OPEN ACCESS, OVER-FISHING AND LIVELIHOOD RISK: A PROPERTY RIGHTS PERSPECTIVE ON THE SOUTH COAST LOBSTER FISHERY IN SRI LANKA

1. Introduction

Sri Lanka's economy, like those of many other island nations, contains a significant fishing industry. Its output is an important source of animal protein,[1] and is estimated to generate close to 180,000 jobs[2]. Export earnings for 2000 amounted to Rs. 9,135 million (National Aquatic Resources Research and Development Agency (NARA) 2001), or close to the Rs. 9,174 million earned by coconut exports, the second highest earnings from a single agricultural crop that year (Central Bank of Sri Lanka 2003).

All over the world, governments, ecologists, conservationists and others have become increasingly concerned with the issue of sustainability of fisheries[3]. Measures adopted to prevent over-fishing[4] range from international agreements with respect to the open seas, to domestic policies aimed at coastal and inland fishing. In Sri Lanka, a multitude of regulations are imposed by the *Fisheries and Aquatic Resources Act No. 02* of 1996. Among its coverage are licensing procedures, restrictions on gear and methods of fishing, controls on exports and imports, and the declaration of management areas, fishing seasons and fisheries reserves.

Government actions to control fishing activity in Sri Lanka have had to take cognizance of several factors. First, there are the ecological processes, which impose limits on fishery reproduction. Second, fishing as an occupation is associated largely with poverty. On the other hand, the absence of perceived economic alternatives results in increasing effort to earn livelihoods from fisheries, paradoxically endangering their very sustainability. Third, compliance with regulations requires acceptance of their need by the fishers, and hence there are attempts to involve fishing communities in the resource management process.

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[1] Coastal and marine eco-systems are estimated to provide 65% of the country's animal protein requirements (Baer 2001).

[2] According to Central Bank of Sri Lanka (1998:106), direct and indirect employment was around 150,000 and 30,000, respectively, while NARA (2001) enumerated the number of "active fishers" as 140, 851.

[3] Along with renewable resources in general.

[4] This term can be defined in several ways, stressing either the ecological or the economic aspect (see Israel and Banzon 1998: 3 for a summary of four definitions). For our purposes, we will refer to both the ecological sense, meaning that some natural optimum has not been met, and economic, in the sense that choices made lead to diminished returns and greater risk of future losses.

The economist's approach to resource management has become increasingly informed by the literature on property rights. There is a greater understanding today on the connection between different "property rights regimes" and rates of resource extraction. The word *regime* refers to both (property) *rights* and (property) *rules* (Hanna and Munasinghe 1995: 4). Rights to the use of natural resources operate within a system of rules. Rules, in turn may be set formally (e.g., by legal enactment), or informally (as in traditional practices of communities). A property rights regime then typically specifies conditions governing both *ownership* and *access* to (or *use* of) a resource.

Fisheries are typically associated with an "open access" regime, which allows any economic agent to enter the industry as long as there are profits (or "rents") to be made. It results in an influx of effort, placing the fishery stock in danger of depletion/extinction. In such a case, there is a *prima-facie* argument for State regulation of the fishery[5]. At the same time, the expected *outcome* of a specific regulation can be viewed through the lens of the property rights framework.

The problem of low sustainability of coastal fisheries in Sri Lanka has been recognized for some time. Most of the literature focuses on social and ecological aspects of the problem[6], including the connection with other aquatic resources, such as coral reefs[7]. A recent study by Madhavie (2003), however, provides space for adopting a property rights perspective on the problem. She estimates a biological growth model of the Sri Lanka South Coast (SLSC) lobster fishery[8], which can be supplemented with economic information – specifically lobster prices and costs of fishing – to compare outcomes of alternative policies.

The objective of this paper is to explore the implications of Madhavie's (2003) results for management of the SLSC lobster fishery. We do that by first identifying policy *direction*, and then comparing different options based on the experience of different management strategies, both in Sri Lanka and elsewhere. The paper is organized as follows. Section 2 gives an outline of property rights regimes, tracing their connection with resource extraction and earnings. Section 3 describes the salient features of the SLSC lobster fishery, including efforts at government regulation, while section 4 considers evidence from Madhavie (2003) for over-fishing. Section 5 then goes on to explore different management options, and section 6 offers a conclusion.

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[5] Another justification is when the industry generates "externalities", or effects experienced by those outside the industry.

[6] E.g., Dayaratne 1997, Sideek and Jayakody 1987.

[7] See Monagurusamy and Dhanasiri (2001) and Rajasuriya (undated).

[8] The author focuses on the class of lobsters known as "spiny lobsters", which is predominant in the region. "Slipper lobsters" are also prevalent in smaller numbers, but are usually treated as a by-catch, and have little economic value (Jayakody 1999). Price and export data of slipper lobster are not available.

2. Property rights regimes and resource extraction

Interaction between humans and natural resources takes place at different levels, ranging from small, subsistence-type extraction to large, capital-intensive commercial operations. All these activities can be fitted into a range of conceptually distinct property rights regimes, although in practice, there can be some overlap. In this section, we begin with that of open access and then go on to compare other regimes and their outcomes, conducting the discussion in terms of *fisheries* to keep it in context.

(a) Open Access

With open access, it is assumed that there is no clearly specified owner of the fishery, and hence it is also referred to as "non-property" (Hanna, *et al.* 1995:29, Charles 2001: 285). As long as the average cost of fishing is below the output price, effort levels in the fishery will increase. This will take place both by the entry of new fishers to the industry, as well as by higher effort levels of existing fishers. This process can be expected to lower the profits ("rents") from fishing, eventually making them too small to attract additional effort. Thus the open access equilibrium outcome is consistent with a combination of low economic returns and high fishing effort. There is little incentive to conserve fishery stock by any *individual*, because he/she cannot limit others' efforts, and hence cannot guarantee the existence of the fishery in the future. As will be argued later, there is a relatively high probability of stock extinction, and with it, fishing livelihoods.

(b) Private property

At the other end of the scale is the *private property* regime, where the fishery has a clearly recognized owner. The owner will control effort to that level which maximizes his/her rents. This effort is lower than that of open access, hence resulting in a larger unexploited fish stock[9]. In addition, a private owner with long-term fishing rights may vary effort across time, engaging in resource conservation so as to exploit a future stream of profits. Theoretically, then, a private property regime would be more favorable to resource conservation[10] than an open access regime. Note that due to the profit-maximization motive, fishing earns high rents for the owner, unlike the case of open access, which yields zero rent.

[9] But not necessarily a lower catch. This depends on the biological process, and where the industry currently is, in relation to it.

[10] Or *less* amenable to over-fishing.

(c) Other forms of property rights

If we consider open access and private property as two extremes, they contain between them, *common* property and *State* property (Hanna, *et al.* 1995:29). In the former, a community holds the property in common, defines who outsiders are, and excludes them from access to the resource. In contrast, in the latter case, the State, acting on behalf of the citizenry, determines who the actual users will be. Theoretically, both these forms of ownership allow for the exercise of *some* regulation of the rate of resource extraction. But it is not always clear what the degree of regulation will be.

For instance, under common property rights, the community is assumed to self-regulate access in accord with some communal objective, whereas "outsiders" are denied access. In practice, however, if self-regulation breaks down, members of the community will be free to increase effort, and the equilibrium will approach that of open access. Similarly, State ownership is compatible with *de facto* open access when there is no regulation, or it is not effectively implemented.

Observed outcomes of different property rights regimes suggest that the significance of their differences for sustainability lies more in their inherent *tendencies*, rather than in a universal or inevitable cause-effect relationship. I.e., there is no guarantee that a specific regime will always ensure sustainable use of resources. Private, communal or State owners, may, for different reasons[11], allow rapid exploitation of resources. What matters for sustainability is

> ... a well-specified property rights regime and a congruency of that regime with its ecological and social context. (Hanna and Munasinghe 1995:4)

There is general agreement in the literature, however, that open access is the least desirable form of property rights regime. The expenditure of large effort reduces returns *per unit of effort* to very low levels. By depleting the stock, it can seriously impair its regeneration potential, thus raising the probability of extinction. The latter, in turn puts fishing livelihoods at risk. The solution therefore to open access, whatever the new property rights regime that is proposed, is to reduce fishing effort, which incurs the social cost of job loss. Any measure implemented, will, therefore have to come up with methods of creating viable alternative employment.

Before concluding this section, we look at broad types of regulations usually adopted by the State to control effort. These regulations may be viewed in purely *enforcement terms*, i.e., assuming their imposition on a reluctant

[11] E.g., private owners may want immediate returns to finance another, more profitable investment; a community may foresee a fall in the future value of the resource and relax rules of use; and the State may give in to pressures of special interest groups (Hanna, *et al.* 1995:17).

fishing community, whose expected response is taken into account. Alternatively, they can be viewed as a blueprint for a negotiated outcome between the State and a community organization. We shall use the term "regulated access" to encompass both possibilities.

i. Types of Fishery Regulation

Table 1a

TAXATION OF FISHERIES & ANTICIPATED OUTCOMES

Type of regulation			Outcomes	Problems/Issues
TAXATION	Tax on catch/price		♦ Drop in effort ♦ Capture of rent by the State ♦ Taxes imposed only if there is a catch	♦ Difficulty of setting tax rate to both minimize job loss and achieve sustainability ♦ Need to adjust tax rate frequently due to changes in market and environment ♦ Under-reporting of catch
	Tax On Effort	Industry license fee	♦ Increase in total cost ♦ Drop in industry effort ♦ Tax paid up front	♦ How the industry license fee is to be shared among fishers ♦ How the marginal entrant is identified and taxed ♦ Taxing some forms of effort lead to substitution by other forms
		Tax per unit effort	♦ Total tax increases with effort ♦ Drop in effort	

Sources: Hartwick and Olewiler 1998: 142-45

Table 1b

QUOTAS ON FISHERIES & ANTICIPATED OUTCOMES

QUOTAS	Total Allowable Catch (TAC)		Set for the whole industry	Too much effort expended in a short time, to exploit resource
	Individual Quotas (IQ)	Administrative Allocation	Individuals selected administratively	♦ Political factors may influence selection of recipients ♦ Without transferability, no guarantee that quotas will go to low-cost fishers ♦ High administrative cost of quota distribution
		Transferable	Initially distributed free or via auction	♦ Political process in initial free distribution ♦ Eventual allocation efficient because quotas have market value
	Quota on effort alone		Quota on some component(s) of effort	Substitution by non-quota forms of effort

Sources: Hartwick and Olewiler 1998: 145-52, Townsend and Pooley 1995a: 49-50

Of the two types of intervention described above, taxes seek to lower effort *indirectly* by reducing its economic return, while quotas constitute a more direct type of action. With taxes, the expected outcomes are predicated on there being open access, apart from the effects of taxation. Thus the typical open access equilibrium of low (or zero) returns per unit effort does not change. The State merely appropriates the high fishing rents that would normally accrue to fishers at this lower effort level[12].

When quotas are set, however – either on effort or on output – the quota holders are given highly valuable rights to fish, especially in the case of

[12] But the State can, if it so wishes, spend some of it on the needs of the fishing community.

individual quotas. They receive the difference between income[13] from the catch, and payment, if any for the quotas. Thus quota holders are more privileged than those who are taxed. Note, however, that these "quota rents" can be dissipated by a system of *auctioning* of the quotas. Distribution of individual quotas in fact, is problematic and tends to involve the political process, and can be costly to administer as well. Setting a quota on catch for the *industry* ("total allowable catch") usually results in a frantic rush to harvest, and can actually deplete fish stock.

ii. Community involvement

Several forms of management involving the State and the community/industry[14] can be seen in practice. All of these require the existence or creation of a community institution, as well as a clear specification of the roles of the different stakeholders. "Co-management" and "contractual management" are some of the common forms of cooperation.

Co-management can be defined as

> ...any institutional arrangement that structures an external relationship for resource governance between a local fishery management institution and the government (Townsend and Pooley 1995: 50)

Contractual management is

> ...any delineation of rights and responsibilities between a government and a local fishery management institution (Townsend and Pooley 1995: 51)

The difference between the two is that there is a greater separation of rights and responsibilities in the latter, as compared with the former. If the local fishery management institution (LFMI) is seen as effective, then contractual management allows it more power and freedom over its actions. The State, however, has to retain the rights to intervene in clearly specified instances, such as in dealing with externalities[15].

The capabilities of the LFMI are likely to be critical in determining the effectiveness of fishery management. More broadly, what is needed is "distributed governance" among the State, local communities and private

[13] *Net* of costs of fishing effort.

[14] The two terms are used interchangeably here, although in commercial fisheries, the two groups can be distinct.

[15] A good example in the Sri Lankan context is the depletion of coral reefs, which in addition to affecting lobster reproduction, has other ecological consequences.

interests (Townsend and Pooley 1995a: 48). Hanna *et al.* (1995) discuss the principles of designing a property rights regime in terms of being "..congruent with societal objectives for economic performance, equity and ecological maintenance" (Hanna *et al.* 1995: 19-20). How far this is possible for the SLSC lobster fishery will be taken up in the discussion on management options.

3. The SLSC Lobster Fishery

(a) Description of the fishery

The area defined for purposes of the study is the coastal fishery situated between *Bentara River* in the southwest, and *Menik River* in the southeast of the island. The coastline is around 240 km in length, with the fishery defined as falling within 3 km from the shore[16], and having a depth of 20-30 m (Jayakody 1999). The study area contains the three administrative districts of *Galle*, *Matara* and *Hambantota*. It is the only coastal fishery, which is home to all six spiny lobster species[17] found in Sri Lanka (Jayakody and Kensler 1986, cited in Jayakody 1991, 1999). Of these, *Panulirus homarus* is the most abundant, while *Panulirus ornatus* is the largest in size.

Lobster fishing is a nighttime activity, with nets[18] being laid during the late evening, and retrieved the next morning. Darkness and dry weather constitute optimal conditions for fishing. Thus periods of heavy rainfall, such as during the southwest monsoon during March and April bring lobster fishing to a standstill. Also, nights of high light intensity, such as the full moon, affect fishing adversely. Weather-wise, August to March of the following year is considered the best period[19], and there is an influx of fishermen from outside the area during November and December (Jayakody 1999).

Fishing effort should ideally be measured as an *index number*, comprising combinations of boats, equipment and labor. But data is available for this fishery only in terms of boat-days (or more appropriately, "craft-*nights*" (Jayakody 1999)). Four types of vessels predominate in the area, viz., 3.5 ton 1B-engine boats, 17"-18" FRP OB-engine boats, and traditional *oru*[20] – both of the motorized and non-motorized type (Jayakody 1999). The four types differ in

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[16] This is the *coastal* fishery, whereas deep sea fishing of lobsters is possible beyond this limit. Note that there can be some variation in definitions. So DeCosse and Jayawickrema (1998: 217, endnote 4) define the coastal zone as the "...area lying within 200 metres landward of the mean high water mark and 2 km seaward of the mean low water mark."

[17] *Panulirus homarus, Panulirus longipus, Panulirus ornatus, Panulirus penicillatus, Panulirus poliphagus and Panulirus versicolor*

[18] Apart from the use of nets, *diving* is also practiced, but on a much smaller scale.

[19] However, lobster fishing is banned during February and September, to allow for breeding.

[20] Or, "small boats"

their fishing productivity in two ways. First, input capacity per trip, measured by the number of nets and labor units, are different. Second, the larger vessels can operate in weather conditions too adverse for smaller craft. Four types of nets are used as follows. "Bottom set gillnets" with two mesh sizes – 3-4" (for any species of spiny lobster), and 7-9" (targeting the large *Panulirus ornatus*), "terminal nets" and "lobster rings". The first two types are the most popular in this fishery, followed closely by terminal nets[21].

Domestic consumption of lobster is negligible, with around 95% of the catch being exported and the balance going to the local hotel industry catering mainly to the tourist palate[22]. The export sector is dominated by five firms, whose major markets in recent years have been Hong Kong, South Korea, Singapore and Japan (Jayakody 1999)[23] There is no systematic recording of prices, although some data is maintained at the Statistical Unit of the Ministry of Fisheries. The latter shows price varying from a low of Rs.250 per kg, to a high of Rs. 1,550 in 1999. This range includes the highly valued *P. ornatus* species – which occasionally registers a 100% premium – as well as low-demand species. Unit price usually increases with lobster weight and also varies with the month.

[21] Terminal nets have the disadvantages of catching undersize lobsters and damaging the coral reef.

[22] Based on information available at the Statistical Unit of the Ministry of Fisheries and Aquatic Resources.

[23] The data source in footnote 22 also indicates Kuwait, Lebanon, The Maldives, Canada and Australia as other important markets. In addition, relative importance of markets seems to change from year to year.

(b) Fishing effort, catch and regulation in the lobster fishery

Table 2 below, shows annual data on fishing effort and catch for the fishery.

Table 2

SLSC LOBSTER FISHERY – EFFORT AND CATCH DATA, 1985-98

Year	Effort (E) *('000 Craft Nights)*	Catch (C) *(Metric Tons)*	CPUE* (C/E) *(Metric Tons per'000 Craft Nights)*
1985	96.6	303	3.135
1986	82.4	272	3.301
1987	109.7	262	2.389
1988	98.3	217	2.208
1989	101.1	201	1.987
1990	106.1	185	1.743
1991	111.6	145	1.299
1992	84.2	90	1.069
1993	106.4	110	1.033
1994	134.0	117	0.873
1995	180.0	178	0.989
1996	104.0	116	1.115
1997	116.0	121	1.043
1998	126.6	110	0.869

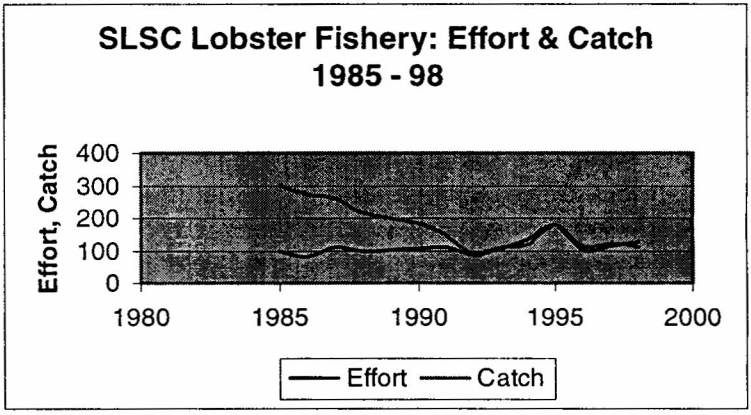
* *Catch Per Unit Effort*

Sources: Jayakody 1999, Madhavie 2003

The above data are somewhat limited in that the measure of effort, viz., number of craft- nights, does not capture the variation in productivity of different vessels. They also contain a few unusual sets of observations; e.g., effort for 1992 is rather low, while both effort and catch are unusually high in 1995. However, they are the only available measures, and are used here. There is some indication of increasing effort over time. Even leaving out the 1995 figure, effort has increased from an average of 98,000 over the latter part of the 1980s, to 111,000 over the 1990s, an increase of about 13%. Catch, on the other hand, has declined over the same period more spectacularly, from an average of 251 to 124,

i.e., by 50%. In fact, the 1998 figure is only just over one-third the 1985 figure. The following diagrams illustrate these trends.

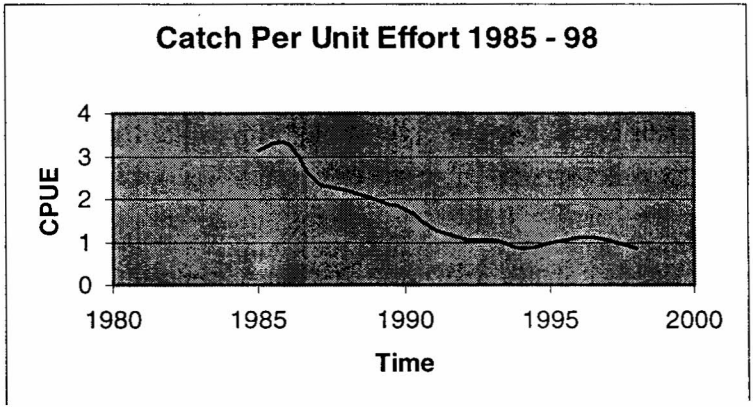
Diagram 1



Source: Constructed from data in Jayakody 1999

The above diagram discloses two features. On the one hand, the decline in catch from the mid-eighties to the early nineties is accompanied by an increase in effort. On the other, effort and catch appear to move together over the rest of the nineties. These are also evident in Diagram 2, which plots catch per unit effort over time.

Diagram 2



Source: Constructed from data in Jayakody 1999

Diagram 2 seems to suggest that the CPUE, while falling throughout most of the period, has stabilized during the mid-to-late nineties. Without in-depth knowledge of the accuracy of data, one can hypothesize different interpretations of the above. For instance, suppose the pattern observed does reflect the true situation. The initial decline may have been caused by factors *other than effort*,[24] which have changed over the nineties, thus arresting the decline. An alternative view is that CPUE has not stabilized; it merely *appears* that way due to the method of computation used. This would be the case if catch data were calculated *using effort data*; i.e., on the basis of an *assumed* CPUE.

Whatever the merits of the different possible interpretations, however, the inverse relationship between effort and catch for the overall period suggests that there is a sustainability problem. This has been recognized for some time, and several regulations were imposed by the *Government Gazette Extraordinary* of March 13, 2000, replacing all previous regulations. These cover south coast lobster fishing specifically, and its key elements are as follows.

i. Only those possessing licenses *carrying express permission to catch lobsters along the south coast* are permitted to engage in the activity.
ii. Prohibition on buying, selling, transport and keeping in possession, of lobsters below a given length – specified separately for *P. ornatus* and for other spiny lobsters.
iii. Prohibition on buying, selling, transport and keeping in possession of both spiny and slipper lobsters carrying eggs externally.
iv. An annual fee of Rs.300 for a fishing license.
v. A fee of Rs.1,000 for an export license, valid for six months.
vi. Prohibition of the export of both spiny and slipper lobster during the months of February and September.

There is no ready information on how well the above regulations are being enforced. Their intent, however, is clear. Items i, iv and v seek to control fishing

[24] Examples applying to fisheries in general include environmental contamination, changes in water temperature, changes in predator-prey relationships and fish genetics (Hartwick and Olewiler 1998: 147). Townsend and Pooley (1995b: 34) cite Polovina and Mitchum (1992) and Polovina *et al.* (1994) as discovering a decline in the carrying capacity of the Northwestern Hawaiian Islands Lobster Fishery due to "changes in nutrient levels associated with atmospheric and oceanographic cycles." For Sri Lankan coastal fisheries, depletion of coral reefs would affect reproduction.

effort in general, while ii, iii and vi seek to protect breeding of lobsters. These *regulations can be matched with the policy implications of recent findings, to* which we now turn.

4. Over-fishing in the SLSC lobster fishery: recent evidence

Madhavie (2003) fitted catch and effort data to a number of "surplus models", viz. (the) Fox Model (Fox 1970), Shaefer Model (Pauly 1984), CY & P Model (Clarke, *et al.* 1992) and Schnute Model (Pauly 1984, Clarke *et al.* 1992), ultimately selecting the Shaefer model[25] as the best on statistical criteria[26]. These models characterize the growth of a fish stock per time period as being dependent on the existing stock size – given other factors, such as water temperature. Stock growth is typically measured in terms of the net increase in biomass, which is the difference between the sum of fish births (or "recruitment") and increase in body weight on the one hand, and fish mortality, on the other. At very low stock levels, growth of biomass occurs slowly due to the small initial fish population. Increase in stock tends to increase the growth rate, reaching a maximum at a certain stock level. This maximum growth is referred to as the "maximum sustainable yield" (MSY). If the fish stock becomes larger than that corresponding to the MSY, then the growth rate drops again as there are more (and larger) fish competing for scarce resources[27]. The local habitat[28] can only carry a finite stock, which is referred to as its "carrying capacity". When the stock size reaches its carrying capacity, growth becomes zero.

Biologically, the maximum catch that can be sustained indefinitely, i.e., harvested period after period[29] is the MSY, which was estimated at 256 MT per year, with a corresponding lobster stock of 312 MT and effort of 71,280 craft-nights. These results can be used to obtain an idea of the extent of over-fishing, if any, of the lobster fishery.

First, let us compare the above results with actual effort and catch data. What the model tells us, is that for effort levels *both* below *and* above 71,280 craft-nights, the sustainable lobster catch drops below 256 MT. Data for 1985-98

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[25] A model of the type $(C/E) = \alpha + \beta E + U$ is estimated, where C refers to *catch* and E, to *effort.*

[26] See Madhavie 2003.

[27] Thus a given growth in biomass can be generated by, *either* a low stock level, *or* a high one.

[28] The discussion in this section holds strictly only for the category of fish known as "demersal", which typically do not range over a wide area. Lobster is an example of this group. In contrast, "pelagic" species are free-swimming, and migrate over a wide area. Private property rights are more easily applicable to demersal fish because of their relatively fixed location (Hartwick and Olewiler 1998).

[29] As long as other relevant factors, e.g., the kind and level of pollution remain constant.

indicate that *effort exceeded this level every single year.* This is one piece of evidence for over-fishing, and can be supplemented with information on catch. Using the estimated model[30], predicted (sustainable) catch[31] levels are compared with actual catch below.

Table 3

Actual vs. Sustainable Catch Levels-SLSC Lobster Fishery 1985-98[1]

(*Metric Tons per year*)

Year	*Actual* (AC)	*Sustainable* (SC)	AC *minus* SC (% of SC)	Effect on Stock[2]
1985	303	224	+35	*Negative*
1986	272	250	+09	*Negative*
1987	262	182	+44	*Negative*
1988	217	219	- 01	*Positive*
1989	201	211	- 05	*Positive*
1990	185	194	- 05	*Positive*
1991	145	174	- 17	*Positive*
1993	110	194	- 44	*Positive*
1994	117	58	+102	*Negative*
1996	116	202	- 43	*Positive*
1997	121	155	- 22	*Positive*
1998	110	102	+08	*Negative*

Notes:

1. Excluding 1992 and 95, which were omitted from the original estimation on grounds of being *statistical outliers*
2. Catch *above* sustainable levels lead to stock depletion, while those *below* help replenishment

Sources: Madhavie 2003, and authors' computations

Actual catch has *exceeded* sustainable catch for five of the twelve years considered; been *below* sustainable catch for six years; and has approximately equaled the latter in one year (1988). It is possible also to portray a pattern here, with several years of over-fishing (1985-87) being followed by a period of low catches (1988-93)[32]

Second, we can use the estimated model to generate open access and private property equilibrium outcomes. This requires the computation of lobster *revenue* (as a function of effort) on one hand and total *cost* (of effort) on the

[30] $C = 0.007185E - 0.0000000504\ E^2$ (Madhavie 2003:118.202)

[31] These are *conditional* predictions, i.e., based on actual effort for each year.

[32] And "under-fishing" being followed by over-fishing. Note, however, that this could be a statistical artifact, since the OLS regression technique employed would generate a curve going through the mid points of the data range.

other. The former is obtained by multiplying catch by price[33], while the latter is dependent on the cost of all the inputs going into the composite index of effort. With open access, we would expect fishing effort to be (approximately) compatible with total revenue equal to total cost, whereas at the same price, the private property equilibrium would entail only *half* that effort level[34].

What is interesting here is that data on both price and cost of fishing could be used to *check* whether or not the fishery is at the open access equilibrium, for any given year. Unfortunately there is no time series on price or cost. Some information on price is available for a few months in 1998 and 1999[35], but there are no means of verifying them. Cost estimates were derived for 1998 by Madhavie (2003), but are of limited value for other years[36]. What is possible at this point, therefore, is to *assume* that *observed effort reflects the open access equilibrium.* Proceeding from there, one can make some limited inferences about the appropriate range of policy choices. This is taken up in the next section.

5. Management Options for the Lobster Fishery

We commence this section by taking the results of Madhavie (2003) as *prima facie* evidence for over-fishing in the SLSC lobster fishery. Its obvious policy implication is that fishing effort should diminish; which then leads to the two questions of, (by) *how much*, and by *what means*[37]. To take the first question first, the answer depends on the desired alternative to open access. There are at least two of them, viz. private property, and the biological equilibrium.

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[33] For a given price we obtain a revenue *curve*, which essentially scales the catch curve up or down. Allowing for price variation across different years, on the other hand, only gives us different *points*.

[34] This is an outcome of the assumed biological relationship, given by footnote 25. To see this, let us take the catch function as $C = \alpha E+\beta E^2$, with price (given) as P and (fixed) unit cost of effort as c. At open access, *total revenue* = *total cost*; i.e., $P^*(\alpha E+\beta E^2) = c^*E$, which implies equilibrium effort as $E_{OA} = ([c/P] - \alpha)/\beta$. Private property requires *marginal* revenue to equal *marginal* cost, with the resulting equilibrium effort $E_{PP} = ([c/P] - \alpha)/2\beta$, or half of E_{OA}.

[35] from records at the Ministry of Fisheries and NARA.

[36] Even for the single year of 1998, assessing the cost of fishing for an abstract unit such as craft-night is problematic, and several assumptions have to be made. Its actual use requires some sensitivity analysis over different assumptions.

[37] Getting into specifics of the desired *exact* effort reduction, or the *precise* value of a policy instrument, however, is premature. This requires further study, which involves at the least, for the estimated model, sensitivity analysis of uncertain parameters. Beyond that, there is a vital need for the accurate recording of data on prices and costs, and also of ecological factors. Such an exercise will help to estimate (possibly) more applicable models, as well as measures of over-fishing.

(a) From open access to private property?

In section 2, we discussed the difference between open access and private property. If we treat actual annual effort as open access equilibrium values, then we would expect a private owner to operate at half the effort level for the *same price and cost combination* (see footnote 34). This would involve, e.g., a reduction in the 1998 effort level from 126,600 craft-nights to 63,300. Using the 1998 unit cost estimate of effort in Madhavie (2003), one can first impute lobster price, and then use it to estimate fishing rent at the halved effort level. The price is Rs. 1,147 per kg, yielding an annual (private property) rent of Rs. 231.66 million[38]. This is a measure of the monetary loss of the open access fishery.

The above comparison between the two equilibria can be viewed from several angles. First, one would like to know the actual earnings lost *per fisher* at open access. To arrive at a figure, we convert the 63,300 craft-nights into 264 craft, on the basis of 240 nights of fishing per year[39]. To calculate the equivalent number of fishers, we take the composition of craft as 4.17% of the four-person type, and 95.83% of the two-person type (Madhavie 2003). This gives us a figure of 550[40] fishers, so that rent foregone per fisher is Rs. 421,200 per year, or Rs. 35,100 per month. Second, this is only a potential figure, because the fishers would be *employees* of the fishery owner, and their earnings would depend on how the total rent is shared between employer and employees. It is also potential because there is no guarantee that the owner will actually make this optimum choice[41]. Third, the associated job loss, on the above basis of computation, is (also) 550, or over one-third of the estimated number of "active fishers" on the south coast.

A fourth dimension, and one which is important from the policy point of view, is that the magnitudes of the differences in effort between the two equilibria depend on prevailing prices and costs[42]. Determining the amount of effort reduction required, is then, a tricky issue without accurate data. Also, even if the latter were available for a given year, changes across years would necessitate frequent changes in the values of policy parameters. This would be administratively costly and difficult to implement, and involve uncertainty in meeting the required targets as well.

A final point must be made about trying to attain the private property outcome. If the fishery is privatized, and expectations about diminished effort

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[38] The calculations are as follows: Price is obtained for open access from the expression $P(\alpha+\beta E)=c$, where c = 922.74 (Madhavie 2003) and α and β are as in footnote 32. For the private property effort of 63,300, catch is 252.9 metric tons, so that rent, or the difference between total revenue and total cost, is P*252.9 – 922.74*63,300, where price is measured per *metric ton*.

[39] 30 nights' fishing for the eight months from August to March.

[40] Calculated according to the formula 264*[4*(25/600) + 2*(575/600)]

[41] See footnote 11

[42] And a host of environmental factors as well

are realized, it results in a potentially dramatic redistribution of income within the fishing community. Fishers who remain are likely to lay claim to increased earnings and improved lifestyles, whereas those who lose their livelihood may or may not reach the same standard of living with their new occupations. The resulting social tension will well nigh threaten the enterprise[43]. Also, private ownership, or even (private) *management* of natural resources, is not yet viewed popularly by society at large. In fact, the role of the private sector in the economy is not quite a settled issue, despite the pro-private sector reforms initiated in 1977. Without privatizing, however, it is possible to (attempt to) regulate effort[44]. by the means described in table 1 of section 2. If successful, it will reduce effort, but not necessarily leave fishers much better off.

In regulating the fishery, it might be tempting to aim at the biological optimum as an alternative to private property. This is because it is not dependent on changes in prices and costs. Once estimated, it remains stable[45] - e.g., 71,280 craft-nights – and is therefore more easily understood by policy makers. In the consideration of *how* to get to the optimum, we shall therefore pick this effort level. However, as will become clear in the discussion, a stable *target* does not imply *stable values for policy instruments.*

(b) Getting to the biological optimum: policy options

In this section, we initially discuss what State regulation of the otherwise open access fishery (or the case of "regulated access") would entail. We use the evidence previously presented for over-fishing, to assess the suitable magnitudes of taxes on price/catch and effort, taking the biological equilibrium as our target example[46]. Later on, we briefly cover the possibilities of involving fishing communities as stakeholders.

i. State enforcement

In both open and regulated access, we assume that the fishers will spend effort to the point at which total revenue is equal to total cost. Given biological

[43] The performance of a property rights regime can be judged not only according to economic and ecological criteria, but also by its equity properties, such as "social definitions of fairness in the distribution of benefits and costs" (Hanna, *et al.* 1995: 18).

[44] Note that this argument does not necessarily abandon the idea of private ownership. There could, for instance, be a sequence of property rights regimes over time, *ending* with private property. Privatization of state-owned enterprises in Sri Lanka have typically begun with the privatization of *management* only. In this case, what the private owner entity will be – say, person or institution – needs investigation. Also, apart from acceptability, there is the issue of whether the costs of managing the vast area under the SLSC lobster fishery would be excessive.

[45] Except when there are sudden shifts in ecological parameters

[46] Justification of this target follows from the discussion at the end of part (a). The only difference in setting a private property target would be the difference in the target effort level.

parameters, lobster price and cost of effort will determine effort. More precisely, equilibrium effort can be shown to depend on the (unit) cost: price ratio[47]. This same relationship can be reversed when we assume, as we have done in this section, that actual effort is, in fact, open access (equilibrium) effort. We can now derive annual *cost: price ratios corresponding to levels of (open access) effort*[48].

To achieve the biological optimum, we require effort to drop to 71,280 craft-nights, yielding a catch of 256 MT per year. The associated cost: price ratio (c/P) is 3.59 (footnote 48), measured in units of kg/craft-night. Reduction of effort via taxes can be brought about by increasing cost, decreasing price or by both measures together. Table 4 below gives selected c/P figures during 1985-98, and also shows the required increase in this ratio through regulation.

Table 4

Regulation of Unit Cost Price Ratios for Selected Years – 1985-98

Year	Effort (OA)	c/P (OA)	% increase in c/P
1986	82.4	3.03	18
1988	98.3	2.23	61
1991	111.6	1.56	130
1994	134.0	0.43	735
1998	126.6	0.80	349

Note: OA refers to open access
Source: Authors' calculations

Increasing (decreasing) levels of effort are associated with decreasing (increasing) cost price ratios. Thus, the higher the open access effort, the higher is the desired increase in c/P, as indicated above. Thus, the stable target effort level involves vastly different changes in the cost price ratio, and hence taxes from year to year. If taxes *are* contemplated, imposing them on *exports* may be more feasible than other options, such as taxing catch, or effort. This is because exports can be tracked more easily, and taxing the relatively wealthy may be more socially acceptable, whatever the actual incidence of taxation. If export prices are fixed in the world market, as is assumed here, the tax burden would be shifted back onto lobster suppliers by lowering their purchase price. Continuing

[47] See footnote 34.

[48] Mathematically, $c/P = \alpha+\beta E$, where E can represent effort at either open or regulated access.

backwards along the supply chain, the price received by the fisher would fall, in line with the policy objective[49].

In practice, export taxes can meet with stiff opposition from fishing communities. This is because the aggregate impact on industry effort works through its distributional effects. Relatively high cost fishers; i.e., those operating on a slender profit margin, would not be able to absorb the losses, in comparison to their low cost companions, and would exit from the industry. Where the hardest hit, are relatively small-scale operators, and in addition, have few alternative income opportunities[50], the policy becomes politically unacceptable. The perception of political drawbacks is one reason for the low usage of taxes in fisheries (Hartwick and Olewiler 1998: 143, 145).

Before leaving taxes, we note that the gazette regulations of March 2000 seek to impose costs on both catching and export of lobsters by way of license fees. These fees constitute fixed charges per time period, and in the case of fishing licenses, are equivalent to a tax on individual effort. How likely is the fee of Rs.300 per fisher to obtain the biological optimum? This is gauged by first computing the desired increase in *total cost* and then expressing it in *per fisher* terms. We use data for 1998 given in Madhavie (2003) as follows. The goal is to move the fishery from open access effort of 126,600 craft-nights to (the regulated access of) 71,280. At the imputed price of Rs. 1,147,000 per MT (see the discussion under part (a) of this section), and catch of 256 MT, total revenue is Rs. 293.63 million. The tax must then be sufficiently high to make total cost equal to this revenue figure[51]. *Without taxes*, given unit cost of Rs. 922.72 per craft-night, total cost is Rs. 65.773 million. The increase in total cost is therefore, Rs. 227.85 million. Sharing the tax by all units of effort, i.e., 71,280 craft-nights or 619 fishers[52] requires a fee of Rs. 368,094 per fisher! While the exact figure will vary according to price and cost estimates, the huge gap between actual and desired taxes reflects the problem of achieving a significant reduction in effort.

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[49] Of course, the actual impact may over-shoot the target – with effort dropping drastically, catch falling way below ecological "danger levels", and the loss of employment seen as disproportionate. Conversely, effort may not drop enough, to reduce the catch to "safe" levels.

[50] Economists account for alternative earnings opportunities by calculating (fishing) profits *in excess of* such earnings; i.e., *economic* profits. Negative economic profits can be expected to divert fishers to their alternative occupations. When the latter does not exist, however, negative profits imply destitution, and the outcome is clearly not socially or politically acceptable.

[51] The expected equilibrium under both open and regulated access

[52] Computed on the basis of 240 nights of fishing per year, and the percentage of 4-person and 2-person craft being 4.17 and 95.83, respectively (see the calculations under part (a) of this section).

Quotas would be easier to set than taxes. For instance, a quota on effort of around 70,000 craft-nights can be determined, and translated into more tangible measures of effort, such as number of vessels, gear employed and number of fishers. They can be costly to administer, however, and become less effective when there is substitution among components of effort[53]. The disadvantages of quotas on catch have already been discussed, in particular the problems of distributing individual quotas, which are advocated on efficiency grounds.

In the Sri Lankan context, given the generally accepted view that State regulations are poorly implemented, it is worthwhile considering the possibilities for community participation in the conservation effort. We do that here by briefly reviewing some experiences in Sri Lanka.

ii. Involving the Community

Achieving effective participation of the community to control fishing effort requires, in the first instance, an understanding of its social benefits. From the discussion so far, by reducing effort, not only do lobster stocks get adequately replenished, but catch and rents increase substantially as well. Since the alternative, open access, only guarantees very low or zero rents, any action which promises surpluses *to all*, would be welcome. Recall, for instance, that the 1998 fishing rent at the biological equilibrium was Rs. 277.85 million, earned by the equivalent of 619 fishers. The *potential* number of fishers however is given by the open access figure; or 126,600 craft-nights (for 1998), which translates to almost 1,100 fishers[54]. Suppose the community were to organize fishing activity such that only 619 individuals engaged in actual fishing, *but shared the rent among all 1,100*. The annual rent per person then would amount to Rs. 252,591, or around Rs. 21,050 per month. Clearly this is superior to the negligible returns experienced when all 1,100 take part in fishing. To be an acceptable solution, of course, the role/contribution of the non-fishers vis-a-vis the fishers would have to be worked out.

To move from open access to coordinated effort would, in practice, depend on many factors. First, there would be the need for building up awareness of the potential benefits of co-operation. This should not merely be in terms of ecological sustainability, but perhaps also, or even *more* in terms of the *economic* sustainability of fishing. Second, there would be the need for an institutional form, capable of meeting the economic, equity and ecological concerns of the community. In fact, given that there are many distinct communities operating in different parts of the fishery, the challenge would be even greater. Not only would each community require an institution, but the different institutions would need to co-operate with each other as well. In other

[53] See the discussion under *types of regulation* in section 2.

[54] Computed as follows. No. of fishers = [126,600/240]*[(0.0417)*4 + (0.9583)*2]

words, the demands on distributed governance[55] would be great. Third, these institutions should be capable of meeting a range of needs – such as research, education, marketing – which could change over time. These considerations imply active roles for the State, as well as non-governmental organizations (NGOs) and community-based organizations (CBOs).

The record on co-operative economic activity in Sri Lanka is mixed. On the positive side, there are grassroots organizations such as the *Thrift and Credit Co-operative Society* (TCCS) network, and *Janashakthi Bangku Sangam*, which have succeeded in mobilizing rural communities to save, borrow and invest. On the negative side, the State-supported Multi-Purpose Co-operative Society (MPCS) movement is widely regarded as a failure. These societies are believed to lack effective management, and are allegedly run by corrupt officials.

Over the years, various environmental NGOs and CBOs, in partnership with donor agencies, have been working with communities on resource-based issues. The State's role in this process has sometimes been an enforcer of regulations, rather than a partner of the community in resource management (Jayatilake *et al.* 1998). On the other hand, efforts at co-management on the south coast, especially those targeting coast and coastal resource conservation, have shown greater promise of bearing fruit. The Coastal Resources Management Project of the Coast Conservation Department (CCD) is credited with engaging the participation of local stakeholders (Jayatilake *et al.* 1998, Ekaratne *et al.* 1998, Harakunarak [undated]). One such experience, which has drawn the attention of several researchers, is that of the Rekawa Lagoon fishing community.

The communities using the Rekawa lagoon, situated in the Hambantota district, were initially mobilized against an impending influx of outsiders to set up shrimp farms. This was perceived as being both socially disruptive and ecologically harmful. In the ensuing developments, co-operation was achieved in the abandonment of environmentally unsound fishing practices and restriction of fishing effort. Further, the community managed its own shrimp production, obtaining technical advice, and marketing shrimp communally (Ekaratne *et al.* 1998). The institutional form of co-operation was a co-operative – the Rekawa Lagoon Fishery Cooperative Society (RLFCS). By the end of the 1990s, the RLFCS had almost ceased to exist, ironically because of alleged financial irregularities of the leadership[56] (Senaratne and Milner-Gulland 2002).

Any serious attempt to involve communities must then develop appropriate institutional forms, which are compatible with the needs of

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[55] The possibilities for co-operation will depend on the importance of the fishery as well. So, in Hambantota, where the lobster stock is relatively concentrated, it may be easier to obtain community participation.

[56] It is interesting that a resuscitated institutional form proposed avoids the word "co-operative". Instead, its title is Rekawa Lagoon Fisheries *Management Committee* (our emphasis).

individuals, communities, and the ecology. Whatever the forms they take, and whatever the type of distributed governance that emerges, the chances for success will be greater if the focus is on preserving livelihoods, rather than natural processes. This calls for a good deal of co-operation among the communities, NGOs, CBOs and State agencies.

6. Conclusion

Coastal fisheries in Sri Lanka, like in many parts of the world are being over-fished. Depletion of fish stocks not only brings about low returns, but also puts future livelihoods at risk by increasing the probability of extinction. This study looked at the problem as it applies to the South Coast lobster fishery of the island. A biological growth model estimated for 1985-98 was used to obtain a preliminary insight into the prevalence of over-fishing. This model was then combined with a property rights framework, to illustrate the kinds of options available to policy makers.

Over-fishing was indicated on two counts. First, for the entire period 1985-98, actual annual fishing effort exceeded the level consistent with maximum growth of the lobster stock. Second, there were several years for which, actual catch was higher than the sustainable catch, as predicted by the model. This situation, if unchecked, runs the risk of depleting the lobster stock drastically, hence endangering the sustainability of the industry. The immediate goal would appear to be that of reducing fishing effort.

From a property rights perspective, the problem can be described as one of open access, where effort keeps on increasing as long as the average (total) cost of fishing is below average price (revenue). The lack of time-series data on lobster prices and fishing cost however precludes *testing* for the prevalence of open access in the fishery. Instead, we *assumed* open access, and looked at its policy implications.

Theoretically, control of effort and stock conservation would be achieved from private ownership of the fishery. These results follow from the private owner maximizing his/her (expected) flow of fishing rent over a long time horizon. In practice, even if an owner's actions fit into this model, there may be issues of equity and social acceptability, which preclude their use. The desired property rights regime should, in fact, meet economic, social and ecological criteria to be sustainable.

State regulation of an otherwise open access fishery – or "regulated access" – would be one option for management, where the State essentially enforces the rules. This has its own problems in the Sri Lankan context. Required financial data, such as on prices and costs, are not available on a regular and reliable basis. If available, the actual regulations would have to change at short intervals, in line with changes in these values, and in ecological

factors. On the other hand, monitoring of effort, catch or both, would be administratively costly as well as open to abuse.

A better option may be to obtain the participation of the communities concerned in limiting effort to both ecologically and economically superior outcomes. While co-operative effort is not guaranteed, the development of effective grassroots level institutions will be vital. There may need to be many such institutions, catering to the multitude of communities along the coast. The experience of ongoing efforts at resource conservation and development of alternative income opportunities will be useful in this exercise. Its success will depend on the coordinated input of the local people, NGOs, CBOs and the State. In all these attempts, however, gathering of reliable data on economic and ecological factors will be essential.

REFERENCES

Baer, A. 2001. *Aquatic Biodiversity in the National Biodiversity Strategy and Action Plans of Signatories to the Convention on Biological Diversity Part 2: Country Thematic Reviews: Mexico to Sri Lanka.* Victoria, BC, Canada: World Fisheries Trust. <http://www.unep.org/bpsp/fisheries/Mexico%20-%20n%20Lanka.pdf>

Charles, A.T. 2001. *Sustainable Fishery Systems.* Fish and Aquatic Resources Series No: 5. Oxford: Blackwell Science.

Central Bank of Sri Lanka. 1998. *Economic Progress of Independent Sri Lanka.* Colombo: Central Bank of Sri Lanka.

Central Bank of Sri Lanka. 2003. *Annual Report 2002.* Colombo: Central Bank of Sri Lanka.

Clarke, R.P., S.S.Yoshimoto, and S.G. Pooley. 1992. "A Bionomic Analysis of the Northwestern Hawaiian Island Lobster Fishery". *Marine Resource Economics.* Volume 7. 115 – 40.

Dayaratne, P. 1997. Some observations on the biology and fishery of *Sardinella gibosa* in coastal waters off Negombo. *The Journal of the National Aquatic Resources Agency.* 35: 1-11

DeCosse, Philip J., and Sherine S. Jayawickrama. 1998. "Issues and Opportunities in Co-management: Lessons from Sri Lanka". in Kothari, A., N. Pathak, R.V. Anuradha, and B. Taneja (eds.). *Communities and Conservation.* 191-218 New Delhi: Sage Publications

Ekaratne, S.U.K., John Davenport, D. Lee, and R.S. Walgama. 1998. "Communities Protecting Coastal Resources: Rekawa Lagon, Sri Lanka". in Kothari, A., N. Pathak, R.V. Anuradha, amd B. Taneja (eds.). *Communities and Conservation.* 481-91 New Delhi: Sage Publications

Fox, W.W. 1970. "An Exponential Surplus – Yield Model for Optimizing Exploited Fish Populations". *Transactions of the American Fisheries Society.* Volume 99. 80 – 88

Hanna, Susan, Carl Folke, & Karl-Goran Maler. 1995. "Property Rights and Environmental Resources" in Hanna, Susan & Mohan Munasinghe (eds.). *Property Rights and the Environment: Social and Ecological Issues.* 15-29 Washington, D.C.: The World Bank.

Hanna, Susan & Mohan Munasinghe. 1995. "An Introduction to Property Rights and the Environment" in Hanna, Susan & Mohan Munasinghe (eds.). 1995. *Property Rights and the Environment: Social and Ecological Issues* pp. 3-11. Washington, D.C.: The World Bank

Harakunarak, Ampai. [undated]. *ICM Profiles: Sri Lanka.* Center for the Study of Marine Policy, University of Delaware http://www.globaloceans.org/country/srilanka/srilanka.html

Hartwick, John M. and Nancy D. Olewiler. 1998. *The Economics of Natural Resource Use.* 2nd edition. Reading, Massachusetts: Addison-Wesley.

Israel, Danilo C., and Cesar P. Banzon. 1998. *Overfishing in the Philippine Marine Fisheries Sector.* EEPSEA Research Report Series Singapore: Economy and Environment Program for Southeast Asia.

Jayakody, D.S. (ed.). 1999. *South Coast Lobster Fishery – Sri Lanka.* Colombo: National Aquatic Resources Research and Development Agency.

Jayakody, D.S. 1991. *Fishery Population Dynamics and Breeding Biology of Panulirus homarus on the South Coust of Sri Lanka.* Unpublished Ph.D Thesis. Department of Biological and Molecular Sciences, University of Stirling, United Kingdom.

Jayakody, D.S., and C.B. Kensler. 1986. "Some Observations on the South Coast Spiny Lobster Fishery for 1985-86". *Proceedings of the Forty Second Annual Sessions of the Sri Lanka Association for the Advancement of Science.* (Abstract) 226.

Jayatilake, A., N. Pallewatta, and J. Wickramanayake. 1998. "The Practice of Community-Based Conservation in Sri Lanka". in Kothari, A., N. Pathak, R.V. Anuradha, amd B. Taneja (eds.). *Communities and Conservation.* 170-88 New Delhi: Sage Publications.

Madhavie, A.V.K. 2003. *Fishery Management and Property Rights: A Study of the Sri Lanka South Coast Spiny Lobster Fishery* (transl.) unpublished M.Phil thesis. Department of Economics and Statistics, University of Peradeniya, Sri Lanka.

Monagurusamy, P., and A. Dhanasiri. 2001. *Corals at Risk: The Need for Protection.* <http://www.elaw.org/resources/text.asp?id=687>

NARA 2001. *Sri Lanka Fisheries Yearbook.* Colombo: National Aquatic Resources Research and Development Agency.

Pauly, D. 1984. *Fish Population in Tropical Waters: A Manual for Use with Programmable Calculators.* Manila: International Center for Living Aquatic Resources Management.

Polovina, J.J., and G.T. Mitchum. 1992. "Variability in Spiny Lobster Panulirus Marginatus Recruitment and Sea Level in the Northwestern Hawaiian Islands" *Fishery Bulletin* 90: 483-93.

Polovina, J.J., G.T. Mitchum, N.E. Graham, M.P. Craig, E.E. Martini, and E.N. Flint. 1994. "Physical and Biological Consequences of a Climate Event in the Central North Pacific". *Fisheries Oceanography* 3(1): 15-21.

Rajasuriya, A. [undated]. *Coral Reefs of Sri Lanka: Current Status and Resource Management* http://www.fao.org/docrep/X5627E/x5627e09.html

Senaratne, Sonali, and E.J. Milner-Gulland. 2002. *Community Management of the Rekawa Lagoon Resources.* International Union for the Conservation of Nature http://www.iucn.org/themes/sustainableuse/rekawa.html.

Siddeek, M.S.M., and D.S. Jayakody. 1987. "An Assessment of the Status of Commercially Important Penaeid prawns in the Chilaw Sea Sri Lanka" *The Journal of the National Aquatic Resources Agency.* 33 & 34: 1-14.

Townsend, Ralph E., and Samuel G. Pooley. 1995a. "Distributed Governance in Fisheries" in Hanna, Susan & Mohan Munasinghe (eds.). *Property Rights and the Environment: Social and Ecological Issues.* 47-58 Washington, D.C.: The World Bank .

Townsend, Ralph E., and Samuel G. Pooley. 1995b. "Distributed Governance in the Northwestern Hawaiian Islands Lobster Fishery" in Hanna, Susan & Mohan Munasinghe (eds.). *Property Rights in a Social and Ecological Context: Case Studies and Design Applications.* 33-39 Washington D.C.: The World Bank.