table 1) and does not appear to be related to the level of technical inefficiency (Table 4).

4.5. Technical inefficiency and engine brand

The dummy variable for engine brands other than Yanmar on the west coast (D_B) is negative, significant, and comparatively large. Engines other than Yanmar *increase* efficiency. Data limitations prevent further investigation of how the brand of engine affects efficiency and whether it is a proxy for other variables.

4.6. Differences between coasts

Important differences exist in the variables that affect technical inefficiency on the two coasts. Individual characteristics of captains -- proxies of human capital, appear to be more important on the more isolated and less developed east coast while vessel characteristics-- proxies of physical capital,

appear to be more important in explaining differences in technical efficiency on the west coast. On neither coast, however, do fisher training programs provide a positive and significant impact in terms of technical efficiency. The differences imply that a uniform and national fisheries development strategy is likely to be much less successful than targeted regional or local development strategies.

5. Integrated sustainable fisheries development

The results suggest that, paradoxically, the most preferred form of assistance to artisanal fishing communities may be to redirect aid and development efforts away from fishing and the harvesting sector to onshore development. Short of completely transforming the fishery with a different method of harvesting fish, development strategies that focus on upgrading the vessel, engine, and gear and training fishers may provide few or no benefits in raising efficiency. This result is true whether or not the fisheries are over-exploited, and goes beyond the existing literature which stresses the negative consequences of increasing harvesting in over-fished artisanal fisheries (Smith, 1979) and the potential for technological change to affect traditional structures in communities (Soysa et al., 1982; Lawson, 1984).

If the sustainable catch is fixed, improved technical efficiency is a benefit only if resources are freed from the catching sector for productive use elsewhere. Because there is a general labor surplus in the coastal areas, partly due to immobility, efficiency improvements may only generate widespread benefits if they are capital saving. Although no general relationship exists between the capital-labor ratio and efficiency on either coast, efficiency improvements may be capital saving for the smaller vessels on the least developed east coast where smaller and older east coast vessels are more technically efficient.²⁵ To the extent that results from the MGF can be generalized, the study suggests that greater levels of human capital (as proxied by formal education, captain's training and fishing experience) may

generate the greatest benefits in less developed regions where education attainment is less and economic opportunities outside of fishing are fewer.

A strategy that redirects priorities away from technological innovation, capital formation, and improving efficiency in the harvest sector contrasts with the past development approaches in agriculture where technological innovations, such as the introduction of high-yielding varieties and mechanization, have traditionally been viewed as critically important to improving the welfare of farm households. In the case of agriculture, the "poor and efficient" hypothesis implies that raising the incomes of farm households can be effectively accomplished through technical innovation, capital formation, and raising efficiency without endangering the resource base.

This paper proposes a different development strategy for artisanal fisheries called integrated sustainable fisheries development (ISFD). This approach redirects funds and assistance away from the harvesting sector to on-shore and community development; integrates the management of fisheries and the coastal littoral and the environment; promotes sustainable harvesting practices and fisheries management; and protects and even enhances the ecosystem.²⁶

5.1 On-shore development

The policy shift away from the harvesting sector, other than for the purposes of conservation and sustainable management, may be characterized as building "bridges not boats" and "selling not searching" for fish. Such an approach would necessarily take many forms depending on the country, region and institutional setting where it were to be applied. One priority, already identified in the literature, is to improve the handling and storage of highly perishable fish and fish products. Freezing or refrigeration, for the appropriate scale of production, could also prove useful in some fisheries, as would quality improvements or changes in product forms that can raise incomes, provided that the scale of infrastructure investment for the post-harvest handling of fish matches the size of the harvests

(Williams, 1996).²⁷ Not only would the benefits from fisheries increase, but their distribution would increase, because women are often the main participants in processing (Williams, 1996). Improvements in preservation, processing, and marketing may also increase the value-added from fisheries, as well as increase product utilization and the quantity of fish sold, by increasing the opportunity to sell fish species previously discarded or utilized inefficiently.

A complementary strategy is investment in infrastructure and transportation (Ben-Yami, 1977; Squires, 1978).²⁸ In particular, the cost of marketing can be high for artisanal fisheries, especially in comparison to urban-based large-scale fisheries (Lawson, 1984; Panayotou, 1982), because of collection costs, greater spoilage, and risk taking. Thus infrastructure development in artisanal fisheries may reduce barriers to market competition, especially with larger vessels home-ported in urban centers.²⁹

In some instances, voluntary exit out of the fishery to employment in other sectors, and in other instances, diversification into agriculture, aquaculture, or utilization of other resources may be required to ensure sustainable use of fisheries (Firth, 1975; IPFC, 1994; Neal, 1992; Panayotou, 1982; Pauly, 1977; Smith, 1979; Squires, 1978).³⁰ To this end, improved infrastructure, communications, and credit formerly directed toward the harvest sector would encourage diversified and supplemental employment and employment outside of the fishery.

Enhanced educational opportunities for fishers may help, especially when the initial level is low, and technical training may prompt exit from the sector. Education for women may even offer the highest return, including improved fish marketing and processing, and lower fertility rates.

5.2 Management of the coastal littoral and environment

An important component of ISFD is the integration of fisheries development with coastal and environmental management (Soysa et al. 1982; IPFC, 1994). An integrated approach would focus upon

sustainably managing both fisheries and related coastal resources. These coastal environments provide market and non-market benefits through erosion and storm control, locales for fish nursery and breeding grounds, biological diversity, and primary biological productivity supporting fish populations. Thus, agricultural and aquacultural practices incompatible with coastal wetlands would be discouraged. Instead, efforts should be made at encouraging and enhancing alternative or supplementary sustainable sources of income, which could include the harvesting of perennial crops such as coconuts, cashews, and seaweed, sustainable gathering from mangrove swamps and other wetlands, recreational fishing, or even eco-tourism.

Support for alternative enterprises would also help direct effort by artisanal fishing communities away from over-exploited and degraded resources (Smith, 1979) and may be viewed as a broad-based sustainable utilization of the entire ecosystem and coastal littoral. The approach would recognize that artisanal fishing communities use many facets of their environment and that the exploitation of living aquatic resources involves many interdependencies. For example, over-exploitation of one aspect of the environment, such as the clearing of mangrove trees, may have repercussions on other components of the ecosystem, such as the availability of prawns and fish. ISFD recognizes the part that fishing communities play in the coastal environment, so that the resources they use can be sustainably managed. Such an approach also has value beyond the persons it directly assists because estuaries, tidal marshes, mangroves, and coral reefs are estimated to provide over 40 percent of the value of all ecological services on earth (Costanza et al., 1997) and may be worth as much as US\$20,000/hectare.

5.3 Sustainable use of fishery resources

Technical assistance programs reoriented from increasing efficiency and productivity in fishing towards conservation and management measures would promote sustainable renewable resource use. Conservation and sustainable resource exploitation could be fostered by introducing and supporting

harvesting practices that do not damage the resource base, such as the replacement of dynamite, cyanide, and fine-mesh fishing by the demonstration and testing of alternative methods (Barber and Pratt, 1997; Pauly, 1997).³¹ Such an emphasis on conservation would, necessarily, be coupled with resource management goals and methods that limit overall catch levels to sustainable levels and that also recognize uncertainty and manage risk consistent with the Precautionary Principle (FAO, 1995). These management measures would reduce fishing to sustainable levels in areas and on stocks currently heavily exploited or over-fished; adopt policies to reduce bycatches (unintended catches) and at-sea fish discards; support property rights structures that provide greater exclusivity to artisanal fishers; ensure that capacity of fishing fleets is consistent with sustainable yields; and recognize the risk of using maximum sustainable yield as a target.³²

5.4 Community development and management

Strategies for cooperative and community management are increasingly recognized as highly effective means to control fishing activity and promote sustainable fishing practices (Christy, 1986; Pomeroy, 1994; Kurien, 1996). Many artisanal fishing communities have some form of community control over fish resources. Decentralization and devolution of fisheries management to the community level enhances greater community enforcement of fisheries, and territorial user rights exclude persons outside the community from fishing. This decentralization and devolution, where appropriate, would be helped by strategies that increase returns to communities. In some cases, as in Sri Lanka, fishers are even able to earn substantial resource rents because of effective controls on entry.³³

Community management of the resource, often coupled with a ban of large-scale commercial vessels in nearshore areas, also has the potential to increase sustainable use of the resource and retard or even halt environmental degradation (Kurien, 1996).³⁴ The shift to community management and elimination of large-scale trawling can shift the gear type used from relatively unselective trawls, which

can be destructive to the sea floor and can lead to many fish species being discarded as unwanted bycatch or "trash fish", to artisanal fishing gear which is often much less destructive to the environment. Greater community management of the resource would also help curtail influxes of people into fishing who may have been forced out of their traditional and alternative occupations.

Comanagement between the state, fishing communities, and other artisanal fishing institutions recognizes that the overriding custodianship of the marine resources rests with the state, requiring a partnership with decentralized management (Kurien, 1996). Comanagement also allows for coordination among artisanal groups, helps balance their interests, and keeps in check the potential for conflicts, including those between different ethnic groups (Kamaruzaman pers. com., 1998).

6. Concluding remarks

This paper finds that the traditional focus of artisanal fisheries development on technical assistance and training in the harvesting sector has only a very limited potential to improve efficiency in the Malaysian gill net fisheries and that the factors explaining efficiency differ by region and overall level of economic development. While this is the first efficiency study of artisanal fisheries, the results may reasonably be expected to hold in many other artisanal fisheries of Southeast Asia which employ comparable technology and harvesting practices, and operate in similar environments.

The shift from technical assistance and training in the harvesting of fish to a broader and more comprehensive development strategy may be described as integrated sustainable fisheries development. This strategy has four key components. First, target assistance in fisheries to onshore development and infrastructure that reduces wastage and spoilage and increases the value-added and utilization of fish, reduces fishing, and promotes supplemental or alternative employment to fishing. Second, develop strategies so that fisheries and related coastal resources are managed in an integrated and sustainable way which encompasses all important aspects of the environment. Third, implement sustainable

renewable resource policies that provide the incentives and resources to communities to prevent or reduce environmental degradation and promote conservation of the habit and environmental carrying capacity, particularly in the ecologically important estuaries, marshes, swamps, and coral reefs. Such an approach includes the adoption of sustainable harvesting techniques and fisheries management to preclude over-fishing and explicitly recognizes environmental uncertainty and the possibility that fish stocks may be fully exploited. Fourth, strengthen responsible community fisheries management by providing, where appropriate, legal protection and status to existing *de facto* community rights that govern access and use rights over coastal resources, and prevent or reduce conflicts between large-scale and artisanal fisheries. The four components of integrated sustainable fisheries development are not a panacea but offer the potential to improve the welfare of the "poorest of the poor".

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Table 1. Summary Statistics of the Data

East Coast				
Vessel and fishing characteristics	Mean	St. Dev.	Minimum	Maximum
Hull length (meters)	12.17	1.82	8	15
Gross registered tons	10.57	3.62	3	18
Engine horsepower	25.79	8.87	8	37
Length of net (meters)	712.07	318.14	250	1400
Mesh size (meters)	0.0987	0.0086	0.06	0.11
Remaining economic life: hull (yrs)	18.57	2.87	13	25
Remaining economic life: engine (yrs)	15.62	3.81	10	25
Remaining economic life: net (yrs)	6.83	1.73	4	10
Years of ownership: hull	8.12	3.96	0	18
Years of ownership: engine	7.10	2.86	1	14
Years of ownership: net	4.93	2.35	2	10
No. of fishing trips per month	19.14	5.16	7	25
Total fishing days per month	21.83	2.59	15	25
Trip duration (days) per month	1.14	5.70	1	3
Hauls of net per day	1.95	0.82	1	4
GRT-days per month	233.03	86.35	54	375
Labor-days per month	69.86	18.10	30	100
Net-haul-days per month	29018.43	18560.5	7500	86400
Operating distance (nautical miles)	9.57	5.12	3	20
Crew size (including captain)	3.17	0.62	2	4
GRT-crew size (capital-labor) ratio	3.31	0.87	1.50	5.33
GRT-crew size ratio vessels < 10 GRT	2.60	0.58	1.50	3.50
Catch of all species per month (kg)	2177.36	484.32	1190	3165
Revenue all species per month (M\$)	387,591	79,628	213,900	541,260
Family size of captain	7	2.35	3	13
Fishing experience of captain (years)	22.67	7.49	10	35
Number of total observations	42			
Number of captains with training	3	(7%)		
Number of Malay captains	5	(12%)		
Number of Chinese captains	37	(88%)		
Number of owner-operators	34	(81%)		
Number of non-owner-operators	8	(19%)		
Number of respondents with:				
No schooling	9	(21%)		
Primary schooling	33	(79%)		
Secondary schooling	0	(0%)		
Number of vessels < 10 GRT	17	(40%)		

Notes: 1. GRT-days is number of days at sea per month multiplied by GRT of vessel.
2. Labor-days is number of days at sea per month multiplied by crew size.
3. Net-haul-days is number of days at sea per month multiplied by net size and number of hauls per day.

Source: Alam (1991).

Table 1. Summary Statistics of the Data (continued...)**West Coast**

Vessel and fishing characteristics	Mean	St. Dev.	Minimum	Maximum
Hull length (meters)	10.50	1.83	7	13
Gross registered tons	6.33	3.01	2	15
Engine horsepower	17.35	7.81	4	36
Length of net (meters)	586.10	297.61	200	1200
Mesh size (meters)	0.0881	0.0189	0.06	0.11
Remaining economic life: hull (yrs)	17.53	1.93	15	21
Remaining economic life: engine (yrs)	12.50	2.48	8	18
Remaining economic life: net (yrs)	8.43	1.65	6	12
Years of ownership: hull	5.93	3.02	1	12
Years of ownership: engine	4.65	2.96	0	13
Years of ownership: net	3.00	1.99	0	7
No. of fishing trips per month	17.43	4.91	7	26
Total fishing days per month	21.68	3.16	15	27
Trip duration (days) per month	1.24	3.97	1	3
Hauls of net per day	3.23	0.73	1	4
GRT-days per month	133.65	61.55	40	300
Labor-days per month	53.43	14.74	30	81
Net-haul-days per month	38561.6	18820.8	14400	100800
Operating distance (nautical miles)	5.33	3.03	2	14
Crew size (including captain)	2.45	0.50	2	4
GRT-crew size (capital-labor) ratio	2.70	1.51	0.67	7.50
GRT-crew size ratio vessels < 5 GRT	1.21	0.43	0.67	2.00
Catch of all species per month (kg)	819.35	256.66	478	1620
Revenue of all species per month (M\$)	175,757	52,584	82,835	310,350
Family size of captain	5.80	2.15	2	12
Fishing experience of captain (years)	14.40	7.09	3	33
Number of total observations	40			
Number of captains with training	5	(12%)		
Number of Malay captains	14	(35%)		
Number of Chinese captains	26	(65%)		
Number of owner-operators	31	(77%)		
Number of non-owner-operators	9	(22%)		
Number of respondents with:				
No schooling	2	(5%)		
Primary schooling	31	(77%)		
Secondary schooling	7	(18%)		
Number of vessels < 5 GRT	11	(28%)		

Notes: 1. GRT-days is number of days at sea per month multiplied by GRT of vessel.

2. Labor-days is number of days at sea per month multiplied by crew size.

3. Net-haul-days- is number of days at sea per month multiplied by net size and number of hauls per day.

Source: Alam (1991).

Table 2. Generalized Likelihood Ratio Tests of Hypotheses for Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Function

East Coast

Null Hypothesis	Likelihood Ratio	df	Critical Value (5%)	Critical Value (1%)
1. $\gamma = 0$ (No stochastic frontier)	62.309	2	5.138	8.273
2. $\alpha_6 = \alpha_7 = \dots = \alpha_{15} = 0$ (Cobb-Douglas frontier)	58.199	10	18.307	23.209
3. $\delta_1 = \delta_2 = \dots = \delta_{11} = 0$ (No technical inefficiency fn.)	56.114	11	19.675	24.725

Notes: 1. Test for $\gamma = 0$ follows mixed chi-square distribution with critical values found in Table 1 of Kodde and Palm [1986].
 2. Df = degrees of freedom.
 3. A truncated-normal distribution is assumed for the technical inefficiency error term.

West Coast

Null Hypothesis	Likelihood Ratio	df	Critical Value (5%)	Critical Value (1%)
1. $\gamma = 0$ (No stochastic frontier)	30.179	2	5.138	8.273
2. $\alpha_6 = \alpha_7 = \dots = \alpha_{15} = 0$ (Cobb-Douglas frontier)	30.913	10	18.307	23.209
3. $\delta_1 = \delta_2 = \dots = \delta_{13} = 0$ (No technical inefficiency fn.)	30.099	13	22.362	27.688

Notes: 1. Test for $\gamma = 0$ follows mixed chi-square distribution with critical values found in Table 1 of Kodde and Palm [1986].
 2. Df = degrees of freedom.
 3. A truncated-normal distribution is assumed for the technical inefficiency error term.

Table 3. Parameter Estimates of the Stochastic Production Frontier

Variables	East Coast			West Coast		
	Coefficient	Std. Error	t-Ratio	Coefficient	Std. Error	t-Ratio
Intercept	10.5913	0.9057	11.694	12.7098	0.9746	13.040
ln K	5.0371	0.9200	5.475	4.7873	1.0054	4.761
ln L	-4.7997	0.8222	-5.838	-7.4008	0.8621	-8.584
ln T	2.0509	0.8557	2.397	-3.5336	0.9736	-3.629
ln N	-2.4563	0.8818	-2.785	1.2196	0.7266	1.678
ln OD	0.6650	0.1533	4.337	-0.2487	0.1298	-1.916
ln K ²	-0.4395	0.4154	-1.058	0.7444	0.2266	3.286
ln L ²	-1.2599	0.1821	-6.918	-0.2749	0.3955	-0.695
ln T ²	-0.1317	0.0814	-1.617	-0.5990	0.1556	-3.849
ln N ²	-0.9716	0.4107	-2.366	-0.5460	0.2408	-2.268
ln K*ln L	0.1949	0.2175	0.896	-1.3288	0.3558	-3.734
ln K*ln T	-1.0061	0.2573	-3.910	0.4441	0.2747	1.617
ln K*ln N	0.9470	0.3625	2.612	0.5746	0.4867	1.181
ln L*ln T	1.6993	0.3055	5.562	0.2487	0.2304	1.080
ln L*ln N	-0.0108	0.0910	-0.118	1.2194	0.3344	3.647
ln T*ln N	0.0464	0.0463	1.069	0.0950	0.0696	1.364
σ^2	0.0491	0.0139	2.997	0.0127	0.0042	3.009
γ	0.9999	0.0001	24340.6	0.3380	0.1372	2.464
log-likelihood	47.5686			37.1789		
No. of observations	42			40		

Notes: 1. K = GRT-days (tens), L = labor-days, N = net-haul-days (hundreds), T = No. of trips,
 OD = operating distance from shore.

2. Translog functional form.

Table 4. Frequency Distribution of Technical Efficiency Scores

East Coast

Range	Total	Malay	Chinese	Mean Fishing Experience	Captain Training		Captain Education			Owner-Operator		Small Vessel		Mean Years of Expected Life			Capital-Labor Ratio		
					Yes	No	None	Primary	Yes	No	Yes	No	Hull	Engine	Net	Mean	Min	Max	
0.90 - 0.99	21	3	18	23.76	2	19	2	19	17	4	10	1	19.44	16.67	7.71	3.33	1.50	5.33	
0.80 - 0.89	6	0	6	18.67	1	5	2	4	4	2	3	3	18.17	16.83	5.83	3.28	2.50	4.00	
0.70 - 0.79	5	0	5	23.00	0	5	1	4	5	0	0	5	17.60	15.40	5.40	3.93	3.00	4.67	
0.60 - 0.69	2	1	1	24.50	0	2	1	1	2	0	1	1	22.50	12.50	6.50	3.00	2.67	3.33	
0.50 - 0.59	8	1	7	21.13	0	8	3	5	6	2	1	7	17.00	12.88	6.25	3.56	2.00	4.50	

Mean: 0.84 Minimum: 0.50 Maximum: 0.99

- Notes:
1. Measures are in terms of efficiency and not inefficiency.
 2. Small vessels < 10 gross registered tons.
 3. Fishing experience of captain in years.
 4. Capital-labor ratio is GRT/fisher.

West Coast

Range	Total	Malay	Chinese	Mean Fishing Experience	Captain Training		Captain Education			Owner-Operator		Small Vessel		Mean Years of Expected Life			Yanmar Engine		Capital-Labor Ratio		
					Yes	No	None	Primary	Secondary	Yes	No	Yes	No	Hull	Engine	Net	Yes	No	Mean	Min	Max
0.90-0.99	21	5	16	9.76	1	20	2	12	7	16	5	6	15	17	12.8	8.8	15	6	2.43	1.00	7.50
0.80-0.89	9	3	6	21.11	2	7	0	9	0	8	1	2	7	17.82	8.78	7	2	2.75	1.00	4.50	
0.70-0.79	5	4	1	18.80	0	5	0	5	0	4	1	1	4	16	18.2	7.0	4	1	4.30	3.50	5.50
0.60-0.69	4	2	2	16.25	1	3	0	4	0	4	0	1	3	18	18.0	7.50	4	0	2.89	0.67	3.31
0.50-0.59	1	0	1	10.00	1	0	0	1	0	1	0	1	0	18	11.0	8.00	1	0	2.22	2.22	2.22

Mean: 0.88 Minimum: 0.57 Maximum: 0.99

- Notes:
1. Measures are in terms of efficiency and not inefficiency.
 2. Small vessels < 5 gross registered tons.
 3. Fishing experience of captain in years.
 4. Capital-labor ratio is GRT/fisher.

Table 5. Estimated Technical Inefficiency Function

Variable	East Coast			West Coast		
	Coefficient	St. Error	t-Ratio	Coefficient	St. Error	t-Ratio
Intercept α_0	4.1338	0.7067	5.849	-0.6221	0.4441	-1.401
Remaining economic life: hull (years) (EXLIH)	-0.0261	0.0277	-0.939	0.0472	0.0169	2.788
Remaining economic life: engine (years) (EXLIE)	-0.0981	0.0262	-3.744	0.0273	0.0165	1.682
Remaining economic life: net (years) (EXLIN)	-0.0366	0.0479	-0.765	-0.0711	0.0259	-2.747
Fishing experience (years) (FEXP)	-0.0254	0.0110	-2.306	0.0107	0.0065	1.637
Mesh size (meters) (MESH)	0.4247	0.9968	0.426	0.3972	0.9859	0.403
Family size of captain (persons) (FSIZE)	-0.0766	0.0363	-2.113	-0.0333	0.0220	-1.510
Dummy variables for:						
Chinese captain (D_{CH})	-0.4335	0.2264	-1.915	-0.2546	0.0981	-2.595
Non-owner-operator (D_{NOP})	-0.0847	0.2296	-0.368	0.0224	0.0828	0.271
Captain training (D_{CT})	-0.4763	0.4856	-0.981	0.4024	0.1244	3.235
Small vessel (D_{SM})	-0.5088	0.1754	-2.901	0.2531	0.1304	1.941
Primary education captain (D_p)	-0.4887	0.1511	-3.235	0.2545	0.2054	1.239
Secondary education captain (D_s)	-	-	-	0.1105	0.2694	0.410
Non-Yanmar brand of engine (D_B)	-	-	-	-0.2329	0.0930	-2.580

Notes: 1. Estimated coefficients from a truncated normal distribution for technical inefficiency error term and translog stochastic production frontier.
2. Coefficients obtained from estimation of Equation (2) where technical inefficiency is the dependent variable.
3. Small vessel: < 5 GRT on west and < 10 GRT on east coast.

End Notes

¹ Some 200 million people worldwide depend on fishing and fish-related industries for their livelihood. Artisanal fisheries employ about 24 times as many people as large-scale commercial fisheries and generate almost 50 percent of total world landings for human consumption (Pauly, 1997). Artisanal fisheries are often the main if not sole provider of fish for the domestic market. (Lawson, 1984).

² Immobility of artisanal fisheries labor arises for several reasons. The fundamental reason is the profound geographical, social, and cultural isolation and consequent marginalization to society. Their specialized way of life, evolved to adapt and exploit their unique ecosystem, and job skills further contribute. The geographical isolation limits educational opportunities, knowledge of opportunities elsewhere, and kinship ties in cities and towns which would help emigration.

³ Destructive fishing practices include the use of dynamite and cyanide poison to stun or kill fish, and coral mining. Estuaries, coastal wetlands, bays, and nearshore areas of the sea form breeding grounds and nurseries for juvenile fish and prawns. Over thirty percent of marine productivity occurs in these marginal areas and yet they comprise only one percent of the total marine volume (Agardy, 1997). Destruction of these habitats and coral reefs lowers the environmental carrying capacity and the ultimate size of the fish stocks that can be sustainably harvested. Mangrove swamps have some of the highest levels of primary biological productivity of any ecosystem, but are harvested for wood chips and cleared for aquaculture sites. Coral reefs are killed by cyanide, dynamite, or pollution. Over one-half of the world's salt marshes and mangrove swamps have been cleared or drained for development and ten percent of the world's coral reefs have been eliminated by human activity (Agardy, 1997).

⁴ The conflicts arise from the harvesting of fish which, in tropical waters, tend to be concentrated in coastal areas and shallow, inshore waters. Moreover, in overfished tropical waters, only the youngest age classes remain, which are located in nearshore waters. These waters are fished by both artisanal and large-scale vessels, which leads to conflicts. In many instances, artisanal and large-scale commercial fishers are from different ethnic groups, exacerbating the conflicts. In addition, larger vessels home port in larger urban areas rather than in the traditional fishing villages and hamlets strung along the coast. This poses another source of conflict as almost all of the employment gains associated with large-scale fishing and from modernization of fishing fleets are concentrated in towns and cities and not in artisanal fishing communities (IPFC, 1994). Large-scale fishers concentrate on production for urban and export markets (especially prawns for export) while artisanal fishers concentrate on own consumption and local markets, with only a limited export orientation.

⁵ Several lessons can be learned from past experiences. First, artisanal fishers are unlikely to transform their fisheries into large-scale, fully commercialized operations. Second, the gains from introducing motors and upgrading gear are already largely realized. Third, artisanal fishers and their families are unlikely to depart in mass from their narrow strip of land and sea to find employment elsewhere inland. Fourth, most fish stocks are fully or over-exploited, which precludes the introduction of larger-scale production technologies, such as trawl or purse seine nets. Fifth, policies should be predicated on full and sustainable utilization of the largely renewable resources of the complex and varied ecosystem in the coastal littoral and nearby fishing grounds. Sixth, sustainable fishery development is often limited by a yield fundamentally fixed by nature. Seventh, halting or even reversing the extensive ongoing degradation of the ecosystem is required to maintain the renewable resources upon which artisanal fishing communities survive.

⁶ Many efficiency studies exist for agriculture in developing countries, recently surveyed by Bravo-Ureta and Pinheiro (1993), but this is the first for artisanal fishing.

⁷ There are various kinds of drift gill nets in use, with mesh sizes ranging from 2.5 to 4 inches (Bailey 1983). Mesh size varies by net type but also mesh sizes are mixed on a net, since different mesh sizes better catch different species according to their seasonal variability. The *pukat hanyut* hangs from the surface by floats. The *pukat hijau* has a larger mesh size, is heavier, and is more suitable for the relatively heavy seas during and immediately after the monsoon period. Both the *pukat hanyut* and *pukat hijau* are used at night, except during the bright phase of the moon when the fish can see the shadow of the net and avoid it or sharks and dolphins can eat the trapped fish. Hence, fishing stops or slows during full moons or adverse weather. The net let off the stern as the vessel moves slowly away from the coast. The prevailing currents move up and down the coast, depending on the tides, and so the fish, which generally swim against the current, become trapped in the nets which run perpendicular to the coast. A small lantern is placed on a wooden floating platform attached to one end of the net and another placed on the vessel itself mark the location of net. The net is attached by nylon rope to a string of plastic which floats which allow the net to hang about 3 feet below the surface, with the netting running about 30 feet deep and of variable length. *Pukat tansi* is a bottom-set gill net used during the day, is cast and retrieved many more times during the day than *pukat hanyut*, and is used more during the monsoon season since day fishing is then safer. *Pukat hanyut* crews tend to be smaller than *pukat tansi* crews, but all crews are often larger than technically required (input congestion), reflecting the large number of available fishers, many of whom can call upon ties of kinship or friendship to secure a place. Firth also discusses *pukat talang*, larger-meshed than *pukat hanyut*, and *jaring* used for small clupeids. Gill nets of all types are played out over the stern as the vessels chug slowly forward until the full length of the net is deployed. When fishers pull the net in, they essentially pull the vessel back along the course of the net, the net acting as a kind of sea anchor. Square-sterned vessels facilitate this task, since traditional designs require hauling over the side, which hauls the vessels sideways, a more arduous task and increasing the likelihood of swamping the gunwales.

⁸ The species of fish commercially exploited, while generally not migratory, are sensitive to major seasonal variations (Bailey). On the east coast, during and immediately after the northeast monsoon, these species concentrate close to the shoreline, where food is concentrated, and are normally found within 5 miles of the coast, but when the seas enter the prolong calm, coinciding with decreased river discharge and hence lower nutrient inflow and plankton growth, the fish tend to disperse over a wider area to forage. In the season of clear water, the decline in water turbidity signifies lower organic water content and hence reduced marine life.

⁹ Campbell and Hand (1997) discuss the importance of specifying these variables as service flows rather than assuming that the stocks are in full static equilibrium with proportional service flows. A flow specification increases the possibility of multicollinearity for the stochastic production frontier. However, this study is concerned with estimates of technical efficiency, using predictions of output. Hence, multicollinearity does not raise the same problem as it would if the study focused on individual parameter estimates, or combinations of them, as for example in an evaluation of input substitution possibilities.

¹⁰ Net length was chosen over mesh size as a more accurate measure of the volume of water swept by the fishing gear. Specifying mesh size as an additional variable would have increased multicollinearity. Also, GRT-days is scaled by 10 and net-haul-days is scaled by 100 to keep the magnitude roughly comparable to labor-days, number of trips, and operating distance from shore.

¹¹ Because distance from the fishing ground represents an environmental parameter, it is specified as a single-order term in the stochastic frontier. Due to data limitations, the location or state of the vessel was not recorded and thus area dummy variables, which would otherwise capture spatial differences in resource abundance, fishing practices, and socio-economic conditions, are not included in the model. Data limitations also precluded accounting for the type of gill net used.

¹² This gives 11 and 13 explanatory variables for east and west coast variables. In addition, all engine brands are Cumins on the east coast. On the west coast, 31 vessels had Yanmar engines, 1 had Cumins, and the remaining 8

used different (and unspecified) makes. For the west coast, the mean horsepower of Yanmar (non-Yanmar) engines is 18.15 (11.56) with a standard deviation of 6.92 (7.89) and the minimum is 4 (4) and the maximum is 24 (33). The distributions indicate that the engine brand dummy variable for non-Yanmar engines is capturing performance capabilities other than solely a smaller mean horsepower.

⁹ Other variables, such as kinship ties between the captain and boat owner, could also be included in the inefficiency function but were excluded because of missing observations. The captain is the primary decision maker on the vessel (Alam, 1991; Firth, 1975). One way to introduce managerial ability or skipper skill is through fixed or random effects but this requires panel data and we are confined to cross-sectional data. Instead, we introduce skipper skill through the technical efficiency measure. Hence, the captain's human capital variables are assumed to affect production through the technical inefficiency. In the output-oriented technical efficiency approach, this corresponds to the ability to locate and catch fish (output) given the input bundle. This approach disembodies the managerial input or "skipper skill" from the skipper's own contribution to labor power (captured in crew size). To account for inter-vessel differences the best we can, we introduce a small vessel size class dummy into the technical inefficiency equation. Because vessels on the west coast are smaller than those on the east coast, the small vessel dummy for west coast vessels corresponds to smaller vessels than on the east coast.

¹⁴ The specification of technical inefficiency as unexpected and unknown, or as expected and foreseen, when the firm chooses its inputs affects the specification and estimation of the production function (Kumbhakar, 1987). Given the overwhelming importance of "captain's skill" in locating and catching fish and the inherent stochastic effects from weather, temperature, and biological variations in fishing, it is likely that technical inefficiency that is unforeseen is more important than the foreseen. The point is that technical inefficiency is likely to be never entirely foreseen or unforeseen, but in fishing, technical inefficiency is more likely to be unexpected and unknown. Thus we specify the technical inefficiency as unexpected or unforeseen. Given unknown and unexpected technical inefficiency, the argument of expected profit maximization (Zellner, Kmenta, and Dreze, 1966) can be used to treat inputs as exogenous (Kumbhakar, 1987; p. 336). If technical inefficiency is known to the firm, estimates of the production function parameters obtained directly from the profit function will be inconsistent.

¹⁵ All variables are self-reported. Moreover, data on artisanal fisheries are very difficult to obtain due to the great isolation of many villages and hamlets. This difficulty, coupled with the absence of formal record keeping by artisanal fishers, precludes data requests for periods of time longer than about a month or from very far in the past. Ideally, artisanal fisheries would be repeatedly sampled, but these types of data collection programs are very rare. Alam provides further details about the data and sampling procedure.

¹⁶ The null hypothesis $\gamma = 0$, where $\gamma = \sigma_U^2 / (\sigma_U^2 + \sigma_V^2)$ and lies between 0 and 1, tests whether or not $\sigma_U^2 = 0$. If the null hypothesis, $\gamma = 0$, is not rejected, then the U term should be removed from the model and the stochastic production frontier is rejected in favor of ordinary least squares estimation of the production function for the sample. The second hypothesis is whether or not the functional form of the stochastic production frontier, Equation (1), is Cobb Douglas. The null hypothesis is $\alpha_6 = \alpha_7 = \dots = \alpha_{15} = 0$. The third hypothesis is whether the technical inefficiency function, Equation (2), depends on the level of the explanatory variables, Z. Under the assumption that the inefficiency effects are distributed as a truncated normal, the null hypothesis of no relationship between explanatory variables is $\delta_1 = \delta_2 = \dots = \delta_M = 0$.

¹⁷ Any generalized likelihood ratio statistic associated with a null hypothesis involving the γ parameter has a mixed chi-square distribution because the restriction defines a point on the boundary of the parameter space (Coelli, 1996). The critical values are given in Table 1 of Kodde and Palm (1986). The number of restrictions, and hence the degrees of freedom for the null hypothesis $\gamma = 0$, is the difference in the number of parameters in the test of the OLS model versus the stochastic production frontier, equal to one for γ , one for μ with the truncated normal (associated with δ_0 , the intercept of the technical inefficiency function) plus the number of terms in the technical inefficiency function, excepting δ_0 , which would not enter the traditional mean response function

(Battese and Coelli, 1995; footnote 6) . In this case, all variables in Z , except δ_0 , would enter the translog production function as log-linear control variables (such as OD), so that the degrees of freedom for $H_0: \gamma = 0$ is two.

¹⁸ Not including an intercept parameter (δ_0) in the mean ($Z\delta$) may result in the estimators of the δ -parameters, associated with the Z -variables, being biased and the shape of the the distributions of the inefficiency effects, U , being unnecessarily restricted (Battese and Coelli, 1995). Battese and Coelli (1995) note that when the Z vector has the value 1 and the coefficients of all other elements of Z are 0, Stevenson's (1980) model is represented. The intercept δ_0 in the technical inefficiency function will have the same interpretation as the μ parameter of Stevenson's model (Coelli, 1996). The null hypothesis combining null hypotheses one and three, given the translog stochastic production frontier and truncated normal, is rejected for both coasts (one percent critical values are 27.026 with 13 degrees of freedom on the east coast and 29.927 with 15 degrees of freedom on the west coast). In addition, on the east coast, $\gamma = 0.9999$ with a standard error of 0.0001 (Table 3) indicates that the vast majority of residual variation is due to the inefficiency effect, U , and that the random error, V , is almost zero, while on the west coast, $\gamma = 0.3380$ with a standard error of 0.1372 indicates that random error is relatively more important.

¹⁹ A newer vessel, engine, or net might also be in a better state of repair and maintenance, which could also increase its efficiency. In addition, in view of the complexities involved in obtaining information on the year of first purchase or construction of second-hand vessels, their actual age could not be assessed. Instead, estimated remaining economic life for the asset was chosen. The number of years that the asset has been owned by the present owner was available but economic life was deemed a more reliable indicator of capital vintage.

²⁰ A new vessel does not directly contribute to the catch but increases seaworthiness, especially when seas are rough such as during the monsoon (Bailey). New vessels also tend to be faster and require less general maintenance. Nets catch the fish. The relative condition of the net affects catch rates; netting in a poor state of repair may have gaping holes and thread so weakened by age that even a small fish may be able to free itself.

²¹ These results could reflect measurement error of estimated remaining economic life. Maintenance could also differ by age but not be accounted for in the sample. Newer vessels could also incorporate experiments or innovations in hull design that actually inhibit inefficiency. The same result of an unexpected algebraic sign was found for auxiliary regressions when years of ownership was substituted for expected remaining economic life, providing some evidence for measurement error.

²² The results might reflect the proportion of Chinese skippers in the sample. On the east coast, 37/42 of the skippers are Chinese (which is disproportionate to the population) but west coast the numbers are more even.

²³ The limited range of captains' formal education (few captains received secondary education on the west coast and no fishers on the east coast) may also affect the results. The training program might also be inappropriate. The fishers might require a more hands-on, rather than a government training program. Fishers have considerable local knowledge of conditions and networks of fishing information are often only developed on the job.

²⁴ A non-owner captain operating in marine fisheries has avenues to demonstrate behavior contrasting to that found in agriculture. For example, unreported or illegal sales of fish caught can be made at sea. In addition, the percentage of owner-operatorship is quite high on both coasts (81% and 77% on the east and west coasts, respectively), which could affect the results.

²⁵ Selectively removing small vessels would save only a small amount of capital but might benefit the resource stock by lowering exploitation rates on the younger, sexually immature fish.

²⁶ Elements of ISFD already exist in the literature, including an emphasis on the importance of fish marketing and processing (Lawson, 1984), the need to develop alternative employment opportunities (Firth, 1975; Smith, 1979; Neal, 1982; IPFC, 1994; Panayotou, 1982), the importance of investments in infrastructure for fishing communities (Ben-Yami, 1977; Squires, 1978), the importance of the coastal littoral and a broad-based ecological approach to the coastal zone and nearshore waters (Soysa, Chia, and Collier 1982; IPFC 1994), co-operative management and community rights (Christy, 1986; Pomeroy, 1994), and community development (Ben-Yami, 1977). These elements are synthesized for the first time in this paper.

²⁷ To the extent on-shore development is concentrated in larger urban areas, artisanal fishers may not participate and enjoy benefits.

²⁸ These investments can include rural roads (all weather roads for important arteries), clean water, jetties, ports for larger communities, covered market slabs and stalls, and radio broadcasts of fish prices from central fish markets. A similar and highly successful program was developed for smallholder rubber growers in Malaysia who compete with plantations. An export tax on high-valued exported prawns could finance these improvements and finance monitoring and enforcement of sustainable harvesting practices.

²⁹ Improvements in infrastructure and transport systems lower costs and improve the quality of inputs, highly perishable products, and consumer goods. They also help offer alternative markets for both inputs and outputs, improving competition, thereby lowering input prices and possibly raising output prices. For instance, fresher fish can be sold to larger markets and some marketing intermediaries can be by-passed. Ice can be more readily obtained, at lower prices, to raise fish quality and reduce spoilage losses. Transportation may also serve as a catalyst to integrate isolated areas into the market economy.

³⁰ Policies to improve mobility of fishers to exit over-exploited fisheries may also require policies that help limit entry of peoples from other sectors (Pauly, 1997). In some countries, rapid mechanization in agriculture or excessive pressures for land have forced labor without land or only marginal holdings to search for alternative forms of livelihood. While many have migrated to cities, others have entered artisanal fisheries or otherwise utilized coastal resources, especially where property rights over resources are not well defined and exploitation requires little capital. In these instances, artisanal fisheries have become the employer of last resort (Neal, 1982).

³¹ Destructive techniques that destroy the resource base, or use of gears and mesh sizes not sanctioned by government or within the fisher communities, often reflect attempts to maintain incomes in the face of declining catches (Pauly, 1997). Barber and Pratt, 1997) describe an innovative program along these lines, developed by Non-Governmental Organizations (NGOs).

³² In addition, sustainable management measures may be most efficacious and cost-effective if applied at "choke points", given the increasing use of air freight and difficulties in enforcement along extensive coastlines and widely dispersed fishing villages and landing sites and strapped public budgets. For example, an especially effective management measure to promote sustainable resource exploitation might be certification and controls of live fish and minimum count sizes of prawns in export markets (Barber and Pratt, 1997; Kurien, 1996).

³³ Community rights, which may include territorial user rights in fisheries (TURFs), which are exclusive spatial zones (Christy, 1986), and various access and withdrawal rights for members, are important ways to sustain fishery resources. Strategies should assist communities to increase the exclusiveness of their marine resources.

³⁴ The nearshore artisanal fishery resource base can be protected in part by banning harvesting by large-scale commercial vessels, including shrimp trawlers, where up to 90 percent of the catch of finfish is discarded with high mortality. Malaysia has such a ban with its zonal license limitation system, but enforcement difficulties preclude effective enforcement. Also, reduced exploitation can, in some instances, increase yields by allowing

resource stocks to recover and fish to grow to larger sizes. Marine refuges can protect spawning stocks and juveniles and biodiversity. Protection of the fishery resource base and the coastal zone also comes from control of runoff impacts from widespread deforestation, mining, and industrial agriculture; damming and diversion of rivers; the clearance of mangrove and coastal wetlands; sedimentation; intensive aquaculture; marine-based pollution; and other causes.