From growth to malthusian overfishing: Stages of fisheries resources misuse

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Abstract

This contribution briefly reviews the various forms of overfishing, with emphasis on their implications for tropical coastal fisheries, e.g. the coral reef fisheries of the South Pacific. Addressed are: growth overfishing and its relationship to the study of growth and mortality of fish, and of gear characteristics; recruitment overfishing and its links with parental biomasses; as well as 'biological' and ecosystem overfishing. Classical economic overfishing is then defined, along with its younger relative, Malthusian overfishing, which leads to a form of resources destruction not resolvable by interventions solely within the fisheries sector, and requiring alternative, land-based livelihood opportunities.

Introduction

There are different ways of managing fisheries systems, the most efficient probably being those which evolved in the South Pacific, where, usually, tradition-based rules regulate access to commonly held resources (see contributions in Ruddle & Johannes 1985).

In the West, however, a different tradition evolved, which looked first at the state of the fish stocks, and only then at the fisheries depending on these stocks. This is very well illustrated by the historical sequence of scientific concepts used to define overfishing, viz.:

1. Growth overfishing: the form of overfishing that was first to be identified and theoretically resolved (Baranov 1918; Beverton and Holt 1957; Fig. 1);

2. Recruitment overfishing: the second form of overfishing recognised by fisheries scientists, following the seminal paper of Ricker (1954; Fig.2);

3. Biological overfishing: the combination of growth and recruitment overfishing leading to catch decline on the right, descending side of surplus production models (Schaefer 1954, 1957; Fox 1970; Ricker 1975; Fig. 3);

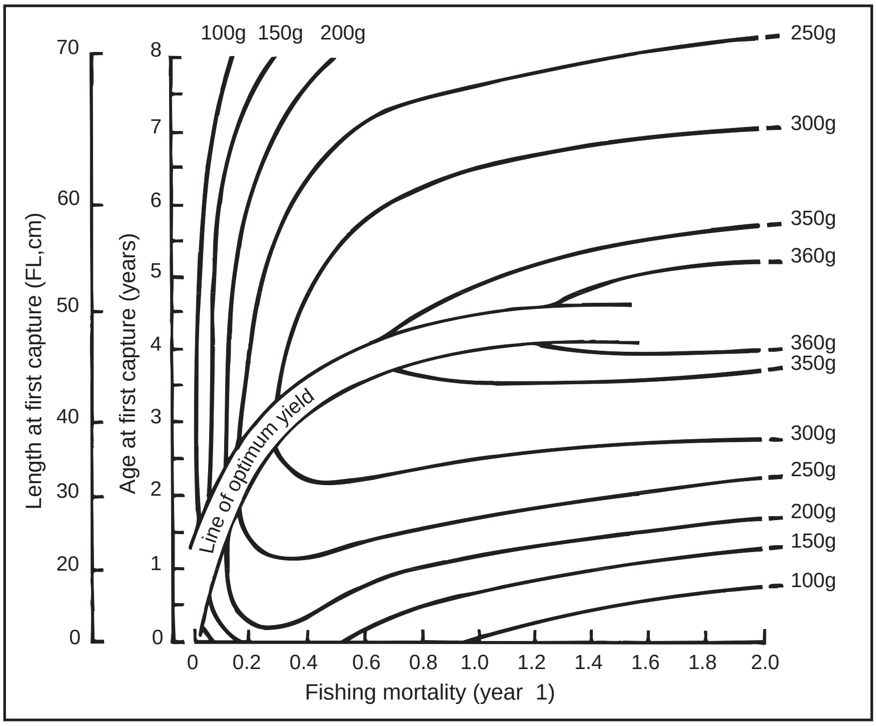

Fig. 1. Characteristic end result of a yield-per-recruit analysis: yield-per-recruit 'isopleths' for the snapper *Lutjanus sanguineus*, i.e. lines of equal yield (per recruit) depending on fishing mortality (usually proportional to fishing effort) and mesh size (and hence mean length and age-at-first-capture). Adapted from Pauly (1979b), with W_∞=12,226 g, K=0.154 year^{-1}, t_0=0.67 year, based on Lai & Lin (1974), and M=0.33 year-1.

4. Ecosystem overfishing: resulting from target species being reduced by fishing and being replaced only in part by other exploitable components of an ecosystem (Pauly 1979a, 1979b);

5. Economic overfishing: initially defined in terms of economic theory by Gordon (1953), then combined by various authors with the parabolic surplus production models in (3) to yield the Gordon–Schaefer model (see, e.g. Anderson 1977 and Fig. 3);

6. Malthusian overfishing: initially proposed by Pauly (1988) and further developed in Pauly et al. (1989) and Pauly (1990), this concept links a (small-scale) fishery with a large adjacent sector (generally, agriculture) generating surplus labour which the fisheries resource system cannot absorb without damage (Fig. 4).

More on various forms of overfishing

Growth overfishing is what happens when fish are caught before they have time to realise their growth potential. This form of overfishing, which began to occur in some Northern European fishing grounds as early as the end of the last century, was first analysed by the Russian scientist F.I. Baranov just after World War I. However, it was the work of R.J.H. Beverton and S.J. Holt, of the Lowestoft Laboratory, Britain, which after World War II presented a method for yield-per-recruit analysis by which growth overfishing could be diagnosed in practice and remedied by fisheries management, for example, through the imposition of appropriate mesh sizes for fishing gears (Beverton & Holt 1957; Ricker 1975; Gulland 1983; Pauly 1984).

Research work related to growth overfishing, conducted in various research institutions throughout the world, consists of estimating the ages, and the growth and mortality rates of fish and assessing the (mesh) selection characteristics of fishing gears, as well as adapting Beverton and Holt's yield-per-recruit and related models to the multispecies situations typical, for example, of coral reef fisheries.

More than 3,000 sets of growth parameter estimates, covering some 800 of the most important fish species in the world, and over 300 estimates of natural mortality are included in FishBase (Pauly & Froese 1991; Froese et al. 1992). Combined with sophisticated, single or multispecies yield-per-recruit models (Silvestre & Soriano 1988), these data make it straightforward to diagnose and quantify growth overfishing for almost any type of fish resource, tropical or not. Hence, fisheries research can now practically always go beyond the study of growth overfishing.

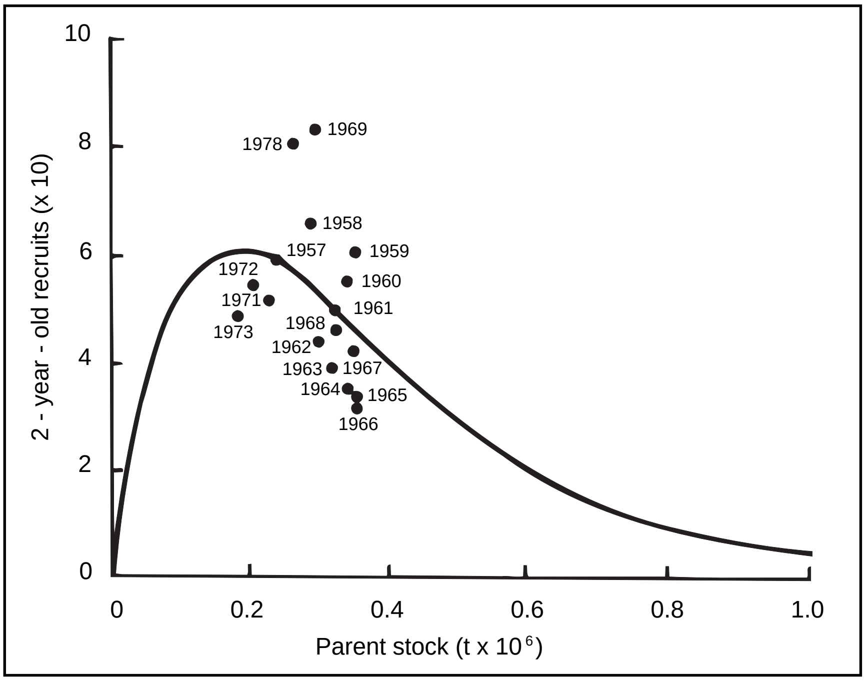

Fig. 2. A Ricker curve, meant to quantify the relationship between parental biomass and subsequent recruitment in Southern bluefin tuna (*Thunnus macoyii*), but in fact illustrating that next to nothing was known about that relationship at the time it was published except that it must pass through the origin (from Murphy 1982).

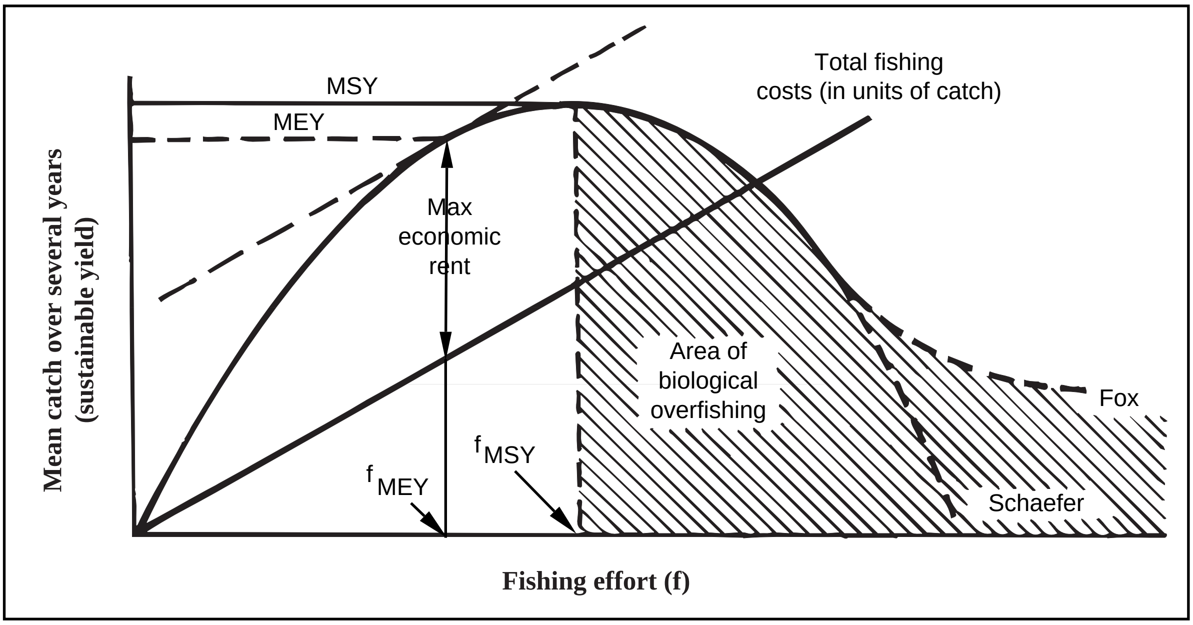

Fig. 3. Schematic representations of *biological* overfishing, due to both *growth* and *recruitment* overfishing (shaded, right area of a Schaefer- or Fox-type production model), and of *economic* overfishing, occurring when fishing effort exceeds the level (f_{MEY}) required to maximise economic rent, i.e. to produce MEY. Note that MEY is always (slightly) below MSY, the stated or implicit goal of many management schemes; and that beyond MSY, subsidies will *reduce* catches (by reducing total costs).

The second recognised form of overfishing is *recruitment overfishing* which refers to fishery-induced reductions of the number of young fish entering fishing grounds. Recruitment overfishing can be brought about by:

1) reduction of the spawning stock (which may become so small as to produce a limited number of eggs and hence of recruits), and

2) coastal environmental degradation, which affects recruitment through its effects on the size and / or suitability of nursery areas. [Note that preventing recruitment overfishing is not, as [some] think, a matter of letting 'each female spawn at least once', since, for example, less than one in a thousand anchovy or shrimp larvae reach a mature age, even in the absence of a fishery. Instead the crucial aspect is that the spawning stock should be large enough to ensure that the subsequent recruitment remains independent of the parental stock.]

Models to identify the levels below which parental stocks should not drop were first developed by the Canadian scientist W.E. Ricker. These models have found little direct application in the tropics, although they have led to generalisations useful for stock conservation (Goodyear 1989; Mathews 1991). Rather, it is surplus-production ('Schaefer' or 'Fox') models that are commonly used, along with their space-structured counterparts to assess tropical fisheries (Schaefer 1954, 1957; Fox 1970; Munro 1980). These models do not distinguish between growth and recruitment overfishing but rather lump the two processes into a single category of 'biological' overfishing (Fig. 3).

Fig. 3 also defines *economic overfishing* as what happens when a fishery is exploited at a level of effort higher than that which maximises the economic rent, i.e. the differences between gross returns and fishing costs. Note that this optimum level of effort is always less than that required to extract maximum sustainable yield (MSY) and that, therefore, maximum economic yield (MEY) is always less than MSY (Fig. 3). (Economic overfishing can also be expressed in terms of *monetary* yield-per-recruit; this and related themes constitute the subdiscipline of *bioeconomics*.)

I introduced, in 1979, the concept of *ecosystem overfishing* to characterise the process which took place in the 1960s in the Gulf of Thailand (and, at different times, in other tropical fisheries), where trawling was so intense that it altered the balance of species on the fishing grounds, with some species increasing, but failing to replace the depleted ones. A typical scenario is that longer-lived demersal species are replaced (but only in part) by shorter-lived small pelagic fish and squids.

This process implies that a larger part of the system's ecological production is now captured by benthic

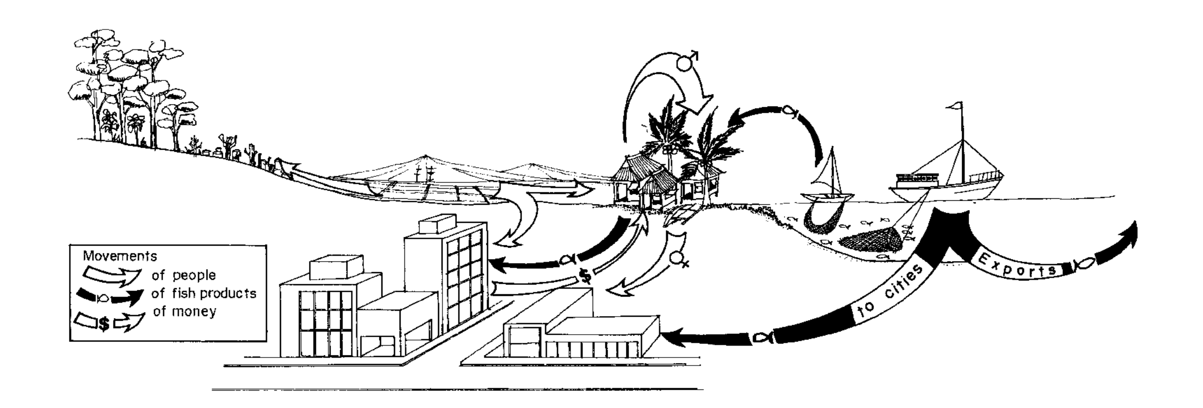

Fig. 4. Schematic representation of the processes leading to Malthusian overfishing: a comparatively large agricultural sector releases excess labour (=landless farmers) who migrate either to urban upland or coastal areas. Under this influx, traditional arrangements preventing open access to the fisheries gradually collapse, leading to excessive fishing pressure, exacerbated by inshore commercial fishing, and by the male children of fishers picking up their fathers' trade; many young women leave the communities to work in urban areas, and their remittances subsidise the men, who continue fishing even when the resources are depleted. The migrants to upland areas accelerate and complete the deforestation initiated by logging companies, which leads to siltation of rivers and streams, and eventually to smothering of coral reefs, thus further reducing coastal fish yields.

invertebrates and large zooplankton, i.e. into non-resource species. Examples of ecological overfishing abound throughout the world, and research to address this issue is being conducted at various institutions, including ICLARM (Christensen and Pauly 1992a, 1992b).

The forms of overfishing listed above are–with the exception of ecological overfishing–well described in textbooks, and the suggested remedies usually involve a mix of management measures aimed at reducing effective fishing effort (e.g. mesh size regulations, closed areas or seasons, limits on gear sizes or on craft designs, etc.). All of these measures imply that the fishers concerned are actually in a social and financial position to either implement or comply with those measures. Usually they can, because the textbooks are written in and for developed countries in which most fishers are the employees of well-financed corporations, or independent (if small) entrepreneurs who generally can generate enough political pressure to obtain governmental subsidies, or to take shore-based jobs if all else fails.

Malthusian overfishing defined

Small-scale fishers in tropical developing countries are usually poor and lack alternative employment opportunities, i.e. once they start fishing, they are forced to continue, even if the resource declines precipitously.

Over time, the number of these fishers usually increases, both because of internal recruitment (i.e. their own male children) and through new entrants, i.e. new fishers recruited from other sectors, usually landless farmers to whom fishing becomes an occupation of last resort (Fig. 4). *Malthusian overfishing* is what occurs when these poor fishers, lacking the usual alternative of 'traditional' fishers (e.g. a small plot of land or seasonal work on nearby farms or plantations), are faced with declining catches and induce wholesale resource destruction in their effort to maintain their incomes.

This may involve in order of seriousness and generally in temporal sequence:

1) use of fishing techniques, gears and / or of mesh sizes not sanctioned by government;

2) use of gears not sanctioned within the fisher communities and / or catching of fish 'reserved' for a certain segment of the community;

3) use of gears that destroy the resource base; and

4) use of destructive 'gears' such as dynamite and fish poisons that endanger the fishers themselves. [Note that this sequence parallels that occurring in upland areas, also subjected to environmental degradation–especially deforestation–exacerbated by immigration from the lowlands.]

This sequence, generally misunderstood by administrators and fisheries scientists alike, as reflective of ignorance, or of putting the short-term gain ahead of future benefit (or even as evidence of a moral decline), is in fact reflective of nothing but declining catch per effort (and hence incomes).

The reason why I chose the adjective 'Malthusian' to characterise this process is not because I wanted to join the chorus lamenting the destructive impacts of population growth on natural production systems–these impacts are now obvious (see for example Southgate & Basterrechea 1992; Homer-Dixon et al. 1993). Rather, I wanted to emphasise an often ignored aspect of Malthus' writings, namely his contention that production (of food) can only increase 'arithmetically', that is, by a *constant amount* and hence, in the long run, would always become insufficient for a human population growing 'geometrically', i.e. by a constant *fraction*, but an ever *increasing amount* (Malthus 1798; Fig. 5A).

There are still many who believe that globally, food production will continue to increase as it has done since 1798 when Malthus published his major essay–despite well-documented, widespread destruction of agricultural production systems through erosion, salinisation, etc. (see for example Lightfoot 1990; Southgate & Basterrechea 1992).

These optimists will have to agree, however, that the production from a fisheries system is over time at best constant once MSY has been achieved; usually, it will fluctuate (Fig. 5B) and even gradually decline, because fishing effort will grow beyond

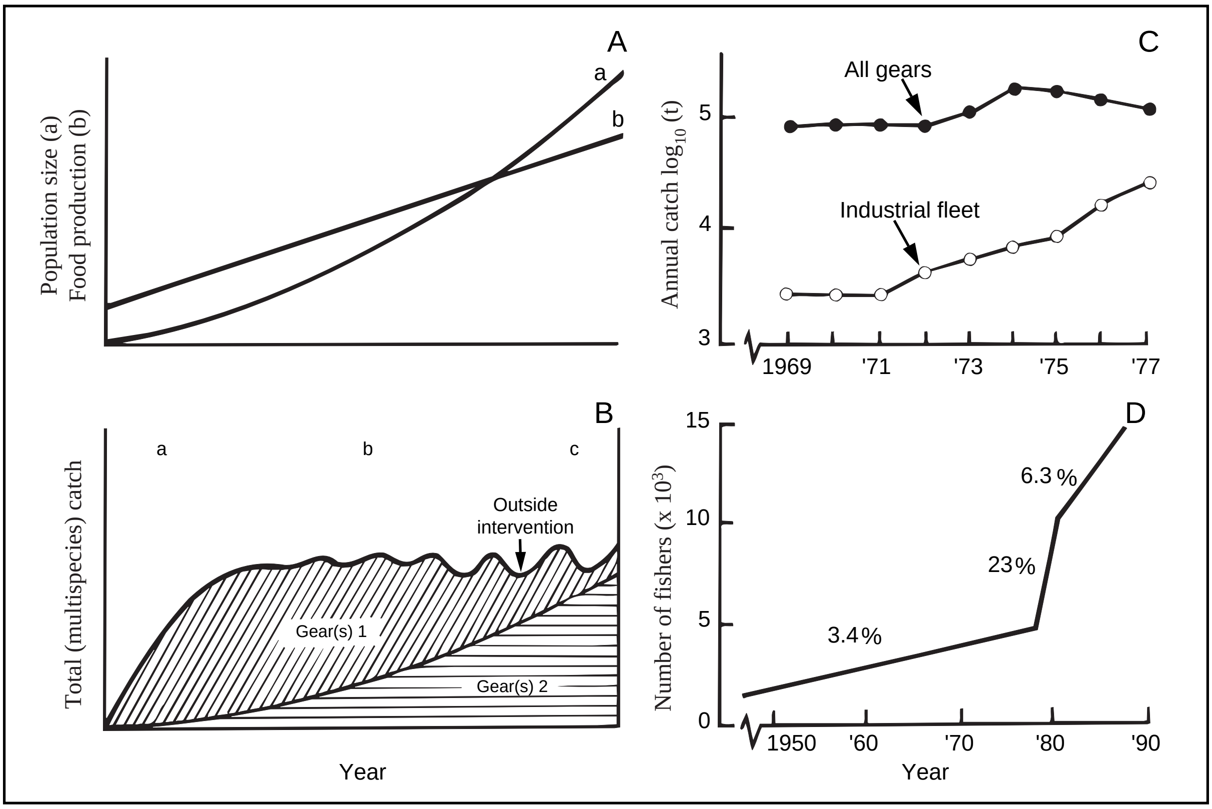

Fig 5. Aspects of Malthusian overfishing (adapted from Pauly 1990):

A: Difference between 'arithmetic' (or linear) growth (a) and 'geometric' (or exponential) growth (b): given sufficient time, (a) *always* overtakes (b) whatever the initial conditions and rates.

B: Phases in the development of a fishery: (a) development phase, corresponding to the left side of the graph in Fig. 3; (b) transfer of an increasing part of the total catch from gear(s) 1 to gear(s) 2 (or from artisanal to industrial fisheries), which may be more efficient, capital-intensive, or subsidised; (c) growth overfishing, leading to a biomass consisting mainly of small fish, induces increasingly large fluctuations, requiring management intervention (to resolve increasingly frequent between-gear conflicts).

C: An illustration of graph (B), showing stagnation of the total catch of Andra Pradesh State, India, and an increasing transfer of catch from the small-scale to the commercial fisheries (from data in Alagaraja et al. 1982).

D: Showing the rapid increase in the number of fishers in the Lingayen Gulf area, Philippines, due to internal recruitment and influx of new fishers (% values refer to mean annual increases during various periods).

that required to extract MSY (f_{MSY} in Fig. 3) and because of the reduction of biodiversity induced by overfishing. Thus for capture fisheries at least, Malthus was definitely right: once a fishery is developed, production will stagnate at best, and won't accommodate an ever-growing demand. Indeed, given enough pollution, e.g. in form of silt (see Fig.4), fisheries production from an otherwise stressed stock will in fact decline (Hodgson & Dixon 1988, and see Fig. 4).

Diagnosis and mitigation of Malthusian overfishing

Given the above description and the elements of Fig. 5, the following features should occur in a fishery for it to be diagnosed as suffering from Malthusian overfishing:

- stagnating overall catches;
- an increasing number of fishers, leading to:
- decreasing catch and hence income per fisher; these jointly lead to:
- evidence of biological and ecological overfishing; and necessarily to:
- classical economic overfishing; also we should have:
- a breakdown of traditional management schemes; and
- non-enforcement of 'modern' management regulations. An important symptom is:
- new fishers recruited from ethnic groups (e.g. traditional pastoralists) or regions (e.g. highlands) without a tradition of fishing; this will lead to:
- increasing or common use of destructive gears (explosives, poisons); and an important, but often neglected corollary of poverty:
- a trend toward the women in fisher communities generating most of the family income and / or producing most of the food consumed in their family.

These criteria may appear to be hard to meet. However, several fisheries have been described in which most of these are met (see for example McManus et al. 1992), and their number can certainly be expected to increase. 'Modern technology' will not help, since, as might be seen from Fig. 3, any decrease in fishing costs (such as that induced by more efficient gears) will tend to deplete further the resource base of (open-access) fisheries.

Mitigation of Malthusian overfishing is conceptually simple, but hard to implement. Its key element is for women in fisher and adjacent rural communities to be offered the means, presently largely unavailable, to limit the number of children they want to bear. Presently, this right is largely negated by husbands and other powerful men (conservative politicians, religious leaders, etc.).

The next 'lever' to mitigate Malthusian overfishing is the creation of land-based alternative employment opportunities for ill-trained young fishers–a tall order.

Given less pressure on the resource, a 'rollback' strategy is then thinkable in which devolution of state authority to local fisher communities would lead to a rebuilding of 'traditional' management mechanisms limiting entry, complemented with 'modern' measures such as gear restrictions, and the establishment of sanctuaries (Alcala & Russ 1990), for which research a programme such as that in ICLARM's Mid-Term Plan[1] should provide the scientific underpinning.

The foregoing should have made obvious that Malthusian overfishing is the effect on the coastal fisheries sector of population growth and of non-sustainable development in the major sector(s) of the overall economy of a country. Hence, Malthusian overfishing can be alleviated only through sustainable development and, ultimately, by checking population growth.

[1] *Available from ICLARM, MC P.O. Box 2631, 0718 Makati, Metro Manila, Philippines.*

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The contemporary applicability of traditional fisheries management in the South Pacific

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The wise management of fishing grounds is fundamental to the sustainable use of marine resources. This is especially so for village-based inshore fishing in the South Pacific, because of the generally restricted area 'owned' by villagers as their traditional, exclusive fishing ground. In this region intensification of fishing efforts in response to increased population, combined with the now greater efficiency of fishing and the resultant consistency of catches, is resulting in the depletion of fisheries in traditional village waters. Since fishing grounds covered by traditional ownership are the most productive inshore fishing areas in the Pacific, as well as being the areas closest and most accessible to villagers, they are those most threatened by overfishing.

Although commercial fishing is relatively recent in most Pacific Island villages, it is a major cause of socio-cultural and environmental change. Village–level fishing includes a wide range of activities that influence society and culture, as well as being a source of employment. However, despite the wide acceptance and adoption of modern fishing and fish marketing practices, traditional influences remain. For example, despite having purchased expensive fishing gear, fuel, and other inputs, fishers are often unable to demand cash for their effort. Generally, too, they still observe certain traditional fishing practices.

In Fiji, village-level commercial fishing is expanding rapidly and involves most of the estimated 20,000 subsistence fishers. Such fishing is village and lineage based. Household production units exhibit a well defined division of labour, with men and women working either individually or collectively to earn cash for the family. In 1991, the number of licences to fish inside the demarcated areas (IDA) increased to 1,975. This did not include either most indigenous Fijian fishers, who do not require licences to fish in their own traditional fishing grounds, or the many people who participate in fishing-related activity.

Fishing practices used in the Pacific are varied, and reflect the fishers' understanding of fish behaviour and the local fishing grounds. Although the sustainability of fisheries resources was not necessarily a specific objective of traditional fishers, it would appear to have been assured under the system of fishing used in former times. The fishing methods and practices used, although occasionally destructive, generally promoted the sustainable use of resources within the limited areas exploited. Problems began, however, when traditional fishing methods were abandoned in favour of newer and more efficient methods, and when fishing became commercialised.