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**by**

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**Jerome Tioti**

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Ronald Kuk & Jerome Tioti

## ABSTRACT

The contribution of the fisheries sector to economic development in Papua New Guinea (PNG) has been remarkable. The future of the sector depends to a considerable extent on the economic efficiency, sustainability and competitive advantage of domestic production and export marketing. These have been made possible by the policy and management approaches undertaken by the Papua New Guinea National Fisheries Authority since becoming a statutory authority in 2001.

The aim of this book is to ascertain whether Papua New Guinea is producing at a sustainable level and whether its fisheries resources are being appropriately managed in line with the governmentôs economic policy. The book covers the areas of property rights, fisheries management, surveillance, compliance, economic theory, fisheries production and problems in the fishing industry. It attempts to address bio-economic concepts to assist the understanding of students at a university level. It also summarises the levels of production and exports in previous years, by species.

## SECTION 1: OVERVIEW AND HISTORICAL PERSPECTIVES

The fishing industry in Papua New Guinea remains underdeveloped despite the fact that the country is endowed with extensive fishing grounds around its many islands and within its 200-mile exclusive economic zone (EEZ). The total area within the EEZ is 2.4 million square kilometres (see Figure 1 below).

Current legislation is restricted to the management of commercial and industrial fisheries. Subsistence and artisanal fisheries, involving the majority of Papua New Guineans, remain largely unregulated, unmanaged and unsupported.

This book offers a brief overview of fisheries policy since the passing into law of the Fisheries Act (1984), which later became the Fisheries Management Act (1998). The book will provide a historical overview of the management of Papua New Guineaôs fisheries resources since 1984, including a discussion of the problems that have plagued the industry. The theoretical and practical aspects of the management instruments used will also be discussed. The book will end with a brief summary of the enforcement and monitoring mechanisms provided for under the Fisheries Management Act.

### Fisheries Development

Fishing to eat and trade is a tradition in Papua New Guinea. Fish and other seafood form an important part of diets and are trading items in traditional Melanesian barter systems. In inland areas freshwater eels, freshwater molluscs and macro brachium prawns are commonly caught. In the coastal areas, estuarine catfish, barramundi, mud-crabs, prawns, shellfishes and mullet are the main sources of food. In coral reef systems, various types of reef fish, molluscs, octopus and squid are regular food items. In deeper waters, with the development of deep-bottom hand lining, fishing for snapper and carangids is commonly practiced. Coastal pelagic like rainbow runner, Spanish mackerel and tuna are trawled for and caught in fish traps.

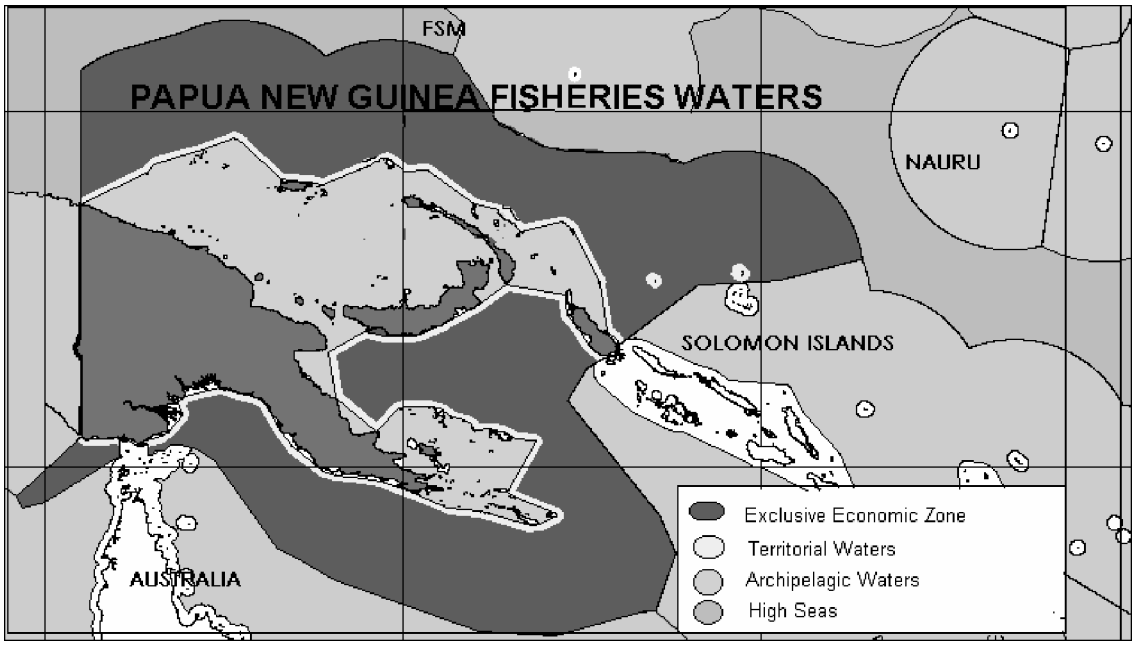
The focus of this tradition changed with the development of a cash-based economy, where money rather than goods became the medium of exchange. Artisanal fishing developed rapidly and increasingly relied on money as the source of buying power, domestically and internationally. However, artisanal fishing is sustained by the need to meet specific wants and needs such as school fees. Once these costs are met, the utility curve stops and fishing stops until the need arises again.

Artisanal fishing by both men and women is a significant source of rural income. Conservative estimates in the mid 1990ôs placed the production from this sector at about 30,000 metric tons annually, generating overall incomes of well over PGK100 million. Actual production by this sector is unrecorded and unmonitored by the National Fisheries Authority (NFA).

The huge task of enforcement is the main reason for the lack of licensing and monitoring mechanisms. In addition, the communal land tenure systems and common property issues

in Papua New Guinea are also seen as impediments to artisanal fishing ventures and have adverse impacts on the overall management of these natural resources. A common perception in Papua New Guinea is that management authorities have no right to charge communities fees for management costs and those communities should be free to fish and earn an income from their own resource. This is also referred to as open access.

**Figure 1: Papua New Guinea Fisheries Waters**




Despite these traditional perceptions, the National Constitution mandates the National Fisheries Authority to sustain and manage the fisheries resources of Papua New Guinea for future generations.

An early measure by the government to meet this constitutional requirement was the establishment of coastal fisheries stations. These facilities were constructed around the country. Refrigerated units were installed and fish buying and fish collection vessels were bought. These stations provided both a market outlet for and a means of transporting fish. Initially, communities started fishing and selling fish. For some it provided a good, if small, small income. However for many fisherman, after the costs of social needs were achieved, fishing stopped.

The then Department of Fisheries and Marine Resources (DFMR) had anticipated that these facilities would eventually develop into viable fishing businesses, owned and run by Papua New Guineans. This did not eventuate as these heavily subsidised stations became commercially unviable. The long-term sustainability of the facilities had not been adequately considered at the time of implementation.

Three critical issues were learned from this costly exercise. Firstly, the economies of scale of these facilities and the ability of the communities to maintain continuous fish supply were incompatible. The facilities were too big and expensive to manage and they

did not have enough committed fishermen to sustain their operations. Secondly, the commercial business principles of such an industry were not factored in to the design of the program and moreover, the government officers who designed the program did not understand and appreciate the socio-economic dynamics of rural communities. Lastly, government policy was to develop the countryôs resources at any cost. This meant that many government programs were expected to be accepted by communities for their own good.

In reality, these programs instead competed with and constrained the development of the private sector. These problems led to the closure of all coastal fisheries stations in the 1990s, the impact of which was the overall demise of commercial fisheries in coastal communities.

Following this period, DFMR tried another strategy in partnership with the South Pacific Commission (SPC). It was thought that the problem of sustaining fishing was caused by inappropriate fishing techniques. In response, the concept of Master Fishermen was established by the SPC. Master Fishermen were to travel throughout the South Pacific Commission member countries (22 countries) to teach fishermen new fishing skills. In particular, the Samoan hand-reel was thought appropriate for PNG and trials were carried out in a number of provinces. It was predicted that these new fishing tools, as well as new fishing vessels, would help the rural fishermen operating on an artisanal basis to view fishing as a full-time vocation.

Under this approach, rural people were taught business skills and basic food processing and marketing techniques. Fishermen were also assisted through the provision of fish buying centres to create market opportunities.

Like the previous initiative, the economies of scale under this program were inappropriate. Sadly these donor-funded initiatives were not sustained and resulted in huge losses.

In the long term, government-funded initiatives, with their poor economies of scale, were huge fiascos. They became commercially unviable and unsustainable.

### *Commercial Fisheries*

The development of commercial fisheries began in the late 1940ôs under the colonial administration. Various surveys were conducted to identify the commercial fish resources of the Territory of Papua and New Guinea, notably the prawn surveys in the Gulf of Papua in 1965 and the tuna tagging studies in PNG waters in 1970ï1972. Much research work was conducted on the biological and population dynamics of the prawn, lobster and tuna fisheries. Many biological surveys into fish resources were carried out which provided PNG with a near-complete knowledge base of the fishery resources.

It was not until the 1960ôs and 1970ôs that various foreign tuna boats, largely from Japan, fished for tuna using long-lines. In the same period, potential commercial prawn fisheries

were identified in the Gulf of Papua and commercial prawn trawling operations commenced. Japanese prawn trawlers were licensed to fish in the mid 1970ôs and over the next ten years they generated revenue for some Papua New Guineans who were trained to fish commercially for prawns and effectively market their product. The Japanese developed efficient and effective operations in the Gulf of Papua and they could fish 24 hours a day, 300 days a year. With high quality products, the Japanese operators could yield very high prices for their wild-caught prawns.

However, by the mid-1980s the government had forced Japanese prawn operators to sell their trawlers and the entire Gulf of Papua prawn fishery was nationalized. Currently the entire prawn fishery is fished by seven nationally-owned companies operating 15 vessels.

The process of domestication was much different in the tuna industry. From 1970 to 1982 the tuna industry flourished under foreign-based fishing operations. The earnings from fish exports contributed about five percent of PNGôs total export earnings.

By the 1980ôs, a number of foreign vessels fishing in PNGôs tuna fisheries had entered into fishing agreements with the government of Papua New Guinea and commercial fishing for various species of tuna had developed, largely in the Bismarck Sea. This resulted in agreements between the government of Papua New Guinea and Mitsubishi Gyogyo Ltd, the Star Kist Co. Ltd, and the Okinawan fishermen to develop pole-and-line tuna fishing operations. During this period, Japan dominated the industry and at various times as many as 600 Japanese long-liners were fishing in PNGôs waters.

Unfortunately in 1982 the reorganization of the global fishing industry, the introduction of purse seine fishing in the central and western Pacific region and low tuna prices resulted in the collapse of the domestic industry.

In 1987, access agreements with Japan were terminated by the government of Papua New Guinea after disputes over increases to license fees. During this period, no national company had the financial resources or the fishing capacity to enter the tuna fishing industry. Other revenues were raised from access fees or resource rents paid by distant water fishing vessels operating outside the 200-mile exclusive economic zone.

Despite the crash of the industry in 1982, tuna remained the single most important resource for industrial fisheries development in PNG, followed by prawn and becheï de-mer fisheries.

In the late 1990s and continuing to the present, the tuna industry experienced major growth in terms of landings, processing facilities and export products. By 1997 an industrial purse seine tuna fishing operation and tuna canning facilities had been established in Madang. Commercial operations in tuna long-lining had been initiated by the private sector and four national companies were engaged in tuna long-lining.

Domestic consumption of tuna products (canned, fresh and other value-added products) had also increased significantly, superseding the consumption of canned mackerel.

Continued growth has demonstrated the potential further contribution that this sub-sector, and the fisheries sector as a whole, can make to the overall growth of the economy.

**Access Arrangements**

Continued access to the PNG EEZ by Korean, Taiwanese, Philippine and other vessels from the region, as part of the Parties to the Nauru Arrangement and other regional agreements, is vital to the maintenance of this important fishery. Under current access agreements foreign-owned vessels are licensed to fish within PNGôs 200-mile EEZ under specific terms. To date, foreign vessels have paid over K40 million to the PNG government as license fees. The bulk of this revenue is used to fund the operations of the National Fisheries Authority, with the balance paid to the governmentôs consolidated revenue.

A second focus should be developing a domestic sector of nationally-owned business enterprises in tuna long-lining and locally-based foreign-owned interests in tuna purse seining operations. With the introduction of the governmentôs export-driven economic recovery strategy, the sector is required to develop an integrated harvesting, processing and international marketing industry. To date we have three loining plants in Wewak, Madang and Lae and three canneries in Lae and Madang. These integrated plants and factories are generating significant spin-off economic benefits in terms of jobs, taxes, and increased revenue opportunities for other small businesses in the local economy.

In the artisanal-commercial type fisheries, lobsters, trochus, sea cucumbers, pearl shells, reef fish and deepwater snapper are other important commercial species that are currently being harvested. The nature of these fisheries is such that artisanal fishermen living in coastal communities do the catching of the product and commercial buyers, who can be nationals or locally-based foreign-owned businesses, do the processing and marketing to overseas markets.

In the aquaculture sector, fish farming is developing gradually, in both the highlands and coastal regions of PNG. The National Fisheries Authority established a freshwater fish culture facility in Aiyura, Eastern Highlands Province in the 1960ôs. This has promoted a carp-raising culture within some highlands communities for 30 years. The increasing interest in pond culture led to a 1983-1985 Technical Assistance to PNG Project by the Food and Agriculture Organization (FAO) to expand and build a better fish hatchery at Aiyura. The feasibility study was finally implemented through a successful partnership between NFA and the Japan International Co-operation Agency (JICA) in 1992. JICA aquaculture experts re-developed a multi-species hatchery at Aiyura.

In addition, Japanese technical experts in fish breeding were attached to the Aiyura Aquaculture Centre and taught many farmers about fish breeding and husbandry and delivered practical courses in aquaculture business management. The multispecies hatchery can produce one million fingerlings annually.

At the farmer extension level, pond culture for carp has been enhanced through the work of the Lutheran Churchôs outreach program where young school-leavers are taught basic fish farming and pond construction systems.

The work of JICA also encouraged the development of trout farming (*Onchorhynchus mykiss*) at Mt. Wilhelm in Chimbu Province. A local farmer from Mt. Wilhelm was taking juvenile trout from the river system and breeding these to market sizes. Through the JICA partnership, a Japanese trout expert was attached to this private farm and taught the owners how to take brooders from the local stream and strip those for fingerling production. This facility became a success and is now mass-producing trout fingerlings for highland farmers. Prior to this development, trout farming had been going concern in the Eastern Highlands in the 1970ôs, but this operation had closed due to financial mismanagement.

In coastal aquaculture, pearl shell farming started again in 1997 in Milne Bay Province, focussing on pearl production from the gold-lip oyster (*Pinctada maxima)*. The progress of this development is currently constrained by the need for a multi-species hatchery to produce spats for commercial production. The pearl-producing sea farms are currently using wild sources of shells for both half-rounds and full pearl production.

In other coastal aquaculture, a farm in Madang Province has started using wild brooders of barramundi (*Lates calcarifer)* caught in the Kikori area of Gulf Province and breeding these in tanks. Fingerlings have been successfully produced and table-sized barramundi are being produced in Madang.

These developments in fish farming are progressing but there are large infrastructure gaps in the provision of fish feeds, fish husbandry, and fish health, nutrition and dietary assistance to support the overall development.

Reef fish are becoming an interest for island communities. Coral trout and other aquarium fish are also starting to be an interest amongst coastal communities. The future potential of aquaculture is good but it will require the development of important infrastructure such as the availability of local, high quality and cheaper fish food, a trained pool of skilled workers, the availability of adequate supervisory and extension expertise and Hazard Analysis Critical Control Point (HACCP)-certified processing facilities. These aspects are critical for PNG to develop a sustainable, safe and high quality aquaculture industry. The global prospects for the industry look attractive if we can produce export products that can satisfy international export requirements.

**Regional Agreements and Institutions**

At the regional level, Papua New Guinea is a member of the Secretariat of the Pacific Community (SPC) where various fisheries issues are discussed at the regional level. The regional scientific body that addresses regional stocks is the Oceanic Program of the SPC and the Forum Fisheries Agency in Honiara, Solomon Islands. These regional

organizations have some degree of influence on fisheries management in Papua New Guinea.

At the international level other legislation exists for shared stocks of fish between Australia and Papua New Guinea. This is the Torres Strait Treaty of 1985. The accompanying PNG legislation to implement this Treaty is a Statutory Instrument, the Fisheries (Torres Strait Protected Zone) Act of 1986. Under this arrangement, licensing powers lie with the minister of fisheries of both countries and the management requirements are implemented by the relevent fisheries department in each country. This legislation has not been updated to conform with subsequent Fisheries Acts (1994 and 1998).

## SECTION 2: PROPERTY RIGHTS AND FISHERIES MANAGEMENT

### Fisheries Regulation

Several major changes to fisheries regulation in recent decades have made it a crucial aspect of fisheries management. First of all, there have been dramatic advances in fishing technology and expansion in fishing power, associated with the rapid development of fish processing and marketing. With this expansion of fishing power, the recognition of the threat of resource depletion has increased, as has the acceptance of the urgency for government intervention to control the rate of exploitation (Pearse 1980a).

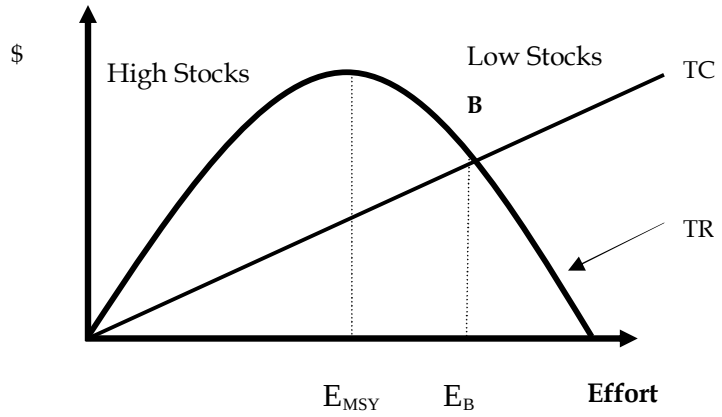
The second major change, closely associated with the first, is the declaration of the 200-mile fishing limit (economic exclusion zone) by coastal states and the contraction of available oceans lying outside national jurisdictions. This development can be interpreted as an effort on the part of coastal states to protect their coastal resources from expanded fishing by foreign fleets. It was less than a century ago that the jurisdiction of states extended from the coast to three miles. This was then extended to 12 miles and then further extended in 1977 to 200 miles, which now encloses most of the worldôs richest fish resources. The governments of coastal states recognised the need for fisheries regulation and the obligation to take a much broader responsibility for resource management.

A third major change concerns the theory and practice of fisheries regulation. Previously problems were regarded by regulatory organisations as almost entirely related to achieving a level of catch for each stock that would lead to a maximum sustainable yield. Economists have now succeeded in ensuring recognition of the alternative goal of maximising resource rents and other benefits. Coastal states have recognised the economic desirability of restricting entry, whilst complementing the effort of regulators to control fishing pressure (Pearse 1980a).

It is evident both in theory and practice that in the absence of regulation, a profitable fishery will be unsustainable over the long term. If access is not restricted, profits will attract new entries into fishing, thus expanding fishing power and labour, and eliminating all returns in excess of the cost of fishing. Sometimes this adjustment towards equilibrium between revenue and cost leads to resource depletion. But even if it does not, or if the catch is carefully regulated at the desired level, the fleet will inevitably expand beyond the required capacity and all potential net yields will be dissipated (Pearse 1980a).

Common property status under traditional fisheries conditions is a root cause of economic inefficiency in the fishing industry. Individual fishermen expand their operations in response to profit opportunities, as a result of normal and rational economic behaviour. However, they neither have control over the fish resources, which they depend on, nor the other fisherman with whom they compete for the catch. This results in irrational exploitation, inefficiency and wastage of resources. Below is a diagram depicting a common property equilibrium.

**Graph 1: Common Property Equilibrium**




This graph illustrates the case of an unregulated fishery (with no catch or effort controls), referred to as a ócommon property equilibriumô, or an equilibrium at point B. With no controls, a órace to fishô effort expands to point B, where all economic profits are dissipated and (given costs) stock size is lower than the corresponding stocks at $E_{MSY}$.

## Property Rights over Fisheries Resources

The major characteristic of fisheries resources, which distinguishes them from most other natural resources, is the institutional arrangements regarding the ownership of the resources. Fisheries resources are usually unowned or fall under the collective ownership of nations, tribes or other groups. There are three major forms of property over fisheries resources.

### *Sole Ownership*

At one extreme, sole ownership, as analysed by Scott (1955), is where a single owner holds the exclusive right of ownership. A small lake or an aquaculture pond under the ownership of a single owner is an example of this type of fishery.

### *Open Access*

On the other extreme is open access or the absence of property rights. Here the resources are unowned (res nullius) and no fisherman can enforce rights to exploit the resource over any other. This absence of property rights has traditionally been associated with High Seas fishing. The bulk of the world catch was caught in the High Seas up until the 1977 declaration of the 200-mile jurisdiction by coastal states.

Between the two extremes are the group forms of ownership, where the resources are common property (res communes). Here, rights over resource exploitation are held by persons in common with others (Pearse 1980b).

### *Common Property Rights*

There are three general forms of common property rights. Firstly, there is unrestricted access, which is closer to the case of no property rights. Here any person in the group that holds the right may use the resource, but no one has power to exclude other members of the group. The non-enforcement of property rights, in this case, has a two-fold impact.

The first impact is the reluctance of individual fisherman to conserve some proportion of current stock for regeneration. This has historically resulted in stock depletion. This is because no fisherman finds it to his advantage to release, or leave in the sea, small fish so that they can grow to a more profitable size. Chances are that these fish are only going to end up in the nets of other fisherman. Therefore, the individual has no incentive to devote resources to habitat maintenance or fish stock enhancement (Copes 1980).

The second impact is the misallocation of resources from excess investment in capital and labour. This results in excessive fishing effort and low productivity per unit of effort.

### *Restricted Access*

The second general form of common property rights involves restricted access, where access is limited to those who hold explicit rights. The rights may be in the form of licenses, heritage rights or common law privileges based on residency. The property rights holders can collectively claim rights over specific resources and have the right to exclude others. PNGôs prawn fishery is an example of this form of common property right, where only licensed trawlers are allowed to exploit the fish resources commercially. Traditional unrestricted access has been ended to pave the way for limited entry policies, involving various forms of restrictive licensing.

### *Individual Transferable Quotas*

A third form of common property rights, regarded as a sub-category, also sees the access rights of an individual holder restricted, allowing only a specific quantity of resources to be taken. This characteristic is called the individual transferable quota scheme. An individual quota is a fixed share of the catch allocated in advance to individual operators (Copes 1986b). The application of the individual transferable quota (ITQ) has been extensively discussed in the context of fisheries management. It has been favoured particularly because of its theoretical merit. There are now several fisheries in Canada, New Zealand, Iceland, Norway, Australia and South Africa where this device has been applied.

The presumed advantage of management by ITQ lies in the elimination of important external diseconomies, both among those associated with open-access fisheries and those peculiar to fisheries subject to limited entry licensing. When fishermen are guaranteed an individual quota, they can take their time, spreading their efforts optimally across the entire season and utilising the most economically efficient configurations of equipment and manpower in the process.

The allocation of ITQôs in fishing has been referred to as óstinting the commonsô because it is analogous to the allocation of quantitative pasturage rights on medieval commons (Copes 1986b). This system is used with a variety of natural resources, such as grazing rights on public land, water taking and oil and gas ventures (Pearse 1980b).

Supporters of individual quotas have stressed that they introduce a system of property rights or quasi property rights into a fishery. They imply that this should help solve the problems of common property resource exploitation, which are linked to the absence of property rights in the fish stock. In advocating individual quotas, the supporters emphasize the need to make them individual transferable quotas. Transferability is an ownership characteristic. It means that fishermen may sell all or part of their quota to another fisherman.

The transferability of quotas was said to encourage further rationalization, if there was an excess capacity of capital and manpower in the fishery. In relation to the total allowable catch (TAC) there would then be insufficient harvesting opportunity to allow fishing vessels to operate at full capacity throughout the season. Rent could be generated from the fishery by the withdrawal of some fishing units from the fishery. The quota rights systems would allow the quotas to be consolidated in the hands of the most efficient operators who could fish full-time and reduce unit costs of production (Copes 1986b).

There are several disadvantages of the individual transferable quotas and they include:

- difficulties for enforcement,
- the culling and discarding of surplus catch at sea, and
- the inapplicability of this method to short-lived species.

Therefore this model is not suitable for many fisheries.

**The 200-Mile Jurisdiction**

governments of coastal states have declared 200-mile jurisdictions in response to concerns about over fishing by distant waters fishing nations (DWFN). It should be noted that the declaration of the 200-mile limits by coastal states by itself did not solve the common property status, which is the cause of economic inefficiency in the fishing industry. These 200-mile zones exclude non-citizens, but citizens of the coastal states are collectively allowed to exploit their own fisheries resources. An unregulated collective exploitation of the fish stock by citizens of a coastal state still amounts to an open access fishery.

There are three major advantages of enforcing the 200-mile jurisdiction. Firstly, it enables coastal states to regulate foreign fishing activities within their jurisdiction. With this regulation coastal states can control over fishing by distant water fishing nations. The fishing activities of these DWFNs have been reduced. Where foreign fishermen are allowed, they have been licensed under stringent conditions. Secondly, the 200-mile jurisdiction enables national fishermen to increase fishing activities without competition from foreign fishermen and to utilise fishing as a means of promoting economic

development. Thirdly, it enables the coastal states themselves to regulate their own national industries and prevent over exploitation of fisheries resources.

However implementation of the 200-mile jurisdiction has also resulted in three major disadvantages. It has encouraged the over exploitation of a number of valuable fish species and the under exploitation of many other fish stocks, through lower levels of effort.

By excluding DWFNs from the 200-mile zones of coastal states, the fishing activities by foreigners could only be undertaken in the High Seas. This has encouraged a rapid expansion of DWFNs fishing effort on the remaining High Seas stocks (Copes 1981). It has also resulted in the under exploitation of certain fishery resources of coastal states that do not have adequate fishing capabilities and have not concluded an agreement with DWFNs to fish in their zone. Finally, it has resulted in boundary disputes between coastal states, especially over more productive fishing banks and migration channels.

## SECTION 3: FISHERIES MODELS

The production function, which is the relationship between inputs and resultant production in a fishery, is affected by the population dynamics of the fish stock and thus cannot be determined without reference to biological factors. Three models that are important to an understanding of fisheries analysis are:

- the Ricker Dynamic Model,
- the Schaefer Growth Model, and
- the Gordon-Schaefer Bioeconomic Model (derived from the Schaefer Growth Model).

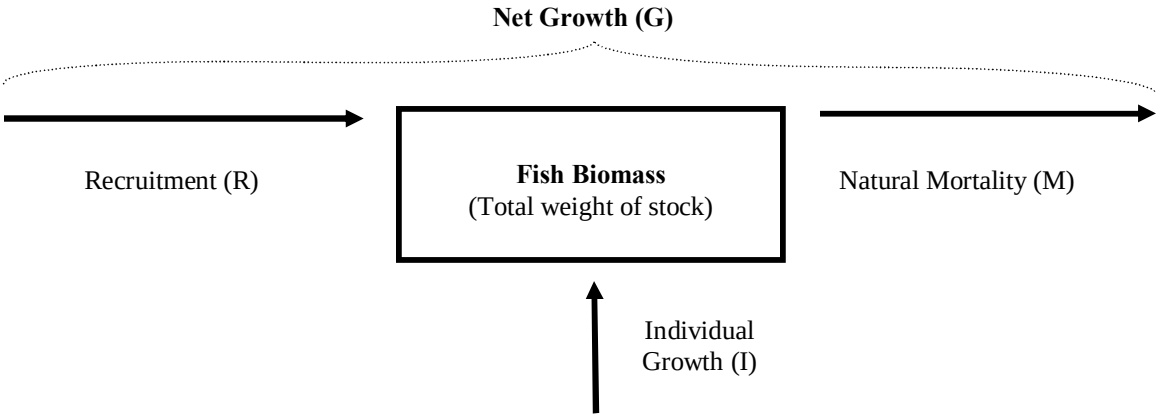
### Ricker Dynamic Model

The basic fishery dynamic model may be understood from a simple Ricker Model that focuses upon the total weight or the biomass of the exploitable fish stock, where all the fish are either at or above the minimum size at which they are capable of being retained in the fishery. In the absence of fishing, the growth rate of such a fish stock over a time period is determined by three major factors, namely:

- recruitment, the biomass weight of juvenile fish entering the fish stock during the time period;
- individual growth of the fish within the fish stock during the time period; and
- natural mortality, being the loss of biomass weight from the fish stock resulting from natural death and predation during the time period.

The Ricker Dynamic Model considers two cases: when the fishery is in its natural state without fishing mortality and when there is fisheries exploitation resulting in fishing mortality. A model of a fishery in its natural state only includes natural mortality and any weight reduction as a result of natural mortality is offset by the recruitment to the stock of juveniles, plus the weight gain of growing individuals in the stock. To maintain a steady condition, the equilibrium condition is G = R + I ï M = 0, where G equals net growth, R represents recruitment, I equals individual growth and M represents natural mortality. Refer to Figure 2 below.

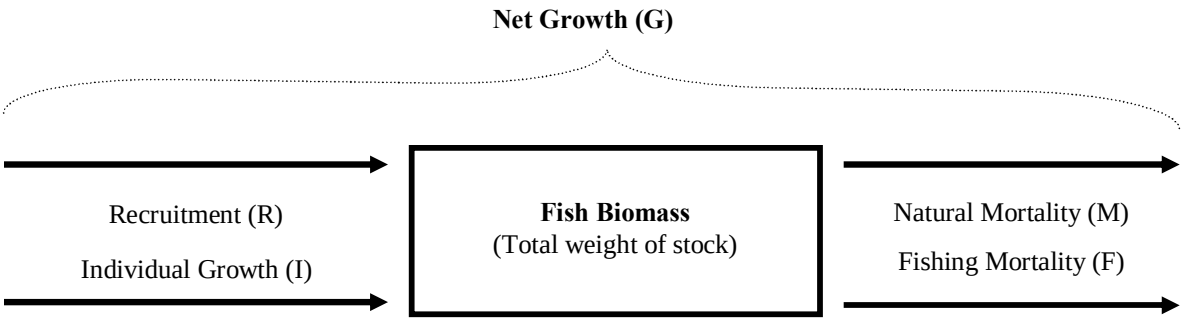
**Figure 2: Net Growth of a Fishery with Natural Mortality**




Source: Ricker 1975

In the second case we include the consideration of fishing mortality. Here net growth is equivalent to recruitment plus individual growth minus natural mortality (M) and fishing mortality (F). The new equilibrium for the fish stock would result when R + I = M + F, as illustrated in Figure 3 below.

**Figure 3: Net Growth of a Fishery with Natural Mortality and Fishing Mortality**

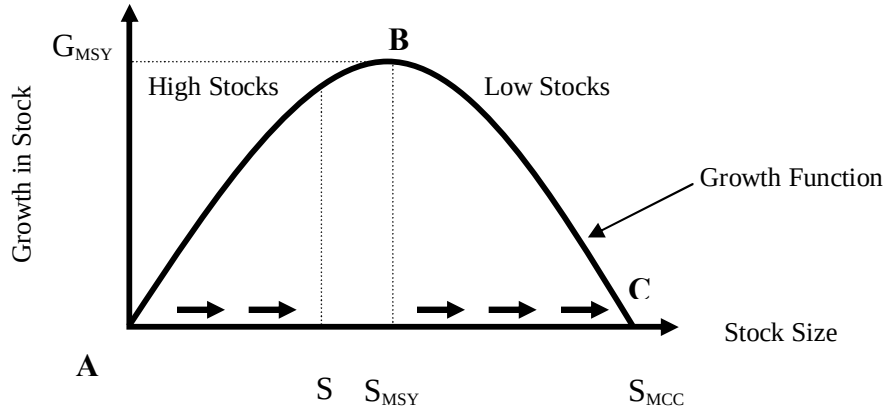



Source: Ricker 1975

## Schaefer Growth Model

The Schaefer Growth Model provides an alternative explanation to that of the Ricker Fishery Dynamic Model. The Schaefer Growth Model treats the population of a fish stock as a single unit, and the growth of a fish stock is assumed to be a function of its weight of stock (Schaefer 1954). The maximum biomass of the fish stock is determined by the carrying capacity of the environment. The point B in Graph 2 indicates this, where net growth is zero as available food and other environment resources are just sufficient to sustain the fish stock at its maximum carrying capacity. At the other end of the scale point A indicates a zero population, which of course does not allow for any growth. The net growth between A and B will be positive. The biomass level of greatest growth is at point C, where there are enough individuals to contribute to the aggregate growth, but where their number are still small enough to avoid crowding, with reduced food supply per individual and increased mortality. It is at point C that fishing can be introduced to subtract the net growth of the stock without affecting the level of biomass at this point.

**Graph 2: The Schaefer Growth Curve**



Given that the biomass of the fish stock differs in size of population and in the net growth per period of time, there is a tendency for a fishery to build up to a stable stock in the environment. In this model, the rate of growth relative to population size would drop monotonically from a small population compared to the case of a larger population. Therefore it is called a compensation model for the entire population with the exception of zero population. The biomass of a fish stock will tend to increase at various rates depending upon its population size. It will grow towards some maximum weight that, once attained, will be maintained. This population size is commonly referred to as the natural size.

The population will tend asymptotically towards its maximum equilibrium level (Gulland 1974). It is impossible to exploit a fish stock without causing some change to the equilibrium level. Fishing effort would have to result in a falling abundance, as evident through a falling catch rate. As fishing effort increases, the greater the catch, the long run relationship of the yield effort curve would be the curve as the growth curve. Therefore, the yield effort curve is a mirror image of the growth rate curve.

The maximum population size of the fish stock, or the natural equilibrium, is associated with no growth in the fish stock. For a new fish stock population the natural growth will determine the catch rate that the fish stock can sustain which has been frequently referred to as the sustainable yield. In terms of the fisheries production function, successive fishing effort will increase catch to a maximum sustainable yield (MSY). This is the case when the marginal sustainable yield, which is the change in the sustainable level, reaches zero at the level of effort then turns negative and becomes increasingly expensive at higher levels of effort.

It should be noted that the observed yield and effort in a particular fishery will not correspond to the sustainable yield effort relationship in the Schaefer analysis (Copes, 1978). This is because the Schaefer curve is an estimated long-run average relationship. Random events in nature will interfere with this yield effort relationship. There is an important discrepancy between the theoretical short-run and long-run yield effort relationships. If effort increases in a fishery that was at equilibrium yield position, one would expect to see a short-run increase above the sustainable yield curve.

However, as this increased level of fishing effort draws down the population of the fish stock, the yield would drop down to a level indicated by the sustainable yield in later years. To revitalise a fishery by rebuilding fish stock levels, one would expect a reduction in fishing effort thus resulting in a short-run adjustment. It would yield a short-run catch adjustment less than originally indicated by the sustainable yield curve.

**Gordon-Schaefer Model**

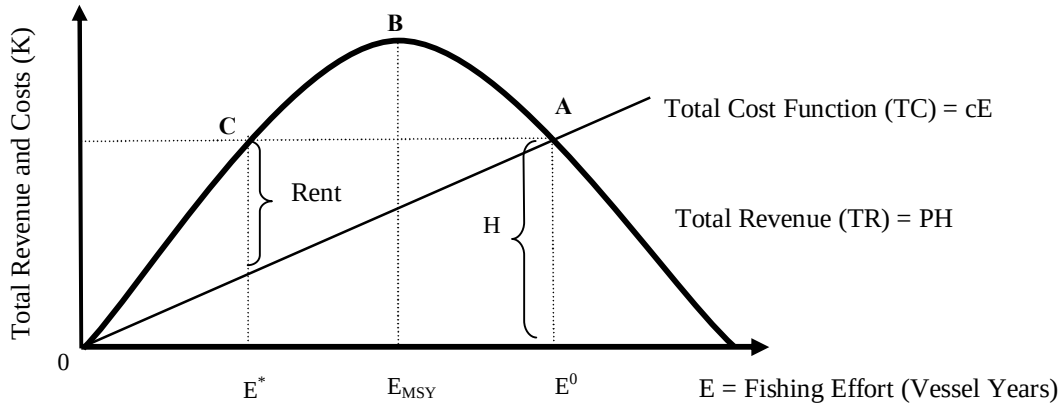
The Gordon-Schaefer Model considers a single fish stock in isolation and is generally concerned with the growth of the stock over time. The yield curve illustrates a relationship of long-run annual catch at different levels of fishing effort. The greater the number of vessels in a fishery, the lower the catch per vessel. The Gordon-Schaefer

Model makes three simplifying assumptions, namely: constant prices, no intramarginal rents (producer surplus) because of identical efficiency of all fishermen, and no dynamic consideration of time discounting. The Schaefer yield curve can be used to illustrate an economic analysis of the basic long-run relationship between fishing effort and the catch taken in harvesting of a single fish stock. The yield curve for a fishery may be turned into a revenue curve if constant price prevails. The cost curve (OA) defines the standard cost (i.e. the normal return or the opportunity cost to capital and labour) and the catchôs effectiveness, where total costs relate proportionally to effort.

As a portion of the population is harvested through increased effort, the short-run increase in catch would be above the sustainable yield curve. However, as population is reduced with increasing effort over the latter years it would drop off, as indicated in Figure 3. In the basic fisheries economics analysis the Schaefer sustainable yield curve can be used in transforming the total revenue as in the case of the Gordon-Schaefer Model.

At any given level of effort, economic rent generated from the fishery will be the difference between the total revenue and total cost. The intersection A of total cost and total revenue at OE3 is the open access equilibrium in the fishery. It will not generate any economic rent. At OE2 the fishery would be at the maximum sustainable yield (MSY). But the resource rent from the fishery will be maximised at the point OE1, where the difference between total cost and total revenue is the greatest. This is usually referred to as the maximum economic yield (MEY). At this point net benefits to society from the fishery are maximised.

**Graph 3: Gordon-Schaefer Model**




Source: Copes 1981

The Gordon-Schaefer Model shows (static) long-run costs and revenues. At MEY (point C), the marginal revenue just equals the marginal cost of effort. Any increase in effort would decrease the annual profit since marginal cost would exceed marginal revenue, if price were assumed to be constant. But if this condition is relaxed than the actual decision of harvesting would be determined by the proper inter temporal calculation. The goal would be to maximize the present value of the stream of the net returns that the fishery

could earn over time (Anderson 1977). The actual decision to harvest would be undertaken only if the present value was greater than the cost of obtaining it.

In an open access fishery an equilibrium level of effort will be reached where the costs and revenues of fishermen are equal. This equilibrium is not optimal because neither the biological potential of MSY nor the economic potential of MEY is achieved. Under open access, potential net benefits will not be realized. Operating at any point to the left of the bioeconomic equilibrium will yield a profit, when total revenue exceeds total cost. However, under the condition of open access, additional units of effort will be attracted to the fishery until all potential economic rents are dissipated.

As an economic activity, fish harvesting has some unique aspects related to the common property nature of most fisheries. Under open access, there is an inevitable tendency towards over fishing because too many fishermen are attracted, thus depleting net benefits to the industry. In analysing various management recommendations in the prawn fishery, they may be compared in terms of net social benefits. Total social benefits or social revenue is to be measured by the maximum price consumers are willing to pay for goods, in this case, prawns. The social cost, on the other hand, will be measured in terms of the opportunity cost of labour and capital. But the net benefits of any fishery consist of three major categories: consumer surplus, producer surplus and resource rent.

The Gordon-Schaefer model only recognises the existence of resource rent, when the social revenue exceeds the opportunity cost of capital and labour. However, there are two other social benefits that are generated in a fishery ð the producer surplus and consumer surplus ð that may be observed by relaxing our two major assumptions (Copes 1972). If prices vary according to supply and the catch in a fishery is large enough to influence the market price, then the fishery is capable of generating consumer surplus.

Consumer surplus is measured by the difference between what the consumers are willing to pay and the market price they actually pay. The amount of consumer surplus generated in any market may be obtained through market demand analysis in conjunction with information on actual prices paid. If the major concern is with the national welfare then consumer surplus may be ignored in this case. Because most of PNGôs prawn catch is exported, any consumer surplus would generally only be of advantage to foreigners (Copes 1986a). Since PNG is a small producer on the world market it cannot influence the prevailing price in any case and the original assumption of a constant price is valid for the prawn fishery. As a price taker, PNG would accept the prevailing international market price as a constant. However, this model requires some qualification, since ten percent of PNGôs prawn catch is marketed locally. Prawn prices vary with supply and demand in the local market. The lower the price, the greater the consumer surplus that benefits the local population. This may be taken into account by the government management authority in determining the amount of fishing effort to be applied to the minor species that are sold locally (Copes 1972).

If the second assumption of no intramarginal rent or producer surplus because uniform efficiency is relaxed, then it is possible to evaluate the presence of any producer surplus.

In practice, fishing vessels have different levels of efficiency, resulting in different levels of profitability. The differential levels of profitability may be attributed to the skills of vessel skippers and crew, better organisational and management plans, efficient capital equipment and other technical factors. The extra earnings of superior fishing units are called producer surplus or intramarginal rent.

Marginal fishermen tend to earn a general or normal wage approximating their opportunity cost, but some fisherman earn significantly more. Where a captain and crew of a fishing vessel have superior fishing skills relative to the general level of skill in the fleet, their vessel will become a ñhigh linerò, taking a larger catch and achieving larger earnings when the crew is paid on a share basis or on a catch weight basis (Copes 1972, 1986a). The higher catch may be attributed not simply to luck but rather to superior attributes, which could be matched by superior equipment, that the superior catch revenue could provide. The extra earnings are called producer surplus.

The cost of managing the fishery is usually incurred by the government and constitutes part of the social cost of operating the fishing industry. The government can recover all or part of this management cost by charging specific license fees or other charges. The final net social benefit that remains after subtracting all social costs, as well as consumer and producer surplus, is called resource rent. It may be collected by the government through taxes and fees, or it may be left with fishing enterprises.

The basic Gordon-Schaefer Model considers a fishery with a zero discount rate on the value of the fish stock. If this assumption is relaxed and the discount rate is assumed to be positive in a dynamic analysis, where the value of the fish stock today is valued more than the stock tomorrow, as presented by Clark and Munro (1975). This presentation is based on the assumption that fish prices remain constant through time and cost function does not shift. But it has been observed that the real price of fish in practice will tend to rise over time so any gains yielded from the Clark and Munro analysis may be offset by rising fish prices over time. Therefore the static Gordon-Schaefer Model is not a bad first approximate after all for analysing the PNG prawn fishery.

In an open access fishery a resources rent is not likely to be realized because any potential rent will be dissipated by excess numbers of men and vessels attracted to the fishery. The resources rent is only attributed to the success of a management regime in limiting effort and in safeguarding the resource through exercising sound management and conservation practices.

In Graph 3 above, the total cost (TC) of fishing can be attained by multiplying catch (c) and effort (E) while the Total Revenue (TR) is computed by multiplying price (p) and harvest (H).

TC = cE, while TR = hP

## SECTION 4: APPROACHES TO FISHERIES MANAGEMENT

### Limited Entry

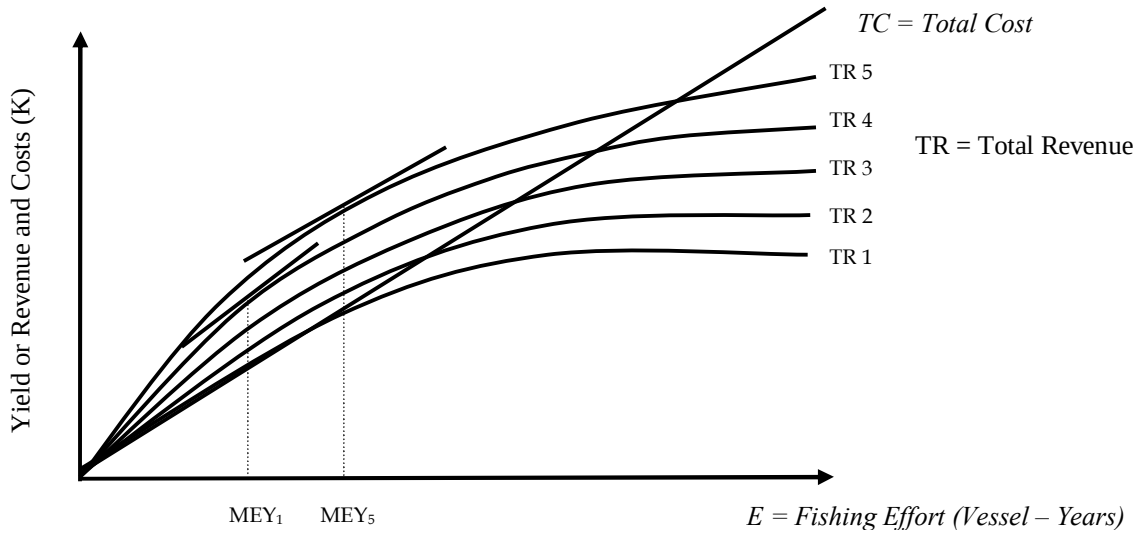
Limited entry has been advocated as a solution to the problems of open access. In this system the limitation placed on capital and labour in a fishery would reduce the level of effort in exploitation and thereby lead to an improved economic performance of the industry. Limiting the number of vessels is one of the options to be considered under a limited entry regime. If the number of vessels is regulated there is a tendency for fishing capacity to increase even after the number of fishing units has been fixed by licensing. Experience has shown that whenever the number of fishing units is limited, operators have attempted to build additional capacity and extra equipment into their individual fishing units to increase their efficiency and catch per unit effort, a process that has been referred to as ñcapital stuffingò (Crutchfield 1979). However there is a limit to the additional equipment that can be added on each vessel. It is also going to distort allocation of the factors of production. The management authority can also limit the fleet size if the number of vessels significantly increases their fishing capabilities. Limited entry can be successful if it is properly executed, but capital stuffing can dissipate part of the gains generated by the rationalisation process.

### Gear Restriction

Gear restriction can be undertaken with or without limited entry as a management option. It can be implemented for both good and bad reasons. Gear restriction has been used in the past for conservation purposes. It operates by forcing fishermen to adopt inefficient technology to reduce effective effort. This is not a good management policy because it significantly increases harvesting costs. However, gear restriction can be introduced for good reasons. For example, a ban on any equipment that is destructive to the environment and which can greatly deplete the fish stock. The use of explosives is a good example of the kind equipment that inflicts serious destruction on the environment, especially by destroying coral reefs. Even if this kind of equipment is beneficial to the individual fishermen it can impose enormous costs on the society.

The option of gear restriction also includes the selection of the optimum net size, which normally requires an analysis of the eumetric yield. Graph 4 below depicts the situation where various ecological factors in the environment pose a series of impacts on the level of yield in a fishery. For instance, MEY1 has a different level of revenue with the corresponding TR4 curve at a certain level of cost. Graph 5 below demonstrates the eumetric yield, whereby the yield, when harvesting, is selective in the sense that all fish above a critical age level are caught while all those below the size limit escape. By regulating the minimum mesh size, fishery managers are in a position to determine the age at which fish will be recruited to the fishery (Cunningham, Dunn and Whitmarsh, 1985). Consideration of the eumetric yield is crucial in maintaining seasonal closure and redirecting the fleet. A basic problem with gear restriction is that it has often been misused, resulting in economic inefficiency. Historically it has often been used to protect certain vested interests using outmoded or technically less efficient equipment.

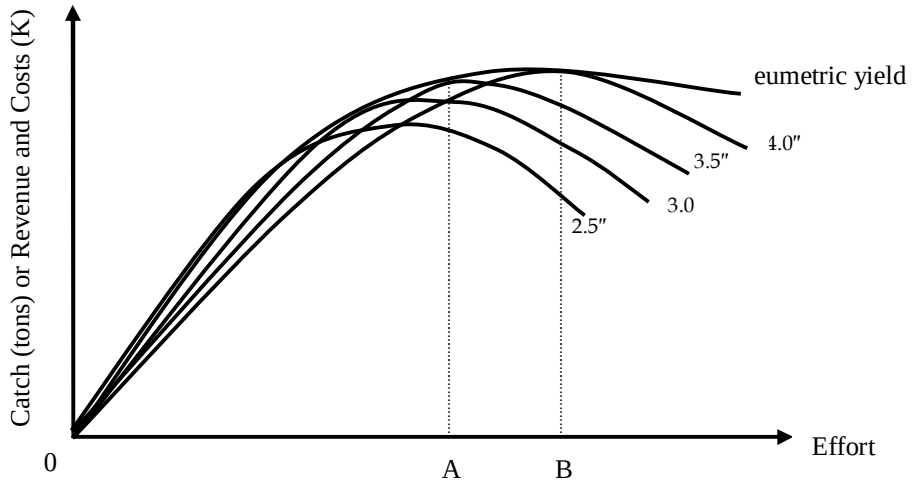
**Graph 4: Variability in Yield due to Ecological Circumstances**




Source: Copes 1978

There are two major difficulties with regulating mesh sizes. Firstly, most trawlers aim for more than one species and the optimal size of different species vary significantly. Secondly, nets are expensive and thus costly to be continually changing.

**Graph 5: The Eumetric Yield Curve**




Source: Cunningham, Dunn and Whitmarsh 1985

The eumetric yield curve is important in analyzing the economics of the fishery. If we assume the price of fish to be constant, then by multiplying the eumetric yield curve by price we derive the long run total revenue curve. If the total number of fishing vessels is controlled, as is the case in Papua New Guinea where vessels are licensed to fish in clearly specified areas, the management authority can regulate the fishery to achieve the social maximum economic yield, which would give the highest net benefit to the fishery.

The Gordon-Schaefer Model is useful in analysing the adjustment process of long lived species. Within a longer time process it would take years to predict the required amount of effort to exploit a given fish stock and its subsequent impact. But with a shorter lived species, the Gordon-Schaefer Model is not so useful in predicting the appropriate amount of effort. Because the fish stock is more likely an annual crop, it is difficult to formulate a long term harvesting plan on the basis of an equilibrium stock.

**Individual Transferable Quota**

As discussed above, an alternative management scheme that may be considered is the individual transferable quota (ITQ). This would be made after setting a total allowable catch (TAC) for the year so that each operatorôs share would then be a specific quantity. Setting a TAC for the prawn stock resource and an ITQ per fisherman would not be a suitable measure for PNGôs prawn fishery. Prawn stocks are unstable and their availability varies seasonally. This makes it impossible to determine a meaningful TAC. Secondly, most of the prawn species (especially the predominant banana species) are short-lived, with individuals usually not surviving much beyond the age of one year (Copes 1975). Each prawn stock turns over almost completely each year, constituting an annual crop.

In the case of many crustaceans there is little relationship between the size of the parent stock and subsequent recruitment. Prawns and many other crustaceans are of high fecundity and constitute a ñnon-self-regulatingò stock, where a relatively modest number of surviving spawners is sufficient to fully restock the available ecological space under favourable ecological conditions (Copes 1986b).

Area and time restrictions on the fishery may insure the survival of a number of spawners to safeguard spawning activity. Apart from that, it is possible to fish a prawn stock heavily without adverse biological effects.

Since tropical prawn species have highly variable and unpredictable recruitment, are short-lived, and available to the fishery as mature individuals for a few months each year, it is difficult to predict the total possible harvest. Under these circumstances it would be irrational to advocate the imposition of individual quotas. Instead harvesting should be organised in such a way as to ensure enough adult spawning prawns, through regulated closures and fishing effort controls. The remaining adult stock should be fished heavily to ñmob upò these stocks, because they only live for one year. It would be counterproductive to force any vessel to quit fishing under an ITQ once its quota is taken. All the available fishing capacity should be utilised to secure a catch that will otherwise be lost to natural mortality (Copes, 1986b). The correct management policy should be to utilise the existing fishing capacity to its optimum, ensuring increased earnings to the industry.

A major limiting factor for managing the prawn fishery is the fact that prawn stocks constitute an annual crop, and that stocks experience a rapid growth process over a short time period. Therefore it is crucial to close the fishery when the stocks are at their

juvenile stage and open the fishery only when the stocks are at their most economically mature size. The designation of an opening day is important to control the commencement of heavy fishing on the adult prawn stocks.

There are major limitations to the policy of heavy selective fishing (pulse fishing), namely spawning timings and juvenile stock protection. The implementation of a pulse fishery would have to include precise timing to fully exploit the resources (adult prawns) while avoiding juvenile prawns. This policy requires detailed and precise biological knowledge on spawning, recruitment and stock interaction by geographical locations. In Australiaôs Northern Territory, the bulk of the adult banana stocks school in heavy concentrations, or óboilsô, facilitating a heavy catch in relation to effort on a timely schedule (Copes 1975). PNGôs prawn fishery does not seem to exhibit evident schooling concentrations. Therefore a precise spawning and recruitment timing with pulse fishing would be difficult to determine, thus creating difficulties for implementation. The policy would require more information on the precise timing of the various underlying factors.

## SECTION 5: FISHERIES PRODUCTION

Fish production from the artisanal, commercial and industrial sectors from 1997 to 2003, as monitored by the NFA, is shown in Table 1. The data in Table 2 provides actual production figures from each of the major resource groups that are monitored by the NFA. The subsistence sector is the least monitored, however estimates of production are currently more than 30,000 mt annually. These estimates were done in 1994 so the figures may have increased or decreased since that time. Table 1 below depicts the total fisheries export quantity, expressed in metric tons, and export values, expressed in USD and PGK. The exchange rates used to convert the values from USD to PGK and vice versa are indicated in Table 2a below.

**Table 1: Aggregated Quantity and Value of Fisheries and Marine Products from 1997 to 2003**

| Year | Qty (mt) | Value (PGK'000) | Value (USD$'000) |
|---|---|---|---|
| 1997 | 9,807 | 37,150 | 24,829 |
| 1998 | 40,145 | 135,636 | 64,061 |
| 1999 | 41,903 | 124,584 | 47,639 |
| 2000 | 52,048 | 158,212 | 58,323 |
| 2001 | 48,889 | 216,349 | 63,590 |
| 2002 | 56,772 | 312,924 | 80,571 |
| 2003 | 50,512 | 246,418 | 67,601 |
| **Total** | **300,075** | **1,231,273** | **406,614** |

Source: Adapted from the NFA Annual Report (2001) and NFA database (2005).

**Chart 1: Aggregated Quantity and Value of Fisheries and Marine Products from 1997 to 2003**

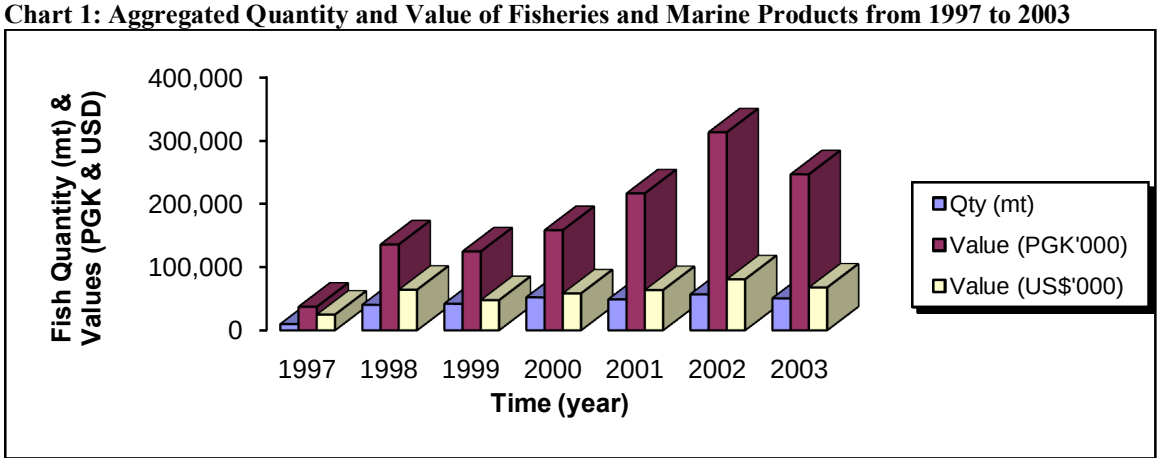


**Table 2a: Fish and Marine Product Exports between 1997 and 2003 from the Formal Fisheries Sector, by Value (K'000)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| Tuna (frozen) | 6,240 | 55,238 | 38,425 | 36,942 | 68,680 | 117,116 | 51,194 |
| Tuna (canned) | 5,324 | 23,946 | 32,173 | 48,728 | 57,298 | 92,065 | 101,007 |
| Tuna (fresh chilled) | 2,336 | 3,480 | 5,752 | 14,120 | 26,815 | 32,723 | 32,703 |
| Tuna (dried meal) | 167 | 507 | 204 | 1,075 | 1,641 | 2,464 | 2,354 |
| Shark (all products) | 492 | 4,371 | 6,140 | 6,641 | 7,934 | 6,648 | 5,003 |
| Shrimp (frozen) | 7,190 | 19,150 | 18,537 | 22,100 | 25,845 | 24,073 | 20,202 |
| BDM (dried) | 7,683 | 16,893 | 11,024 | 16,321 | 17,278 | 21,396 | 19,509 |
| Shell (including pearls) | 3,529 | 5,312 | 5,083 | 4,979 | 3,712 | 4,205 | 5,353 |
| Lobster | 3,622 | 5,972 | 6,227 | 6,255 | 5,660 | 10,595 | 8,069 |
| Other | 568 | 771 | 1,020 | 1,051 | 1,486 | 1,639 | 1,022 |
| Total in PGK | 37,150 | 135,636 | 124,584 | 158,212 | 216,349 | 312,924 | 246,418 |
| Total in USD | 24,829 | 64,061 | 47,639 | 58,323 | 63,590 | 80,571 | 67,601 |
| Average exchange rate | 0.67 | 0.47 | 0.38 | 0.37 | 0.29 | 0.26 | 0.27 |

Source: Adapted from the NFA Annual Report (2001) and NFA database (2005).

**Chart 2a: Fish and Marine Product Exports between 1997 and 2003 from the Formal Fisheries Sector, By Value (K'000)**

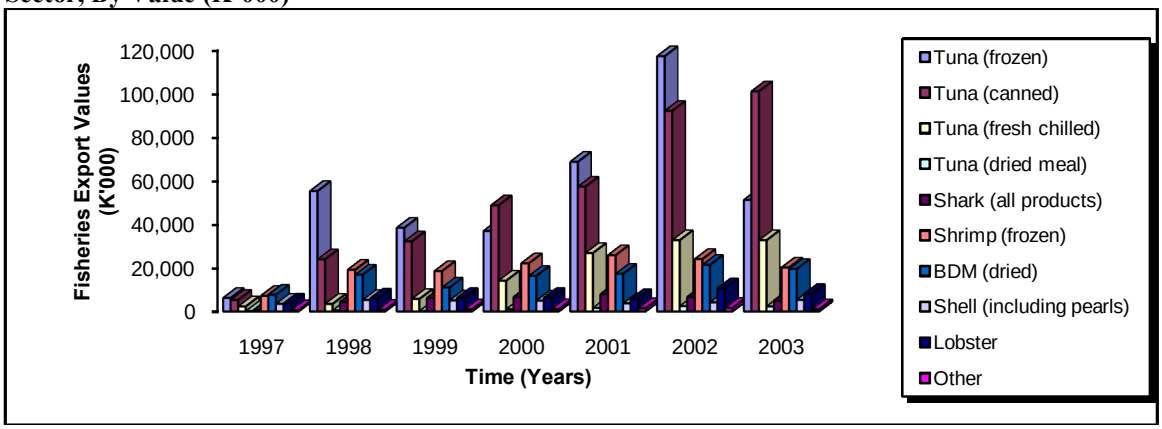
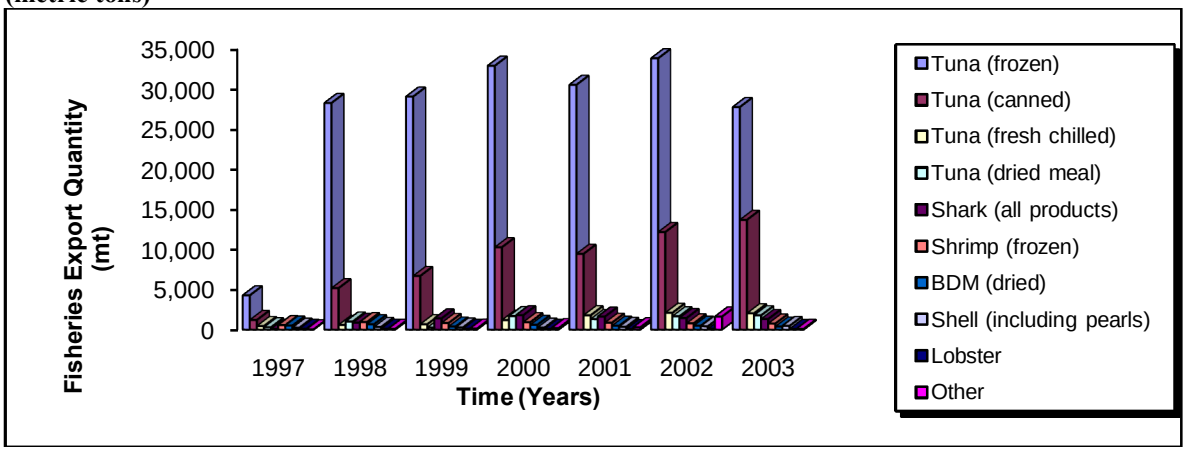



**Table 2b: Fish and Marine Product Exports 1997 to 2003 from the Formal Sector, by Quantity (metric tons)**

| Product | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| Tuna (frozen) | 4,286 | 28,322 | 29,122 | 32,977 | 30,599 | 33,908 | 27,819 |
| Tuna (canned) | 1,210 | 5,184 | 6,711 | 10,299 | 9,476 | 12,197 | 13,720 |
| Tuna (fresh chilled) | 453 | 590 | 679 | 1,197 | 1,799 | 2,104 | 2,043 |
| Tuna (dried meal) | 302 | 1,011 | 260 | 1,690 | 1,320 | 1,670 | 1,791 |
| Shark (all products) | 95 | 867 | 1,410 | 1,804 | 1,629 | 1,451 | 1,332 |
| Shrimp (frozen) | 567 | 946 | 833 | 934 | 869 | 788 | 760 |
| BDM (dried) | 505 | 679 | 395 | 608 | 484 | 485 | 390 |
| Shell (including pearls) | 243 | 333 | 264 | 246 | 347 | 420 | 466 |
| Lobster | 107 | 115 | 105 | 98 | 66 | 108 | 87 |
| Other | 42 | 100 | 125 | 195 | 299 | 1,639 | 100 |
| **Total** | **9,807** | **40,145** | **41,903** | **52,048** | **48,889** | **56,772** | **50,512** |

Source: Adapted from the NFA Annual Report (2001) and NFA database (2005).

**Chart 2b: Fish and Marine Product Exports 1997 to 2003 from the Formal Sector, by Quantity (metric tons)**



## SECTION 6: PROBLEMS IN THE FISHING INDUSTRY

The issues and challenges of the fishing industry in Papua New Guinea can be addressed according to each of the sectors within the industry (subsistence, subsistence/artisanal, commercial and industrial), as well as according to some of the inadequacies of the 1984, 1994 and 1998 Acts, and the development of adequate policies and infrastructure to support the advancement of each of the fisheries sectors.

### Problems in the Fisheries Sector

The subsistence sector applies to about 87 per cent of PNGôs rural population. The 2000 census places the total citizen population at 5.2 million people. The issue facing these communities is diminishing fish resources in some of the lakes, rivers and estuaries, which can be linked to continuing population growth.

The second sector is the subsistence/artisanal sector, which provides for both subsistence and income generation. The issues for this sector are population growth, transport, marketing of rural produce and food quality standards for fresh sales. The market infrastructure available is usually limited to roadside sales along major road systems. Where an urban or semi-urban population exists, business is good.

The third category of fishermen is the purely artisanal fishermen, who largely fish for lobster, trochus, reef fish and beche-de-mer. The rural incomes from this sector rely on private sector transport and marketing systems. In the tropical rock lobster fishery, based in Daru, Western Province, local divers and their dinghies are licensed and freezer-boats process the lobster immediately after a dayôs diving. Divers free dive for lobsters and the issue for them is whether or not they need proper commercial dive certificates that would enable them to scuba for rock lobsters, like the divers in developed economies.

In the reef fisheries, local fishermen from Daugo Island are migrants from Hula village in Central Province. Their sole source of livelihood is from fishing. The community has expanded from approximately 40 people in early the 1940ôs to over 1000 in 2005. The fishermen utilise outboard dinghies and supply fresh fish daily to Koki Market in Port Moresby. These fishermen have received little direct assistance from the government. Their need for survival forced them to develop their fishing practises. For these fishermen, Koki Market provided a one-stop-shop for the sale of fish, and the purchase of market food, water, kerosene and zoom for fishing. The issue for them is having a safe, hygienic and well-supplied market to meet their family and fishing needs.

In the beche-de-mer and trochus fisheries, local villagers fish in groups according to clans and/or family groups. The semi-processed product is either brought to buying centres using motorized crafts, fibreglass dinghies or canoes or, as is the case in Milne Bay Province, the buyers of product provide transport or dories that have store goods on board as well as freezer and/or storage space for bringing back product for re-processing, packaging and export.

In reef fishing and deep-water snapper operations, local fishermen work with private sector buyers who have freezers and packaging facilities. This was the essence of a program initiated jointly by the government and the European Union in seven provinces including the National Capital District. Fish caught are sold to the private sector partners and processed for export or for domestic sales. This sector needs to be strengthened by training PNG nationals to take on this task. The National Fisheries College has designed skills enhancement courses called Start and Improve Your Fisheries Business, and Start Your Fishing Operation which have been taught in workshops throughout the country under a Memorandum of Agreement between the National Fisheries Authority and the provinces. The course has proved to be quite successful and is gaining interest in the nearby Pacific Island Countries such as Vanuatu, Solomon Islands, Tonga, New Caledonia and Kiribati.

Commercial fishing operations cover the domestic prawn and tuna long-lining industries, including tuna purse seine operations. PNG nationals employed by the industry are being trained by the National Fisheries College under a reformed, competency-based training program in areas of commercial fishing operations, post-harvest fishing operations and basic marine engineering. Prawn trawlers or tuna fishing vessels are either owned by PNG nationals or by PNG-registered companies. These operations produce most of their products exclusively for the export market. However there is a small but expanding portion available for local sale. This includes canned and fresh products, which are especially desired by commercial catering clients.

The final category is the industrial sector, which is currently based around the tuna stocks of the Bismarck Sea. This sector comprises locally-based, but foreign-owned industrial tuna fishing and canning operations in Madang, Lae and Wewak, and foreign-owned and foreign port-based tuna purse seiners and long-liners from Korea, Taiwan, the Philippines, Indonesia and Vanuatu. Some of these operations have PNG companies as local agents for sorting out access agreements and port call requirements, however the operations themselves are foreign-based.

In summary, the problems in the industry are multiple. In the industrial tuna fishery, the Fisheries Management Act 1998 was duly passed to enable the National Fisheries Authority to facilitate industrial and commercial development of traditional commercial fisheries (tuna, prawn, lobster, trochus, beche-de-mer, pearl shells and reef-associated fisheries) and to pursue the development of new fisheries. The most critical fishery to focus on is the tuna fishery, given the total allowable catch of 250,000 tons annually. The government policy to domesticate the industry has gradually evolved in the last twenty years. The current Fisheries Management Act and the National Tuna Management Plan have provided the legal framework for that to happen, and the operational steps to achieve both rapid domestication and the mainstreaming of this industry into the economy.

**Problems Associated with Fisheries Legislation**

Fisheries legislation and regulation by the PNG government formally commenced in 1984, with the first Fisheries Act and its complementary Fisheries Regulation. This Act established the Department of Fisheries and Marine Resources as the implementing agency for government policy. The chief executive of fisheries was the minister for fisheries. Prior to 1984, fisheries existed as a sub-sector of the Department of Agriculture and Livestock, and prior to that was part of the Department of Primary Industry, however the lack of legislation at that time provided no incentive to develop a domestic industry. The Fisheries Act gave political and national recognition to fish resources as a matter of national interest.

Under the Fisheries Act and Regulation, the Department of Fisheries and Marine Resources was mandated to be responsible for resource identification, policy formulation, initiating development programs and projects, and facilitating sustainable management policies and practices. Key activities including scientific research and surveys into fish stocks, resource development programs in downstream processing and fishing gear technology, marketing studies and international access negotiations were a regular feature of work. Much interaction occurred between the DFMR, the provinces and international agencies that have an interest in fishing.

The Department of Fisheries and Marine Resources established specific subsections to implement the 1984 Act. Sustainable resource exploitation was under a scientific research and surveys branch, resource development in terms of fishing gear, provincial fisheries stations, resource monitoring and enforcement of the Act was implemented through the inspection and surveillance sections and a Licensing branch dealt with fishing licenses. For international marketing and access agreements an economics branch was created to meet that function.

Resource management under the DFMR was on the premise of biological sustainability. Subsequent monitoring systems were established, such as the development of catch reporting systems to provide information to monitor and manage stocks. The Fisheries Act had absolute control over fisheries development and management. It was during this period that foreign donor money was used to develop the artisanal sector.

In the ten years following the implementation of the Fisheries Act a number of problems and issues plagued the industry. To address them, a review of the Fisheries Act of 1984 was commenced in 1990 to determine any necessary revisions.

The review included a proposal to establish the National Fisheries Authority, which was part of the governmentôs overall privatization policy and right-sizing exercise. This was in line with trends in other renewable resource sectors, such as forestry. The review resulted in a revised Fisheries Act of 1994. The National Fisheries Authority (NFA) was established under this Act.

Below are the main issues experienced at this time and how they were addressed by the review.

***Issuing of Fishing Licenses***

The powers to license lay with the minister of fisheries. This saw resource development and management become politically dictated. In addition, at the in-house organizational level, inadequate governance safeguards saw some corruption and lack of transparency in the issuing of licenses. There were no tangible fisheries management regimes instituted, rather there were only political management processes. Therefore, there was a great need to bring about an impartial system of license allocation, based on a sound knowledge of the natural resource base and the economic viability of the different options. As a result, it was decided to transfer licensing powers from a single person to a board arrangement. This resulted in the amendment of the Fisheries Act to incorporate the existence of the National Fisheries Board and a corporatized National Fisheries Authority.

Under Section 43 of the 1994 Fisheries Act, the powers of licensing where shifted to a Fisheries Board. Upon approval by the Board, the minister and the chief executive of the NFA then signed the licenses.

The National Fisheries Board became the supreme authority over all matters relating to fisheries. It provides general control and guidance over the exercise of the functions and powers of the Authority. The Authority implements Board decisions and can only make recommendations to the Board on the granting of licenses and on policies regarding fishing and related activities.

The Board consists of ten persons: a chairman appointed by the National Executive Council in accordance with sub-section (5), the managing director of the Authority, the head of the department or office responsible for environment and conservation matters or his nominee, the head of the department responsible for commerce matters or his nominee, the head of the department responsible for the treasury or his nominee, the head of the department responsible for provincial affairs or his nominee, the president of the Fishing Industry Association, one person nominated by the Fishing Industry Association, one person nominated by fisheries resource owners, and one person nominated by non-governmental organizations.

***Management of Commercial Resources***

Whilst there was a requirement in the 1984 Act to manage fish resources in ways that would ensure future generations enjoyed the same benefits from fishing, the Act did not specify how major commercial fish resources should managed. The concept of economic sustainability was absent, as were any reliable economic cost structures for individual fisheries.

The review saw resource management guidelines developed to enable the National Fisheries Authority to write management plans for each major commercial fishery.

Section 39 of the 1994 Act provided for Fishery Plans. Management measures such as access restrictions to PNGôs waters (enforced through licensing, access agreements and cooperative arrangements), regulation of fishing practices (through gear restrictions or restricting boat sizes for example) and the establishment of catch limits through the use of total allowable catches (TACs) all resulted from Fishery Plans. To facilitate the preparation of these plans, Section 40 required operators and license holders to furnish the National Fisheries Authority with ñall relevant data and information, including fishing time and effort, landing, processing, sales and other related transactionsò.

***Absence of Economic Analysis***

Fisheries resources were under-developed during the 1980s and early 1990s, hence economic analysis relating to viability of different fishing sectors did not underpin decisions on entry into various fisheries. The local and global processed fish product markets were not actively researched or promoted by the responsible management authorities.

However the imperative to research the economic viability of fisheries development was duly recognized in the 1994 Act, under the provisions that related to the licensing guidelines. Section 41 (1) (e) stated:

*The Minister shall, in consultation with the Authority, draw up Licensing Guidelines for endorsement by the National Executive Council, in relation to –*

> *(e) The economic viability of various kinds of fishing operations and related activities, both current and proposed, and the effects of that viability on the setting of quotas.*

This meant that the economic performance of fishing companies could be monitored in the same manner as biological sustainability. This enabled the NFA to incorporate issues of economic viability when drawing up Fishery Management Plans. This saw the incorporation of bio-economic modelling in the prawn fishery, and the formulation of a cost-benefit framework for the tuna processing sector. Both activities recognized the importance of analysing economic cost structures when designing management plans.

***Development of the Artisanal Sector***

During the 1980ôs, the development of an artisanal fishery sector was actively pursued with the support of foreign donors. However this support was not adequately coordinated with stakeholders and did not have adequate sustainable management safeguards. As a result, the programmes declined as soon as project and donor funding ceased.

The subsistence and artisanal sectors were largely ignored in the 1994 Act. Fishery Plans were basically plans for commercial fisheries. However, there was a growing awareness within the Authority on the need for the development of a coastal zone management

regime, with the assistance of non-government organisations, to address these aspects of the industry.

***Derivation Grants to Maritime Provinces***

Derivation grants to maritime province are grants from the national government budget to provincial governments. They are based on the revenue generating capacity of each province. Derivation grants for tuna and other fisheries were not adequately addressed at this time.

The National Economic and Fiscal Commission has been devising mechanisms for allocating grants on the basis of total exports from each province. To do this the National Economic and Fiscal Commission has liaised with the Department of Treasury, the provinces and the Internal Revenue Commission.

All fisheries resources that are harvested and exported from a particular province should be recorded for the purpose of determining derivation grants. If the resource was harvested in one province and then sold or exported in another province, it was required that the originating province be declared for the purpose of determining derivation grants. The new fishery plans gave effect to this process.

***Links to Other Legislation***

The 1984 Fisheries Act did not link with other natural resource-based legislation (such as mining and petroleum, agriculture and livestock, water resources and forestry), other environmental legislation, or the International Biodiversity and Trade and Fauna Acts that PNG is a party to. For example, this meant that the adverse effects of seabed mining, offshore petroleum drilling and cyanide spills on fisheries were not recognized.

Whilst the 1984 Act was developed in isolation, the review involved consultation of other resource-based legislation, new environmental planning regimes and other relevant legislation.

***Surveillance, Monitoring and Enforcement***

The surveillance and monitoring of fisheries and the enforcement of the 1984 Fisheries Act was done through co-operative efforts between the PNG Defence Force (PNGDF) and the DFMR, using Navy patrol boats. The number of patrols was linked to annual funding allocations and this proved ineffective in relation to tracking shipping and fishing activity in the huge area of the countryôs 200-mile exclusive economic zone.

However, with the rapid evolution of modern technology, the NFA has been able to employ vessel monitoring systems, which allow the NFA to track daily fishing boat patterns via a satellite system. The government has been very rigorous with enforcement, particularly regarding those fishing in PNGôs waters without valid fishing licenses. Approximately 80 percent of cases brought before the courts have resulted in guilty

verdicts. However, even with the use of sophisticated modern technology, the surveillance, monitoring and enforcement of fisheries legislation is still a very tedious task and can be improved with the adoption of more advanced tracking and satellite technology.

**Ongoing Problems after 1994**

Problems continued to emerge even after the enactment of the Fisheries Act of 1994. The ongoing problems that were identified are discussed below.

1. The National Fisheries Authority had still not developed adequate institutional linkages with the various departments, organizations, provincial institutions and interest groups. As the Authority matures, the development of Memorandum of Agreements between the provinces and key industries and agencies is seen as a way of addressing these inadequate linkages.

2. Overfishing remains a problem, reinforcing the importance of appropriate economic, biological and sustainable management and control of fishing activities, combined with effective environment programmes. This problem is being addressed within the National Fisheries Authority as an ongoing sustainable fisheries development strategy.

3. The fishing industry still lacks inadequate incentives and a suitable administrative machinery to stimulate commercial activities. With the recent recruitment of a dynamic team of professionals, the fisheries sector has experienced a rapid phase of development. With reform in fiscal regimes and a changing global and industry outlook, the investment is like to expand over time. The domestication of an integrated fishing, harvesting and marketing industry is targeted to reach one billion Kina of export value per annum in the next 10 years, thus generating over 30,000 direct jobs.

4. Insufficient resources to permit the development of sound fisheries management policies remain a problem. This includes the lack of effective systems to monitor the status of stocks currently being exploited. This problem is being addressed through the allocation of additional resources by the government for resource management and protection. The NFA has been proactive in addressing the issues and is yielding benefits through strategic alliances with local and international partners.

5. There is a growing awareness amongst the stakeholders of the need for more research on the biological, economic and social aspects of the industry. There remains insufficient data to enable the formulation of sound fisheries management and investment policies.

6. There is a growing need for a more effective fisheries surveillance systems to ensure compliance with fisheries legislation and effective monitoring of the proposed Vessel

Days Scheme that is been currently negotiated with Forum Fisheries Agency member countries.

7. There remains a need for more effective inspection services to ensure that fish and fish products meet international standards, especially with the recent accreditation of the National Fisheries Authority as an EU competent authority for the certification of all fisheries and marine products for export to the European Union.

8. The inadequate professional and technical skills of officers, and a lack of training and motivation remains a problem in the fisheries sector. The Authority is currently reviewing the staff remuneration packages in order to develop incentives to retain staff and reward performance. A training package will be developing to address the training needs.

9. More effective extension and the more effective transfer of appropriate technology is needed for the development and management of a sustainable local industry. Memorandums of Agreement with non-government organizations, provinces and other stake holders are being designed to address extension and capacity building.

10. Comprehensive development opportunities need to be stimulated through careful identification and economic analysis and evaluation of investment projects with investors, the provinces and relevant authorities.

11. Licensing guidelines are needed to provide yardsticks to evaluate license applications and should be linked to the perceived economic and financial gains of exploiting an individual fishery.

12. Increased technical, managerial and financial resources are critical if the NFA is to provide adequate and comprehensive support for development programs, plans, policies and training at all levels.

The National Fisheries Authority has identified these issues as inhibiting factors in the development and management of the fisheries sector in PNG. Apart from the first and the last problems, most of these were adequately catered for in the 1998 Fisheries Management Act. It is the implementation and enforcement aspects of the current Act that are now at issue.

**The Gaps in the Fisheries Management Act of 1998**

The 1998 Fisheries Management Act (FMA) was implemented over a period of eight years and substantial changes occurred. Fishery Plans became Fishery Management Plans and were written, gazetted and approved for implementation by the government. Fishing licenses had to be thoroughly assessed prior to board reviews. Fisheries management measures such as access restrictions, regulation of fishing practices and total allowable catches (TACôs) continued under the 1998 Act, but continued to be based on ensuring a maximum sustainable yield, strictly in the biological sense.

Economic sustainability, as implied in Section 25(c), has been gradually pursued However the casual attention paid to assessing the economic factors of fisheries management, in order to complement the assessment of biological factors, has continued to undermine the 1984, 1994 and 1998 Acts.

The exclusion of the subsistence/artisanal sector in the 1998 Act continued despite its huge potential. Mungkaje (1999), for example, discusses the huge potential of fisheries for coastal communities. The 1984 and 1994 Acts included requirements for the NFA to develop the subsistence and artisanal sectors. The reasoning behind the exclusion of these sectors was that it was expected that the 1996 Organic Law on Provincial Government and Local-level Government (OLPGLLG) would cater for artisanal and subsistence fisheries development and NFA would simply raise the finance for the artisanal and subsistence sectors. However, there are no institutional linkages between the 1998 FMA and the 1996 Organic Law on Provincial Government and Local-level Government regarding the development of subsistence and artisanal sectors, so that the Fisheries Management Act of 1998 remains supreme.

Provinces may write their own fisheries acts to fulfil the requirements of 1996 Organic Law on Provincial Government and Local-level Government, however these may cause legal conflicts in relation to fisheries management under the 1998 Act.

The provinces were also ill-equipped to perform this task, because of twenty years of heavy dependence on the Department of Fisheries. In the mid-1990s, provinces in the Momase Region made a comeback through the German Development Coastal Fisheries Project, which was actively buying fish from fishermen.

Because the Fisheries Management Act 1998 is solely focused on commercial and industrial fisheries development, the question of ñauthority on all fish resources managementò has not been adequately addressed. This gap needs to be considered in conjunction with the 1996 Organic Law on Provincial Government and Local-level Governments in the specific fisheries management plans.

The institutional review and reorganization of the NFA to implement the 1998 Act saw the removal of the NFAôs natural resource scientific assessment capabilities. This was despite the fact that this was an area identified as a critical need (see problems 5, 8 and 12 discussed above).

This aspect of fisheries management was to be contracted out. This might be the ówstraw that will break the camelôs backô, especially if private companies have the scientific capabilities to argue that the TACôs set by the NFA are non-scientific. These companies may wish to try to óhike upô the TACôs based on their own assessments. In this situation, the NFA would have no independence, and would be reliant upon private company scientific assessments. Over the years the Authority, with donors, has contracted independent researchers to verify the scientific and economic status of specific fisheries, so the NFA does not have to solely rely on the compulsory self-reporting by operators and license holders, as required under the FMA.

More harmonisation between the 1998 Act and the Torres Strait Protected Zone (TSPZ) Fisheries Act is required. The management, surveillance and administration activities under both Acts are onerous. Consistent and encompassing fisheries management arrangements, that are easy to enforce for the whole country, would be less cumbersome than trying to enforce two very costly and contrasting Acts.

The organizational structure that was formulated to implement the 1998 Fisheries Management Act was seen as the right structure to enable the NFA to become a commercial entity. Manpower was cut and various sections of the 1994 NFA were made redundant. However, by making basic functions like stock assessments and economic assessments redundant, activities like capacity building in fisheries were no longer possible.

Again the 1998 Act failed to establish linkages with other resource-based and environmental legislation to cater for any adverse or complementary effects on the fisheries sector.

Under the 1994 Act, fisheries development was the responsibility of the National Fisheries Authority. However, during that time, the Authority was financially crippled. All resource revenues, by law, had to be deposited back into the Treasury, while at the same time the Authority received an insufficient recurrent budget for facilitating development in the sector. Changes were developed during 1997 and 1998 to commercialise the Authority, so that revenues could be retained.

## CONCLUSION AND RECOMMENDATIONS

The following conclusions can be drawn about the current status of the fisheries sector within the context of the 1998 Fisheries Management Act and taking into account the commercial nature of the National Fisheries Authority.

1. Under the 1996 Organic Law on Provincial and Local-level Government, provincial governments are required to significantly upgrade their technical capacities to develop artisanal and small-to-medium enterprises in the fisheries sector. These sector development strategies can be addressed through collaborative arrangements between major stakeholders including the provinces, the Department of Planning and Rural Development, the Rural Development Bank, the National Fisheries Authority and other relevant institutions and interest groups.

2. There is an urgent need to review the 1998 Fisheries Management Act to incorporate institutional arrangements established under 1996 Organic Law on Provincial and Local-level Government and other natural resource sector and environmental legislation. This initiative will require legal reviews and major legislative amendments by the national government.

3. The NFA is developing the artisanal sector indirectly through specific fisheries projects such as the EU and ADB Rural Coastal Fisheries Development and Management projects. This has seen revenues redirected to building onshore infrastructure such as fishing wharves and fish markets that serve both commercial and artisanal fishermen. The development of the Kavieng, Manus and Lae long-line wharves are examples of this kind of infrastructure.

4. The maximum sustainable yield (MSY) should be re-set to incorporate social and economic factors in order to be consistent with Section 25 (c) of the 1998 Fisheries Management Act. National Fisheries Authority is currently considering an initiative to introduce economic management yardsticks in the new prawn management plan.

5. NFA should review its decision to contract out its scientific stock assessment capabilities and instead reinstate this function. This should be carefully planned and implemented in order to address important strategic fisheries management issues in a clear and transparent manner.

6. The Fisheries Management Act of 1998 needs to be reviewed in order to include fisheries management arrangements for the Torres Strait Protected Zone, given the pressure for access to this area by Australian and Papua New Guinean fishermen.

7. The NFA needs to focus on capacity building and ongoing training programs for national and provincial fisheries personnel in the sector. This is a critical requirement.

8. The NFA should continue to maintain and strengthen its enforcement, surveillance and monitoring capabilities.

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## ANNEX 1

### Fisheries Resources of Papua New Guinea

Papua New Guinea is an island nation in the south western Pacific Ocean, north of Australia and east of Indonesia. The country consists of the eastern part of the island of New Guinea; the larger island masses of New Britain, Manus and New Ireland in the Bismarck Archipelago; Sudest, Rossel, the larger islands of the Louisiade archipelago, and the DôEntrecasteaux islands; all Islands in the Solomon Sea; and more than 600 smaller islands. The country is located between Latitude 0oE and 10oS and Longitude 144oE and 156oE.

The mainland has a rugged terrain with a central dividing range, giving rise to two major wetland areas, the Sepik/Ramu river flood plains to the north and the Fly/Purari river flood plains to the south. The southern wetland has supported a wide range of deltaic systems of pure mangrove forests and large sea-grass meadows in the Torres Straits. The Sepik/Ramu flood plains support a wide diversity of wetland fauna and flora, which contribute to sediment outflows into the Bismarck Sea. The island chains form inshore lagoon systems, fringing and barrier reefs, shallow banks; and in the volcanic arch from which the islands have been formed in the Bismarck Sea, deep submarine vents of lava flows support abyssal micro-organic life forms. Estimates of coastal habitats include 46,000 sq km of estuaries, bays, lagoons and coral reefs, of which estuaries are about 6,000 sq km and the balance is reef, bays and lagoons.

The coastal deltaic mangrove forests and sea-grass beds are important as nurseries and breeding grounds for a wide variety of reef and pelagic fish, prawns and crabs. The estuaries support a wide range of artisanal fishing for barramundi (*Lates calcarifer*) threadfin salmon (*Polydatcylus sheridani*), mullet (*Lisa spp*), mud crabs (*Scylla serrata*), penaeid prawns (*Penaeus merguiensis, Peneaus monodon*) and a range of molluscs. Coral reefs dominate in various coastal areas and island archipelagos. Milne Bay Province has 1.3 million ha of reef, 32 percent of the total reef area of the country. The Warrior reefs of Western Province are one million ha (26 percent of the total reef area) and the reefs of Oro Province are 517,000 ha (13 percent).

The oceanographic features of the Bismarck Sea and northern PNG are shaped by the nature of the geology of the area. The Pacific and Australian plates meet on southern New Britain, forming an upwelling and terrestrial sediment transport system within the Vitiaz basin, which drains into the Bismarck Sea. The Bismarck Sea (2000 meters at its deepest), is the major oceanic system supporting the industrial tuna fishery for skipjack (*Katsuwonus pelamis*), yellow fin (*Thunnus albacares*) and big eye tuna (*Thunnus obesus*).

Papua New Guineaôs extensive and diverse habitat supports a wide range of tropical coastal fishery resources, within its productive Declared Fisheries Zone (DFZ) of over 2.4 million square kilometres (see Figure 1). These resources support a number of fishing activities, including an industrial tuna fishery, largely fished by distant water Korean,

Philippine, Taiwanese and Vanuatu tuna purse-seiners; small domestic commercial long-line vessels targeting yellow fin tuna; a domestic-based Philippine company, operating purse-seiners that land skipjack and other pelagic for canning and exports; and domestic tuna boats targeting yellow fin tuna and commercial boats targeting penaeid prawns (*Penaeus merguiensis, Penaeus monodon, and Metapenaeus ensis*).

Coastal artisanal fisheries target estuarine stocks of mullet, threadfin salmon, mud crab, prawns and various molluscs. In the islands, artisanal fishermen fish for lethrinids, lutjanids and a wide variety of reef fish and deepwater snapper. They also trawl for coastal near-shore pelagic; rainbow runner (*Elagatis bipinnulatus*), small tuna (*Euthynnus affinis*), Spanish mackerel (*Scomberomorus commersoni*), and carangid species (*Belonidae*). A wide variety of sedentary species support artisanal fishing for trochus (*Trochus niloticus*), beche-de-mer (*Several Holothuria spp, Actinopyga spp, Thelenoca spp*), pearl shell (*Black-lip Pinctada margaritifera*) goldlip (*Pinctada maxima*), and green snail (*Turbo marmorata*).

The fishable resource base in the entire range of habitats includes:

1. **Estuarine stocks,** being dominated by Mugilidae (mullets), Polynemidae (threadfin salmon), Ariidae (catfishes), Lobotidae (triple tails), Atherinidae (silversides), Sciaenidae (jewfish and croakers), Lutjanidae (snappers), Hemirhamphidae (garfish), and Centropomidae (barramundi). Production potential is 11,000 mt.

2. **Reef and lagoon fish**, which are abundant and diverse, with well over 2,000 different species. The shallow reef habitats support a diverse range of food fishes including Lutjanidae (snappers), Mugilidae (goatfish), Siganidae (rabbit fish), Haemulidae (sweetlips), Scaridae (parrot fish), Labridae (wrasses), Serranidae (rock cods and groupers), Holocentridae (squirrelfish), Acanthuridae (surgeonfish), Apogonidae (cardinal fish) and Pomacentridae (damselfish). Potential yield is estimated at 80,000 mt per annum.

3. **Sedentary marine resources**, which are the important components of the subsistence and artisanal fisheries in PNG. These include shells (trochus, mother of pearl shell, green snail), twenty-three different commercial species of beche-de-mer, six species of giant clam, a wide range of edible molluscs, ornamental shell species, precious corals and seaweed. The potential is estimated at 2,000 mt.

4. **Crustaceans.** The important crustaceans of export value are penaied prawn and lobsters (*Panulirus ornatus*). Prawns are harvested by locally-based prawn trawlers, lobsters are caught by commercial local divers and processed by private companies operating freezer boats to process lobster tails. Mud crabs and other reef dwelling lobster (*Penicillatus spp*) are caught for subsistence and artisanal fishermen. The potential is 3,000 mt.

5. **Coastal pelagic.** This covers a wide range of reef-associated and oceanic stocks of rainbow runner, trevally and queenfish (*Carangidae*), dolphin fish (*Coryphaenidae*), Belonidae (*longtoms*), Hemirhamphidae (*garfish*), anchovies (*Engraulidae*), skipjack, yellowfin, and big eye tuna (*Scombridea*), Spanish mackerel (*Scombridae*), squids (*Loliginidae*) and cuttlefish (*Sepiidae*). The potential is around 58,000 mt.

6. **Coastal sharks, sawfish and rays.** The elasmobranches common in PNG waters include tiger shark, black tip, white tip, silvertip, bull sharks, spear tooth sharks, silky sharks, and whaler sharks (*Carcharinidae*), cat sharks and epaulette sharks (*Hemiscyllidae*), weasel shark (*Hemigaleidae*), hammerheads (*Sphyraenidae*), sawfish (*Pristidae*), rays (*Rhynchobatidae, Rhinidae, Dasyatididae, Gymnuridae, Rhynopteridae, Myliobatididae*) and guitar sharks (*Rhinobatidae*). The potential production is 6,000mt.

7. **Offshore fishery resources.** Seven main species of tuna are found in PNG waters. These are; skipjack tuna, yellowfin tuna, big eye tuna, albacore tuna (*Thunnus alalunga*), longtail tuna (*Thunnus tonggol*), small tuna (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*). Of these, the important commercial species are skipjack, yellowfin, albacore and big eye tuna.

8. **Skipjack tuna.** Regional tuna tagging and ecological studies by the South Pacific Commission (SPC) tuna program over the last 30 years estimate annual resource potential to be between 200,000 to 600,000 mt as a sustainable harvest tonnage for the PNG EEZ. Current reported catches are about 200,000 mt, indicating room for growth.

9. **Yellow fin tuna.** Regional SPC studies indicate maximum sustainable yield levels at 300,000 mt per annum. Annual reported catches of yellowfin are about 70,000 mt.

10. **Albacore tuna.** This species has not been the focus of any significant population dynamic studies, hence the resource sustainable levels are poorly known. Reported catches of albacore by tuna long-liners to the National Fisheries Authority for the period 1990 to 1999 ranged from 1,149 mt to 99,000 mt.

11. **Big eye tuna.** Like albacore tuna, this species is also poorly known but is taken in purse-seine surface fishing operations. Annual catches reported to the NFA ranged from 25 mt to 1,095 mt (1990-1999). The rest of the tunas (frigate, small tuna and longtail tuna) could yield up to 1,600 mt.

12. **Demersal stocks.** Deepwater (approximately 300m) stocks include families represented in inshore reef areas. They include *Lethirnidea*, *Lutjanidae*, *Serranidae* and other deepwater families like moray eels (*Moridiae*), whiptails, rattails and grenadiers (*Macrouiridae*) and deep-sea armourheads (*Pentacerotidae*). The potential resource estimate is 65,000 mt per annum.

13. **Sharks and billfish.** The other remaining offshore groups are the deep-sea sharks and billfishes. The main shark species include tiger, white tip, mako, blue porbeagle and bronze whaler sharks (*Carcharhinidae*). The main billfishes are blue marlin, striped marlin, sailfish, spearfish (*Istiophoridae*) and swordfish (*Xiphiidae*). The estimated resource potential is 14,000 mt per annum.

14. **Deepwater shrimp.** The deeper waters of PNG harbour a range of deepwater shrimp and scampi. Potential production is 1,000 to 2,000 mt per annum.

15. **Freshwater resources.** The fish resources of inland waters are generally poor, due to the recent geological history of the country. The native species include; Macro brachium prawns, freshwater eels (*Anguilla spp*), freshwater catfish (*Ariidae*), freshwater yabbies (*Cherax spp*) and introduced species (*Tilapia mossambica; Tilapia rendalli, Carpio carpio, Oncorhynchus mykiss, Tor putitora, Puntius gonionotus, Prochilodus margavii, chocolate and golden mahseers*).

While a number of fish resources have had some research done into the dynamics of the stock and potential estimates derived, the sustainable resources of most freshwater and marine fishery resources are unknown. Artisanal and subsistence marine resources are also poorly recorded and reported. Localized over-fishing in some stocks may have occurred.

The tuna fisheries are an interesting case again. Firstly, the stock is part of an overall western tropical pacific stock, which is being fished by various other countries such as Philippines, Indonesia, Palau, Tuvalu, Federated States of Micronesia and Solomon Islands. Tuna stock estimates have to be considered in light of those countries and international laws relating to straddling stocks. Within the fishery, various tuna species are caught by different gear. The interactions of surface gear (purse seine) and deep-water gear (long-line) for yellow-fin is poorly known, hence estimates have to be treated with caution. In the inshore reef fisheries, there is perhaps some localized over-fishing. Generally, the standing stocks of most artisanal and commercial stocks for lobster, reef food fishes, trochus, beche-de-mer, pearlï shell, and barramundi have not been assessed in recent years. Overall, a figure of 680,000 metric tonnes of fish and crustacean resources are possible from PNG waters using information available in 1995.

**ANNEX 2**

National Fisheries Management Plans and International and Regional Conventions, Treaties and Arrangements:

1. National Tuna Fishery Management Plan, 2000
2. National Prawn Fishery Management Plan, 1999
3. National Lobster Fishery Management Plan, 2003
4. Gulf of Papua Prawn Fishery Management Plan, 1994
5. Torres Strait and Western Province Tropical Rock Lobster Fishery Management Plan, 2002
6. Orangerie Bay Prawn Fishery Management Plan, 1994
7. Live Reef Fishery Management Plan, 2003
8. National Shark Long-line Management Plan, 2002
9. National Beche-de-mer Fishery Management Plan, 2003
10. National Fish Aggregating Device Management Policy, 2002
11. Trial Fishing Policy, 2001
12. Barramundi Fishery Management Plan, 2003

1. 1982 United Nations Convention on the Law of the Sea (UNCLOS).
2. The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, UN Implementing Agreement, 1995.
3. The Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas & the Western and Central Pacific Tuna Convention (WCPTC), 2005.
4. Convention Establishing the South Pacific Forum Fisheries Agency (FFA), 1979.
5. Treaty on Fisheries between the Governments of Certain Pacific Island States and the Government of the United States of America (US Treaty), 1987.
6. Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific, 1989.
7. Niue Treaty on Cooperation in Fisheries Surveillance and Law Enforcement in the South Pacific Region (Niue Treaty), 2002.
8. Nauru Agreement Concerning Cooperation in the Management of Fisheries of Common Concern (PNA), 1982.
9. Palau Arrangement for the Management of the Western Pacific Purse Seine Fishery (Palau Agreement), 1992.
10. Federated States of Micronesia Arrangement for Regional Fisheries Access (FSM Arrangement), 1994.
11. Regional Vessel Monitoring System (VMS), 1998.
12. Regional Fisheries Vessels Registry, 1996.
13. Harmonized Minimum Terms and Conditions for Foreign Fishing Vessels (FFC34), 1997.
14. Convention on the Conservation and Management of the Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (2000).