



**PART 3**  
**Highlights of special FAO studies**

## Highlights of special FAO studies

### FISHERIES AND LONG-TERM CLIMATE VARIABILITY

#### BACKGROUND

Natural long-term variations in the abundance of wild marine capture fishery resources have been a matter of debate and concern for more than a century. At first, it was the fishery scientific community who paid most attention to these types of long-term fluctuations. However, as world fisheries develop, and as more and longer fishery records become available, long-term changes affecting fisheries have started to attract the attention of fishers, fisheries managers, policy- and decision-makers and the general public.

The first scientific report of long-term fluctuations in herring abundance was published in 1879,<sup>1</sup> based on observations made since the sixteenth century. This report described the so-called "herring periods" in the Bohuslän archipelago, Sweden, which lasted for anything from 30 to 60 years. Since then, many more reports dealing with long-term fluctuations in marine capture fisheries have appeared. As world fisheries expand and more evidence of long-term fluctuations in fish abundance emerges, increased attempts have been made to relate fisheries cycles to available long-term climatic variability signals as a way to identify the possible causal mechanisms of fish fluctuations.

Over the last two decades, relevant research efforts have been devoted to describing and analysing long-term fluctuations in the abundance of commercial species and the possible relationships between ocean climate and fish stock size. FAO has supported this type of study, in which particular attention is paid to improving the knowledge about possible relationships, causes and mechanisms, as well as to the possible uses and applications of improved

knowledge for world fisheries conservation and development planning.

#### FISHERIES AND LONG-TERM CLIMATE FLUCTUATIONS

The abundance of a number of species that show long-term fluctuations, such as the Japanese sardine and the Californian sardine, has been shown to have some correlation with climatic indices. Long-term observations of Japanese sardine outbursts and atmospheric temperature indices (Figure 38) have led to proposals that the long-term regular changes in Japanese sardine catches could be explained by cyclic climate changes.<sup>2</sup> More recently, available FAO and other data sets of world fisheries landings were analysed<sup>3</sup> in an attempt to explore the possible relationships between various climate indices and the catches of selected groups of fish stocks. A time series model, based on well-known climate cycles, was also developed in order to forecast possible trends in main commercial fish catches for 5 to 15 years into the future. While such forecasts must be made with great caution, their results are both provoking and interesting enough to merit further attention and analysis. This article is, to a great extent, devoted to illustrating Klyashtorin's theories and findings, which refer to fish abundance indices as reflected by the possible relationship between annual catches and climate changes. In this context, the term "climate changes" refers to large-scale, long-term effects – or shifts from one climatic state to another – that seem to respond to deterministic cycles, rather than individual climatic events, such as El Niño, or long-term trends, such as global warming.

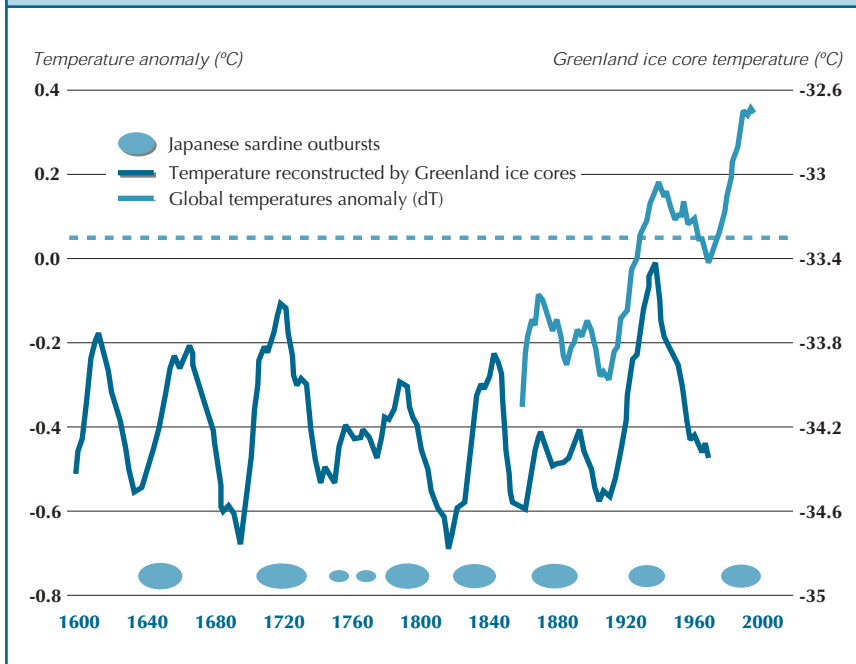
The causal mechanisms that drive most of the

<sup>1</sup> See the citation to A.V. Ljungman (1879) in: FAO. 1983. FAO Fisheries Report, by A. Lindquist. 291(3): 813–821.

<sup>2</sup> T. Kawasaki. 1994. A decade of the regime shift of small pelagics – from the FAO Expert Consultation (1983) to the PICES III (1994). Bull. Japanese Soc. Fish. Ocean., 58: 321–333.

<sup>3</sup> FAO. 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting, by L.B. Klyashtorin. FAO Fisheries Technical Paper No. 410. Rome. 86 pp.

**FIGURE 38**  
**Cyclic temperature fluctuations and Japanese sardine outbursts 1600–2000**



long-term periodic fish abundance fluctuations analysed by Klyashtorin remain unclear, and some of his findings are still working hypotheses. However, the signals and trends in climatic indices and historical fish landings that emerge from his work are of utmost interest, and merit close study so that the mechanisms governing climate change and long-term fish production variability can be understood better and used for management purposes. The argument put forward in most of the cases is that biomass and catches are ultimately driven by climate fluctuations. This runs counter to the conventional wisdom of fisheries management, which considers that biomass and catches are driven mostly by fishing pressure. It has already been suggested<sup>4</sup> that upwelling intensity is linked to large-scale climatic effects, which ultimately affect the rate of nutrient transport into the eutrophic upper ocean layer, thereby changing primary production and, subsequently, fish production. However, while hypotheses relating climate to nutrient availability may be correct, there is no direct evidence of the

<sup>4</sup> A. Bakun. 1996. Ocean processes and marine population dynamics. La Paz, Mexico, California Sea Grant and CIB. 323 pp.

mechanism, and no conclusive modelling of the causal relationship has so far been possible.

Spectral analysis of the time series of the atmospheric global temperature anomaly (dT), the atmospheric circulation index (ACI) and the length of day (LOD) estimated from available direct observations (110 to 150 years) shows a common periodicity of 55 to 65 years (Figure 39). Spectral analysis of the reconstructed time series of air surface temperatures for the last 1 500 years suggests a similar (55 to 60 years) periodicity. Furthermore, the ACI observations show two alternating climatic epochs, each of approximately 30 years duration, according to the dominance in air mass transport on the hemispheric scale (Figure 40). The ACI has therefore been used as a suitable

climatic index for further investigation of long-term regular changes in the landings of major commercial fish stocks.

### **CORRELATION BETWEEN FISHERIES AND CLIMATE**

Evidence for the relationship between climate and fisheries landings comes from two main sources: a few long-term indices of climate and fish stock size for up to 1 700 years, which show similar cyclic patterns as well as correlation between series; and fluctuations in catches from most of the stocks that were examined, which have synchronized since 1900, corresponding to climatic indices over the same period. Both long- and short-term series appear to have a common cycle. The most pronounced periodicity of long-term fluctuations in catches for all time series (excluding anchovy) varies from about 54 to 58 years. The corresponding climate cycles (both measured and reconstructed) vary from 50 to 65 years (with an average of 56 years). Other, less significant, cycles (13 and 20 year fluctuations of summer temperature) may also be of interest, but so far no reliable correlation between these cycles and commercial catch fluctuations has been found.

Among the long-term cycles, Japanese chronicles contain historical information on Japanese sardine abundance for the last 400 years (Figure 38). Changes in the availability and abundance of sardine stocks led to the development of several coastal fishing villages, as well as the collapse of others. The average cycle length is about 60 years, and periods of high abundance tend to coincide with warmer atmospheric periods.

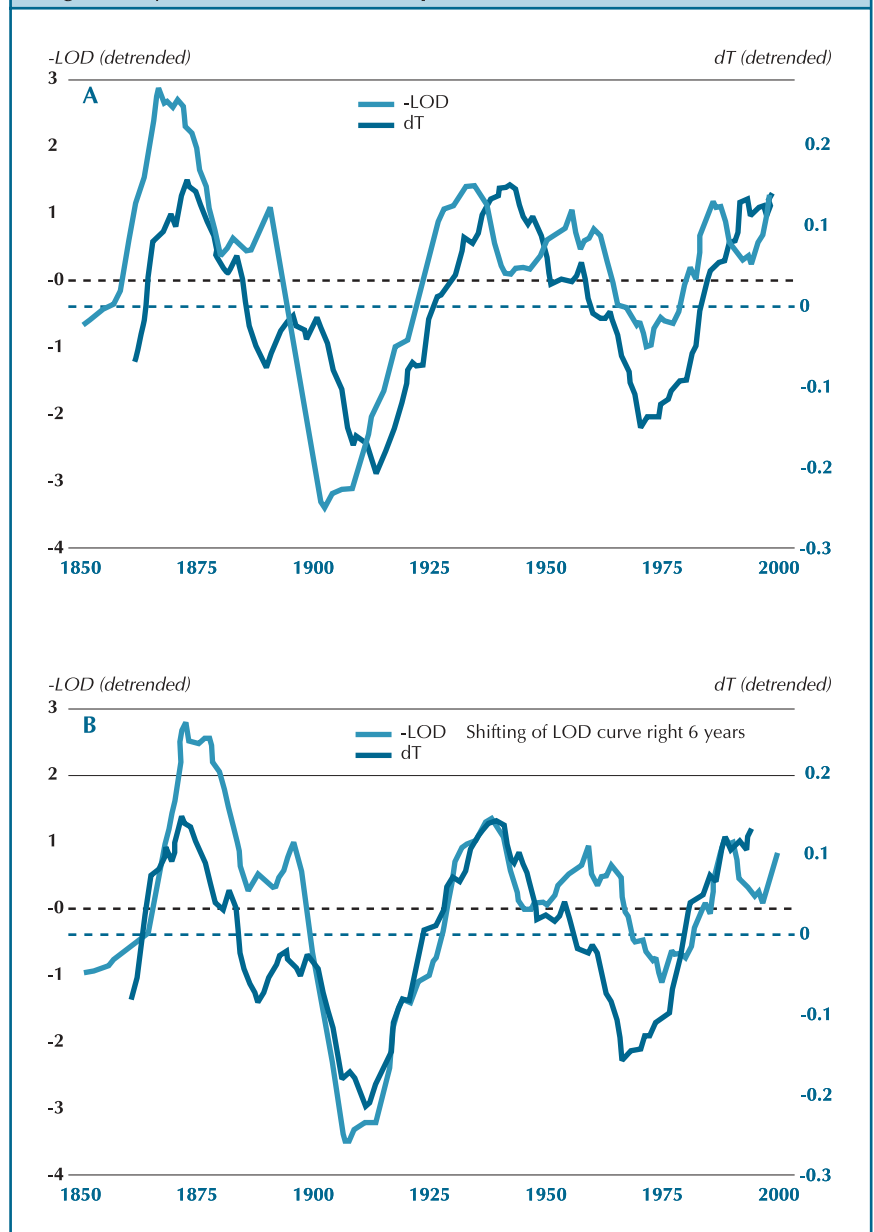
Off the coast of California, anaerobic conditions in seasonally layered sediments have preserved fish scales from populations of small pelagic fish. Two time series of the abundance index could be reconstructed for sardine and anchovy stocks for the last 1 700 years from these sediments.<sup>5</sup> Although they demonstrate large fluctuations, it is interesting to note that these time series show no clear differences between the earlier period, when fishing was negligible, and the more recent period, when exploitation has become far greater.

Analysis of the periodicity indicated two principal oscillations in sardine abundance time series: one occurring every 54 to 57 years, and the other every 223 to 273 years. The first of these oscillations is similar to that observed in both air temperature as measured from fossil ice cores and sardine biomass, making it particularly important for fishery forecasting.

Dominant fluctuation periods for anchovy are about 100, 70 and 55 years in duration. However, unlike other commercial pelagic species, the regular climate-dependent dynamics of Peruvian anchovy are greatly perturbed every 10 to 15 years by strong El Niño events, so the

<sup>5</sup> T.R. Baumgartner, A. Soutar and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. CalCOFI Report, 33: 24–40.

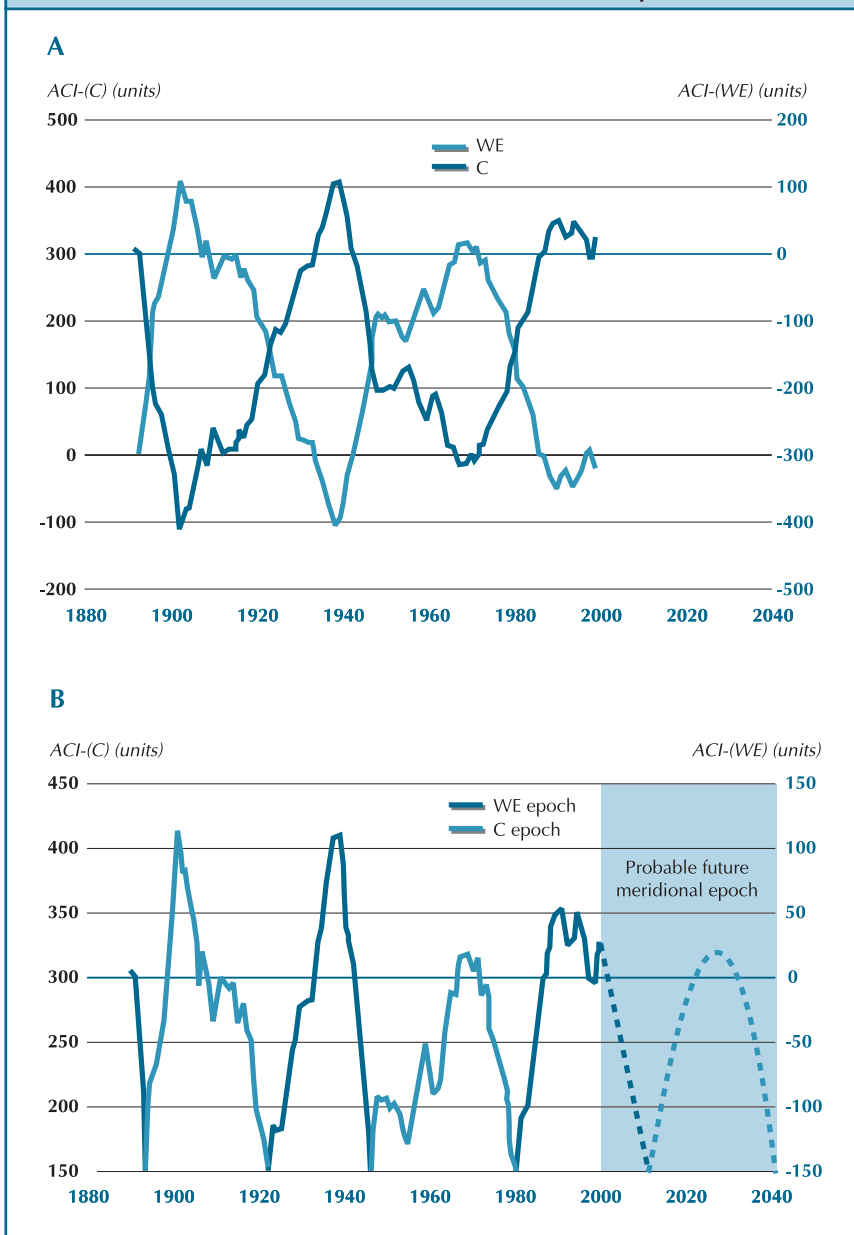
**FIGURE 39**  
Periodicity of detrended values of global temperature anomaly (dT), negative length of day (-LOD) and zonal atmospheric circulation index (ACI) 1850–2000



future catch dynamics of this species are not well approximated by a smooth "average" curve. About 70 to 75 percent of the total anchovy catch in the Pacific is Peruvian anchovy. The increases in sardine and anchovy abundance appear to be linked, respectively, to the two atmospheric regimes (zonal and meridional epochs) that have already been mentioned, suggesting that these two species may be favoured by different climatic conditions.

It is reasonable to expect that fish landings

**FIGURE 40**  
Dynamics of meridional (C) and zonal (WE) forms of the atmospheric circulation index (A) and alternation of meridional and zonal circulation epochs (B) 1880–2040



would have a greater correlation with corresponding regional climatic indices than with more global ones. However, the results obtained so far suggest that the catch dynamics of the main Pacific commercial species (Pacific salmon, Japanese, Californian and Peruvian sardine, Alaska pollock and Chilean jack mackerel) are in closer correlation with the global climatic indices, dT and ACI than they are with their corresponding regional indices. There is not yet a satisfactory explanation for this.

## FORECASTING POSSIBILITIES

Assuming that the observed past correlation between fish catches and atmospheric regimes will continue in the future, Klyashtorin attempts to forecast total catches of a selected group of major commercial species by fixing the cycle periods at 55, 60 and 65 years (based on the climate cycle) rather than relying on estimates of the cycle length from the relatively short catch time series. His analyses suggest that a shift between the two alternative atmospheric regimes is, indeed, occurring. As a result, provided that the observed synchrony between fish and climatic epochs persists, production of the selected major commercial species over the next decade would be expected to decrease in the North Pacific and increase in the North Atlantic (Figure 41). Forecasting of the major commercial fish landings for the next 30 to 40 years is largely insensitive to the choice of periodicity within the 55 to 65 year range. Species such as Atlantic and Pacific herring, Atlantic cod, South African sardine and Peruvian and Japanese anchovy would be expected to increase during 2000–2015, decreasing thereafter. During the same period, total catch of species such as Japanese, Peruvian, Californian and European sardine, Pacific salmon, Alaska pollock and Chilean jack mackerel would be expected to decrease, increasing

thereafter. Overall, the total catch of the main world commercial species considered in the analyses, and representing about one-third of world marine capture landings, would be expected to increase by 5.6 million tonnes by 2015, then to decrease by 2.8 million tonnes by 2030.

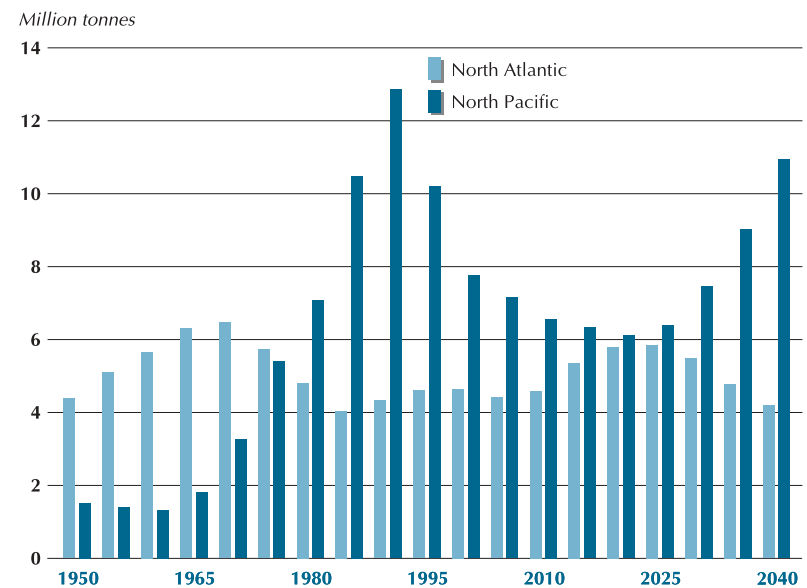
## POLICY IMPLICATIONS

The possibility of forecasting long-term changes in world capture fish production, based on

observable indices of long-term climatic variability, raises justified scientific, economic and policy expectations and concerns. Fishing pressure is usually claimed to have the major influence on the long-term productivity and size of wild fish stocks. It is commonly accepted that appropriate management could maintain stock size levels that are commensurate with sustainably high catches, and that the usual consequences of management failure are depressed – and even depleted – stock sizes and lower yields. Recognition that, for some key species, deterministic long-term climate-driven impacts on stock abundance are, or could be, as important as suggested calls for a review of research and management strategies and objectives regarding fisheries of the species concerned, as well as of related species. Management responses to short-term fluctuations would have to take into account the possibility that underlying long-term deterministic fluctuations exist. Long-term management aims, which would typically involve capital investment and social and infrastructure development, would also benefit from consideration of the long-term climate effects.

Overall, deterministic climate-driven increases and decreases in fish production do not seem to be of great global importance, as increases in a group of stocks in one region tend to be balanced by decreases in another group in another region. However, the fact that long-term climatic changes could determine major epochal increases in fish production from some stocks in some areas, and equivalent declines from other stocks and areas, merits serious consideration because the impacts at the local and regional levels are bound to be far larger. For instance, at present, large international market flows come from developing areas into developed ones (i.e. from the tropics to the North), but the oscillations in production between the North Atlantic and the Pacific Ocean are likely to result in changes to these trade flows. Such changes would have

**FIGURE 41**  
Observed (1951–1998) and forecast (2000–2040) catch changes for selected major commercial species in the North Atlantic and North Pacific



significant impacts on national and regional markets, even though the total supply could remain stable. Changes in investments and fleet movements (and fishing agreements) are also expected to be greater than suggested by the world accumulated total landing figures.

This analysis has not considered anthropogenic climate change and its possible effects on fish production. However, as available data suggest that there is a link between fish production and climate, the need to include the effects of global warming in possible projections is clear. The results reported suggest that shifts in climate could have noticeable positive or negative effects on some, if not most, major commercial fish stocks.

### THE SEARCH FOR AN OPERATIONAL DEFINITION OF SUBSIDIES PROVIDED TO THE FISHERIES SECTOR

#### BACKGROUND

Leading fishing nations are debating the size, the effects and various ways to deal with subsidies in the fisheries sector. The debate is conducted in international fora and started about a decade ago. Progress has been slow, in part because of a lack of clarity in the terms used. Not all participants in

the debate have the same understanding of what is, and what is not, a subsidy in the fisheries sector.<sup>6</sup>

One of the first tasks that FAO undertook in support of this debate was, therefore, to examine the term "subsidy" and to try to obtain consensus – at least among experts – as to what it should mean in the context of fisheries and aquaculture. The examination took the form of an FAO Expert Consultation, held in December 2000.

The experts discussed, *inter alia*, what would constitute a suitable and operational definition of "subsidy" for the purpose of analysing the effects of subsidies on resource sustainability and on trade. This discussion drew the conclusion that no single definition could be agreed to. Instead, the experts identified four sets of subsidies. They went on to recommend that these sets of subsidies be referred to and used as standards in future studies and discussions.

The experts had two major reasons for choosing this solution: they wanted to make the definition independent of any evaluation of the effects of subsidies and, at the same time, they wanted to ensure that the definition would facilitate such evaluation. They achieved these objectives by, on the one hand, tying the definition to the form of the subsidy – as opposed to its effects – and, on the other hand, classifying subsidies into four groups according to criteria that reflect the relative ease of identifying and quantifying a subsidy and its effects: set 1 being the easiest, and set 4 the most complicated.

In addition, the experts intended that the definition respect the notion that a subsidy is a national policy instrument that reflects an exception to a nationwide policy. The exception

is generally reflected both in the form of the policy instrument and in its effects.

The international debate about subsidies continues. It has moved on from the definition of subsidies and is now more concerned with their classification – which is usually based on their perceived effects – and with how to assess their impact.

This article describes the definition of subsidies, as proposed by the FAO Expert Consultation. The text, with a few editorial differences, can be found in the report of the Expert Consultation.<sup>7</sup>

## GENERAL CONSIDERATIONS

Many different definitions of a subsidy have been used in economic analyses of trade and natural resource use. Review of these leads to the conclusion that none of the commonly used definitions is adequate for a comprehensive analysis of subsidies' effects on trade and sustainability in fisheries and aquaculture. Unfortunately, the Expert Consultation did not recommend any single definition for the measurement, analysis and political debate of subsidies in fisheries.

Experts tend to place different emphasis on four attributes of subsidies in fisheries and aquaculture:

1. government interventions that involve only financial transfers to producers;<sup>8</sup>
2. government interventions that confer benefits to producers, without involving financial transfers from the government to producers;
3. an absence of government interventions to correct distortions that confer benefits on producers; and
4. the long- and short-term effects of government interventions on firms' benefits and costs.

<sup>6</sup> Examples of different understandings of the term "subsidy" can be obtained from: FAO. 1993. *Marine fisheries and the Law of the Sea: a decade of change. Special chapter (revised) of The State of Food and Agriculture 1992.* FAO Fisheries Circular No. 853. Rome; M. Milazzo. 1998. *Subsidies in world fisheries – a re-examination.* World Bank Technical Paper No. 406. Washington, DC, International Bank for Reconstruction and Development/World Bank, 86 pp.; FAO. 2001. *Subsidies for fisheries: a review of concepts,* by W.E. Schrank. In *Papers presented at the Expert Consultation on Economic Incentives and Responsible Fisheries*, Rome, 28 November – 1 December 2000. FAO Fisheries Report No. 638, Suppl., pp. 11–39. Rome.

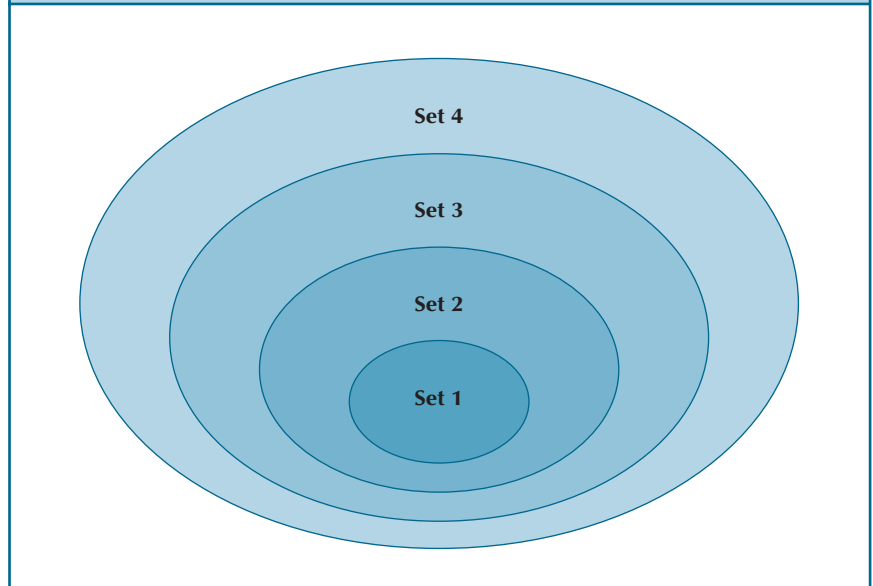
<sup>7</sup> FAO. 2001. *Report of the Expert Consultation on Economic Incentives and Responsible Fisheries.* Rome, 28 November – 1 December 2000.

<sup>8</sup> The term "producers" includes primary producers (fishing firms), fish processors, distributors, wholesalers and retailers of fish and fish products. In other words, producers include all the firms involved in supplying fish to the final users of fish and fish products.

In order to advance the measurement, analysis and discussion of subsidies in fisheries and aquaculture, the experts at the consultation proposed definitions for four sets of subsidies. The consultation recommended that any analysis and discussion of this issue state explicitly which of the four sets of subsidies is being considered.

The numbering of sets 1, 2, 3 and 4 is not meant to imply any ranking of subsidies. Rather, it indicates that the definition of subsidies in higher numbered sets includes more elements. In other words, set 2 includes the elements that are included in set 1, set 3 includes the elements included in set 2, and so on. This is illustrated in Figure 42.

**FIGURE 42**  
**Sets of subsidies**



## SUBSIDIES

### Set 1 subsidies

Subsidies in set 1 are government financial transfers that reduce the costs and/or increase the revenues of producers in the short term.

Set 1 subsidies include direct payments by government to or on behalf of producers, for example, grants to purchase or modernize vessels and income support payments.

All the experts at the consultation believed that definitions of subsidies that include only government financial transfers to producers are too narrow for the present purposes. Such definitions exclude government interventions that affect trade and the use of fishery resources and that involve no financial transfers. Therefore, the definition of set 2 subsidies includes all the government interventions – regardless of whether or not they involve financial transfers – that can potentially reduce the costs and/or increase the revenues of producers in the short term.

### Set 2 subsidies

Subsidies in set 2 are government interventions – regardless of whether or not they involve financial transfers – that reduce the costs and/or increase the revenues of producers in the short term.

Set 2 subsidies include tax waivers and deferrals, as well as insurance, loans and loan guarantees provided by government. Set 2 subsidies also include government provision of goods and services at below market prices.<sup>9</sup> Set 2 subsidies correspond closely to many of the definitions used by, for example, the World Trade Organization (WTO).

Most experts at the consultation viewed definitions of subsidies that require active and explicit government intervention, including set 2 subsidies, as too narrow. The lack of government action to correct distortions (imperfections) in the production of, and markets for, fish and fish products confers an implicit benefit to producers, which can affect trade and the use of fishery resources. The experts at the consultation therefore defined set 3 subsidies as including the lack of correcting interventions by government to remove distortions (imperfections) that can potentially affect fishery resources and trade.

### Set 3 subsidies

Subsidies in set 3 are set 2 subsidies plus the

<sup>9</sup> Note that this applies only to goods and services for which a market exists. It does not apply to goods and services provided by the government and for which there is no market. See the discussion of management costs in set 3 subsidies.



short-term benefits to producers that result from the absence or lack of interventions by government to correct distortions (imperfections) in production and markets, which can potentially affect fishery resources and trade.

Set 3 subsidies include the implicit benefits to producers that are associated with a lack of government regulations requiring producers to bear the costs that they impose on other parties, including the costs on the environment and natural resources. When the costs imposed on others do not have to be paid for, the cost of production is lower, which in turn influences the amounts of fish produced and traded as well as the health of resource stocks. Such implicit benefits are present where government does not require measures to reduce the catch of, for example, sea turtles, sea birds or marine mammals. In such cases, producers impose costs on others, in the form of damage to the environment, which they do not pay for and do not take into account in their production decisions. Another example is where government does not do enough to prevent the overexploitation of a fishery resource. In this case, producers avoid paying for the costs of harvesting the resource in the short term, while imposing costs on others – and themselves – in the long term. Both the sustainability of the resources and the trade in fish are thereby affected.

All the experts at the consultation agreed that these types of implicit benefits (unpaid costs) can have significant impacts on fishery resource sustainability and trade. However, not all agreed that such implicit benefits should be included as subsidies for the present purposes. In particular, some of the experts believed that this definition encompasses measures that are not open to classification as subsidies, and that their inclusion moves the discussion of fisheries subsidies into areas that are distinct from, and should be addressed in different contexts from, the fisheries subsidies debate.

The experts at the consultation were unable to decide whether the failure to charge for the costs of fisheries management services constitutes a subsidy to producers. There is a lack of research on this issue, and economic reasoning leads to ambiguous conclusions.

Clearly, government provision of a factor input at below the market price constitutes a subsidy under all four definitions. However, there is no market for management services in most fisheries.<sup>10</sup> Some experts argue that producers have no demand for management services and that, instead, management is forced upon them. In addition, in managing fisheries, government is attempting to ensure the sustainability of the resource for the use of future generations and the enjoyment of non-producers who value the existence of healthy fishery resources.

The professional literature on recovering the costs of fisheries management essentially concludes that requiring producers to pay user fees improves the overall efficiency of management; in other words, user fees enhance the value gained from the use of scarce management resources. However, the literature does not address the issue of whether a failure to charge user fees (or to introduce some other form of cost recovery) should be considered a subsidy. Charging user fees reduces revenues (or increases costs), but whether such fees affect supply, trade and sustainability, and how they do so, are not clear at this time. More research is required on this important issue.

Some of the experts at the consultation argued that definitions of subsidies that include only those government interventions (or an absence of correcting interventions) that confer short-term benefits on producers are limited because they do not account for the effects over time of such interventions. An intervention that confers an immediate benefit can ultimately confer harm or losses on producers, especially in fisheries. Some of the experts recommended extending the definition of a subsidy to include interventions (and the absence of correcting interventions) that affect costs and revenues in any direction and over time, i.e. in the short, medium and long terms.

<sup>10</sup> The case of sole ownership is an exception in which the owners of the fishery resource would be willing to pay for a set of services that include research, management administration and enforcement.

#### Set 4 subsidies

Subsidies in set 4 are government interventions, or the absence of correcting interventions, that affect the costs and/or revenues of producing and marketing fish and fish products in the short, medium or long term.

Set 4 subsidies include all set 3 subsidies plus such interventions as management measures that may decrease (or increase) the short-term benefits to producers but that result in an increase (or decrease) in long-term benefits to producers. An example is where closure of a fishery (or an area of a fishery), which imposes short-term losses on producers, ultimately results in a rebuilt resource stock and higher long-term benefits to producers. Set 4 subsidies explicitly account for the effects over time of government interventions and the absence of correcting interventions. The effects on benefits to producers in the short term may be the opposite of the long-term effects.

### TECHNO-ECONOMIC PERFORMANCE OF MARINE CAPTURE FISHERIES

#### INTRODUCTION

In 1999 and 2000, in close cooperation with several fisheries research institutions and national fisheries administrations in Asia, Africa, Latin America and Europe, FAO reviewed the economic and financial performance of more than 100 fishing fleets in 15 countries. The results are presented in a FAO Fisheries Technical Paper.<sup>11</sup> The studies are part of the monitoring of the economic viability of marine capture fisheries organized by the FAO Fisheries Department.

The studies highlight two aspects of the economic and financial data: the structure of costs and the profitability. In 1999–2000, the influence of financial transfers on profitability was also reviewed.

This article contains some of the highlights of the data collected and the conclusions reached. Special emphasis is given to an international comparison of the structure of costs for small-scale fishing vessels.

<sup>11</sup> FAO. 2001. Techno-economic performance of marine capture fisheries. FAO Fisheries Technical Paper No. 421. Rome.

#### COST STRUCTURE OF SMALL-SCALE FISHING VESSELS

##### Europe

Labour costs account for the major share of operating costs (45 to 64 percent) in European small-scale fisheries (Norway, Germany and France). Vessel costs are the second highest cost component, ranging from 20 to 35 percent of total operating costs. At 7 to 20 percent, running costs play a minor role, mainly because of lower fuel expenses. The importance of labour costs compared with vessel costs and running costs is even higher than it is in deep sea trawl fisheries.

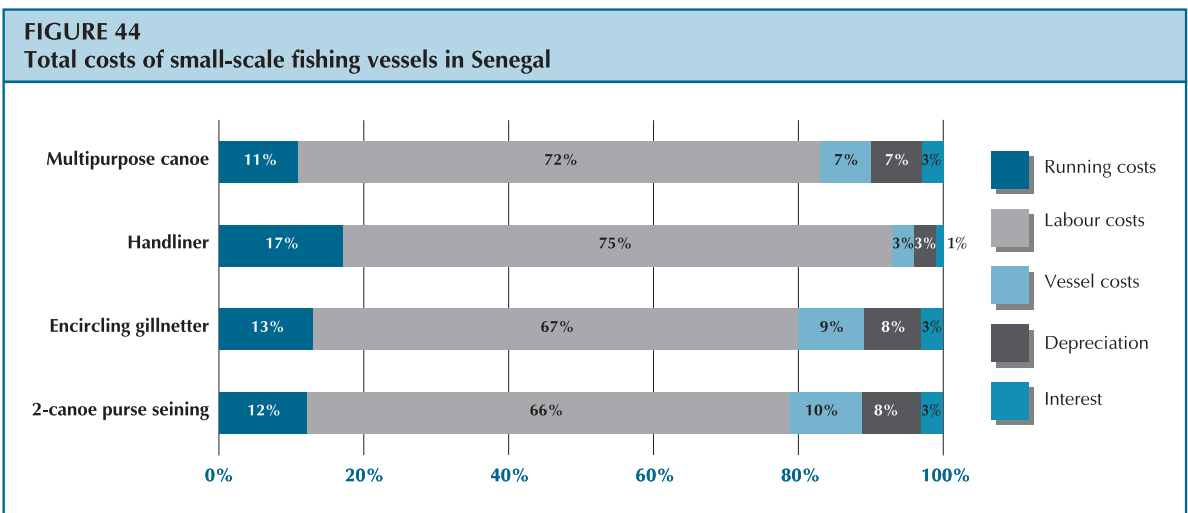
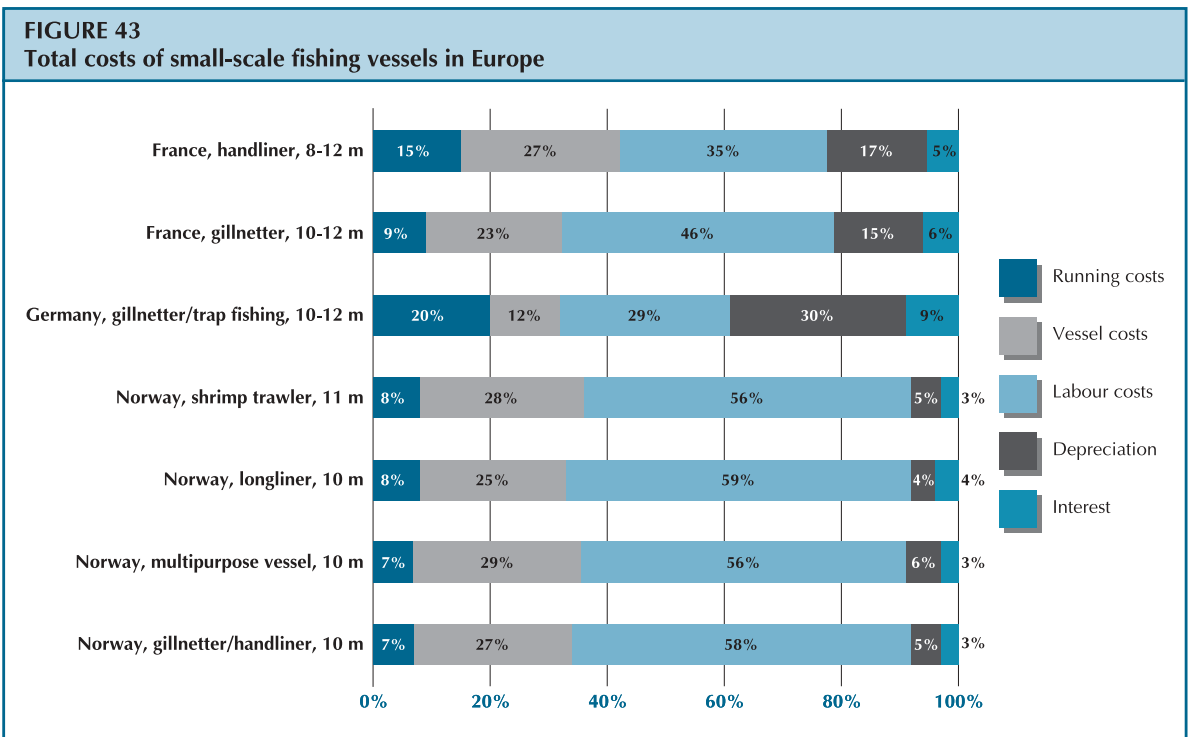
When adding the costs of investment, i.e. depreciation and interest on vessel costs, vessel costs gain considerable importance, as shown in Figure 43. Vessel costs and depreciation and interest combined range from 33 to 51 percent of the total costs.

This finding shows that European small-scale fisheries are relatively capital-intensive and that capital is substituting expensive labour. This trend is more pronounced in the case of German and French vessels than it is in the case of Norwegian vessels.

##### Senegal

The cost structure of Senegalese small-scale fishing vessels differs from that observed in Europe. While labour costs are the most important element of the operating costs in Europe, their share is significantly higher in Senegal than in the developed European countries reported. This supports the general notion that small-scale fisheries in developing countries are more labour-intensive than in developed countries. It is worth noting that vessel costs are the least important element of operating costs in Senegal, reflecting the low costs of vessel maintenance and repair.

Depreciation and interest are less important in Senegal than in most European countries. This reflects the fact that vessels are less expensive, so depreciation and interest are also reduced, and range from 7 percent of the total costs (for handliners) to 21 percent (for two-canoe purse seining), compared with Europe where their share is between 33 and 51 percent.



**The Caribbean**

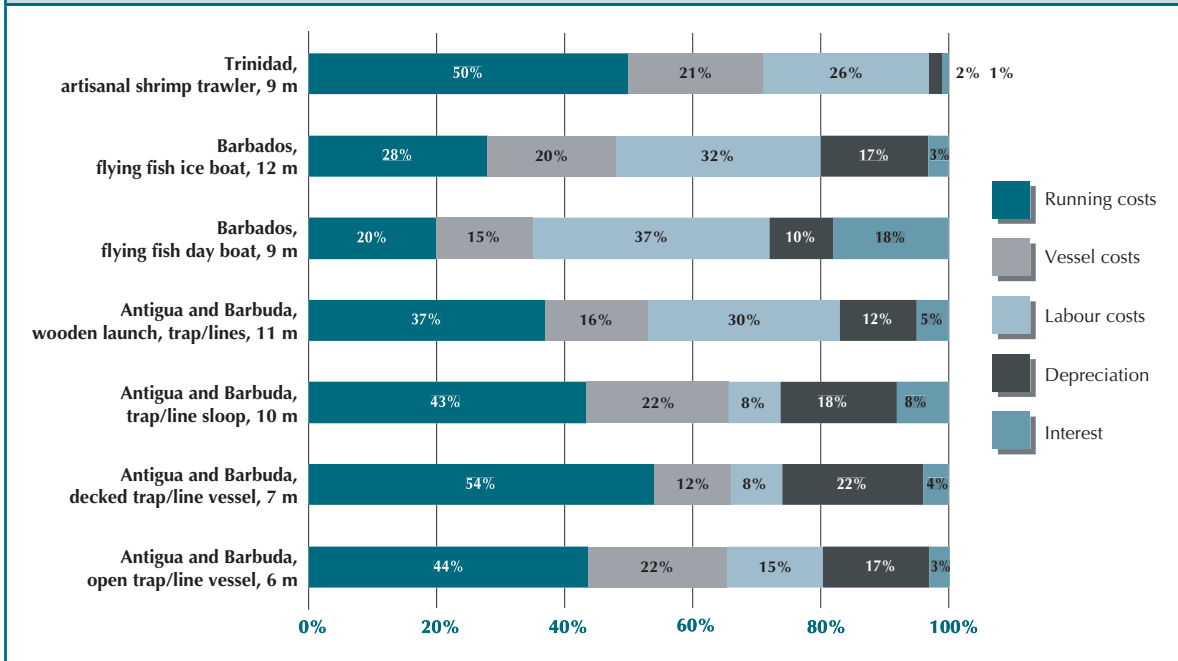
In the case of small-scale fishing vessels in the Caribbean, a different picture emerges. Only for fishing boats that exploit flying fish from Barbados (using gillnets, dip nets, handlines and fish aggregating devices) do labour costs rank as the highest cost component, followed by running costs and vessel costs. In all the other cases (boats fishing for lobster and high-value bottom species in Antigua and Barbuda, and artisanal shrimp trawlers in Trinidad), running costs are the most

important cost component. This reflects the situation observed for deep sea trawlers operating in developing countries.

For traditional lobster boats in Antigua and Barbuda, labour costs are the least important cost component. This contrasts with the situation reported for the country's larger lobster boats and for the artisanal shrimp trawlers in Trinidad, where labour costs are the second highest cost component, followed by vessel costs.

In fact, the total cost structure of small-scale

**FIGURE 45**  
Total costs of small-scale fishing vessels in the Caribbean



fishing vessels in the Caribbean resembles the situation found in Europe more closely than it does the one in Senegal. When depreciation and interest are added, the vessel costs range from 24 to 48 percent, which is close to the situation in Europe and indicates only a slightly lower level of capital investment than that observed there. For boats that catch flying fish in Barbados and sloops that catch lobsters and bottom fish in Antigua and Barbuda the result is even closer to Europe's. For these vessels, the vessel costs plus depreciation and interest account for the highest share of the total operating costs.

Running costs rank second, and labour costs are the least important component of both operating and total expenses for small-scale fishing vessels in the Caribbean (Figure 45). In this they differ from European vessels.

### South and Southeast Asia

In South and Southeast Asia, labour costs are the most important component of the operating costs for four of the six types of small-scale fishing vessels studied. The situation is thus similar to that of small-scale fishing vessels in Europe and Senegal. In the cases of the Indian log raft, which operates trammel nets, and the Thai push-netter,

running costs exceed labour costs. As is the case for most Caribbean and Senegalese vessels (but not for European small-scale fishing vessels), running costs rank second, and vessel costs third.

Figure 46 shows that vessel costs, together with the costs of depreciation and interest, range from 15 to 46 percent, which is more similar to the situation found in the Caribbean and Europe than to that of small-scale fishing vessels in Senegal.

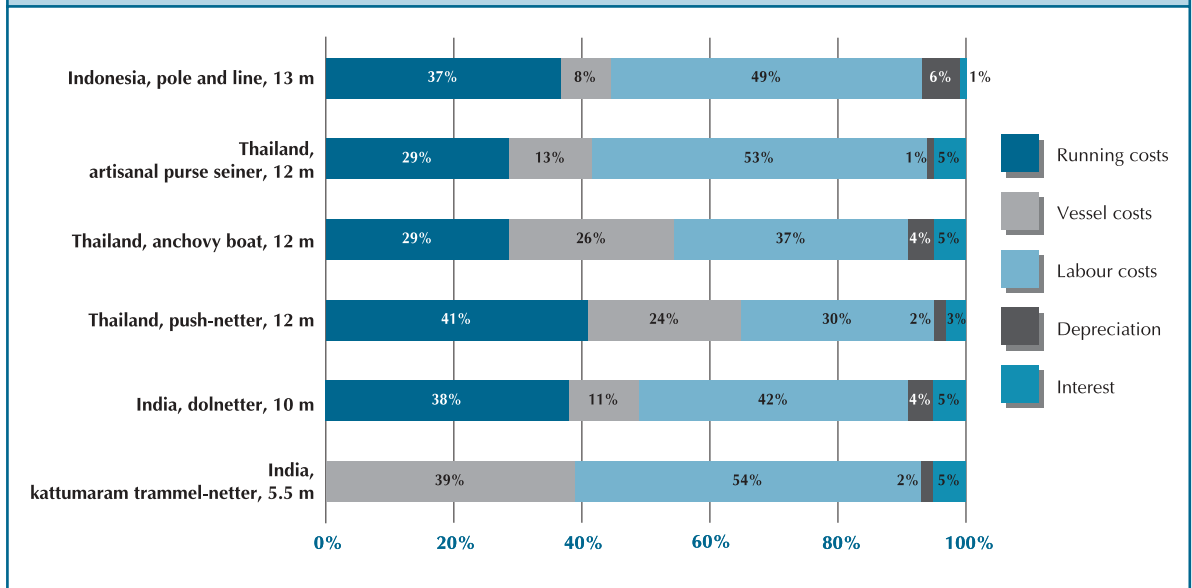
However, in no case do vessel costs plus depreciation and interest account for the highest share of total expenses, as was observed for some categories of vessels in Europe and the Caribbean. In three of the six cases (Thai push-netters and anchovy boats and Indian catamaran), vessel costs plus depreciation and interest rank second, while for the other three fleets they are the least important cost component. Again, this indicates a relatively low level of capital investment.

### RECENT TRENDS IN FINANCIAL AND ECONOMIC PERFORMANCE

The studies carried out in 1999 and 2000 confirm and validate the findings of the cost and earnings studies carried out between 1995 and 1997. Of the 108 types of fishing vessels studied, 105 (97

FIGURE 46

## Total costs of small-scale fishing vessels in Asia



percent) had a positive gross cash flow and fully recovered their cost of operation. Only three types of vessels (stow-netters in China and semi-industrial and industrial shrimp and bottom fish trawlers in Trinidad and Tobago) showed operational losses. Some 92 of the 108 types of vessels (85 percent) showed a net profit after the costs of depreciation and interest had been deducted. This composite result is more positive than that obtained from studies carried out during the 1995–1997 period, when only 61 of the 84 types of vessels studied (73 percent) had a positive net cash flow. The improvement is largely due to the inclusion of fleets operating in Norway, Thailand and the Caribbean, all of which recorded net profits.

Of the ten countries that participated in both the previous and the recent studies, two (France and Spain) showed marked improvements in the profitability of their fishing vessels, while another two (China and Germany) showed declining profitability. In the remaining six countries (Republic of Korea, Indonesia, India, Senegal, Argentina and Peru), the economic results remained substantially unchanged.

The higher prices paid to producers in 1999–2000, compared with the previous study period, contributed to these overall positive results. There were few indications that fishing

effort had been reduced and fish stocks had recovered. It was also observed that some fleets had changed their fishing operations to adapt to the new conditions that resulted from depleted and changing abundances of resources and access to new markets.

The impact of cost-reducing and revenue-enhancing government financial transfers differed significantly from country to country. In two countries in the EC and in India, there were strong indications that almost all the vessel types that were covered by the cost and earnings study and received financial transfers would have been profitable even without those transfers. The transfers played a role, however, in increasing earnings and profitability significantly. In the Republic of Korea the situation was mixed, while in Thailand vessels that could avail themselves of tax exemptions on fuel needed to do so in order to have a positive gross cash flow.

Examples of new trends in coastal fisheries include the expanded use of trammel nets by traditional log rafts (kattumarams) on the east coast of India, the introduction of mini outrigger trawlers fishing for shrimp and demersal species in shallow waters off the Indian coast of Orissa and Bengal, the replacement of day boats by so-called ice boats with improved onboard preservation facilities in the flying fish fishery of

Barbados, the modernization and improvement of sloops and launches to cater to the requirements of export markets in Antigua and Barbuda, the diversification of purse seining and pole and line fishing in Indonesia, and the modernization and upgrading of coastal vessels in Thailand, Norway, France and Germany.

In offshore fisheries, the expansion/development of new profitable fisheries with high capitalization and technology was observed. Examples include French and Spanish tuna seiners, German pelagic trawlers, Norwegian combination vessels equipped for pelagic trawling and purse seining, and tuna longliners in India and Indonesia.

Vessels that had previously shown positive results but now incurred losses were generally older vessels, which were continuing to work on overexploited stocks. Examples are Chinese bottom pair trawlers of 25 to 28 m in length, Chinese single bottom trawlers of 26 m in length, Chinese stow-netters of 30.5 m in length and Chinese purse seiners/set-netters of 36 m in length, all of which showed net losses – the stow-netters even showed operational losses – while previously only pair trawlers had shown a net loss and no vessel showed operational losses. Indian purse seiners of 14 m in length fishing mackerel and sardine in the Arabian Sea also showed net losses, while previously they had made a net profit.

Senegalese purse seiners targeting small pelagics and fishing off the West African coast, which had previously shown net profits, now recorded net losses, although they still recovered their operating costs.

The situation also deteriorated for German cutter trawlers of 22 to 32 m in length fishing demersal fish stocks in the North Sea and Baltic Sea, as well as for German factory trawlers of 60 to 80 m in length fishing demersal fish resources off Greenland and in the waters of the EC. These all showed net losses, but not operational losses, having previously shown a net profit.

Spanish pole and line vessels of 24 m in length also made net losses after making a net profit during the previous study period.

Types of vessels that showed net losses during the first study and a net profit in the second

include three types of Spanish tuna seiners of 56, 64 and 70 m in length, deep sea trawlers of about 30 m in length, and three types of deep sea trawlers ranging from 15 to 24 m in length.

## AQUACULTURE DEVELOPMENT IN CHINA: THE ROLE OF PUBLIC SECTOR POLICIES

### INTRODUCTION

Policy-makers and development agents are increasingly viewing aquaculture as an integral component of the search for global food security and economic development. Mainland China is the world's leader in aquaculture production following a steady development during the last three decades. Identification and analysis of the issues and factors that motivated aquaculture development in China could play a critical role, not only in understanding the future of aquaculture in China, but also in shaping aquaculture development in many parts of the world. It is within this framework that the FAO Fisheries Department and the Government of China jointly conducted this study. The ultimate goal was to evaluate ways in which the Chinese experience of sustainable and lucrative aquaculture development could benefit other countries with aquaculture potential, especially developing countries.<sup>12</sup>

The approach taken to achieving this goal consisted of answering four questions concerning aquaculture in China: Why did aquaculture develop so sustainably? What is its current development level? How was this development achieved? and Where is aquaculture heading?

The information presented in this article came

<sup>12</sup> This article is a summary of FAO. In press. Aquaculture development in China. The role of public sector policies. FAO Fisheries Technical Paper No. 426. The paper and the associated study cover all of China except Taiwan Province of China. It was prepared by a team of Chinese experts and FAO staff and consultants. The data presented on Chinese aquaculture were provided by the Government of China and differ somewhat from some of the data previously published by FAO. Given that the primary purpose of this article is to highlight the policy contributions to the rapid growth of aquaculture in China, it was not considered essential that these statistical differences be reconciled.

mainly from existing documentation on the sector, observations from field visits by experts, and the study team's knowledge of the sector. Major players in the sector also provided useful information. The article discusses the main findings of the study before closing with some concluding comments.

## MAIN FINDINGS

### The reason for aquaculture development

China has a long history of aquaculture development, which can be divided into three main phases: the pre-1949 period, the 1949–1978 period, and the period from 1978 to the present. The foundations for aquaculture development and growth were laid in the period between 1949 and 1978, after which development has been rapid and steady.

Development seems to have been prompted by food self-sufficiency and economic factors. When the People's Republic of China was born in 1949, the country had just emerged from a period of foreign domination and civil strife. The economy was totally wrecked. Poverty was rampant, food scarce and famines frequent and widespread. As the government strived to rebuild the country's economy, its first priority was to mobilize and organize all the available national resources at its disposal in order to produce enough food and raw materials to feed and clothe the population. Given their production cycles, fisheries and aquaculture were considered to be two sources of animal protein that could be tapped in a short time. In addition, fish was already an accepted food item in people's diet and its production through farming and the harvest of natural waters was well established in China. The goal was also to produce for export in order to earn much-needed foreign exchange with which to purchase capital goods for the construction of the economy.

### Current state of the art

Major aquaculture systems, species and production technologies. Major freshwater aquaculture systems include pond, cage, pen and paddy-fish culture in rice fields and indoor running water systems. Pond culture is the most popular and most important fish farming system

in China. Major species cultivated in ponds include carps, Chinese bream (*Megalobrama amblycephala*), mandarin fish (*Siniperca chautsi*), Japanese eel (*Anguilla japonica*), Japanese prawn (*Macrobrachium nipponensis*), mussel (*Hyriopsis cumingii* and *Cristalia plicata*), river crab (*Eriocheir sinensis*), soft-shelled turtle (*Trionyx sinensis*) and introduced exotic species such as channel catfish (*Ictalurus punctatus*), tilapia (*Oreochromis niloticus*), giant prawn (*Macrobrachium rosenbergii*), large-mouth bass (*Micropterus salmoides*) and rainbow trout (*Onchorhynchus mykiss*).

Marine and brackish water culture systems range in type from ponds to floating rafts, pens, cages (inshore, offshore and submerged), tunnels, indoor tanks with water recirculation, sea bottom culture and sea ranching. Before 1980, three species – the seaweeds Japanese kelp (*Laminaria japonica*) and purple laver (*Porphyra tenera*) and the mollusc blue mussel (*Mytilus edulis*) – accounted for about 98 percent of the total marine aquaculture output. Currently, in addition to these species, important marine species include two shrimp species (*Penaeus monodon* and *P. chinensis*), the molluscs oysters (*Ostrea* spp.) and razor clam (*Solen constricta*), scallops (*Argopecten* spp.), abalone (*Haliotis discus hannai* and *H. diversicolor*) and finfish.

Farm organization and structure, and relationships among farmers. Ownership of aquaculture ventures in China comprises state, corporate, individual, joint venture and independent foreign venture ownership. In the southern part of China's coastal provinces and autonomous regions, including Zhejiang, Fujian, Guangdong, Guangxi and Hainan, more than 90 percent of the farms belong to individuals and private corporations. In some areas of the region, such as Wenzhou and Taizhou in Zhejiang Province, joint ventures and cooperative farms account for 100 percent of aquaculture businesses. Most partners in joint ventures with foreign investors are from Taiwan Province of China. In the northern part of China's coastal provinces, about 80 percent of aquaculture businesses are corporations. In the country's inland areas, more than 90 percent of freshwater

fish farms are individually or family-owned.

Farm sizes and distribution depend on the species cultured and the geographical location. In northern areas, especially in Shandong and Liaoning provinces, most mariculture farms are large-scale, commercial operations producing mainly kelp, flatfish (*Paralichthys olivaceus*), scallop and abalone. In southern and inland areas, small-scale farms are preponderant; most of them are freshwater fish farms operated by family units.

Mutually reinforcing relationships between small- and large-scale producers exist. The heads of large-scale companies, referred to as "heads of dragons", can sign contracts with small-scale fish farms involving capital investment, product collection, technical guidance and provision of market information to the small-scale farms. In return for these services, large-scale companies gain community support, which is an essential ingredient for the sustainability of their enterprises, and economic gains.

**Seed and feed production.** Because of the high demand for seeds, China has hatcheries for a host of different species.

With the exception of eel farming, which still collects seeds from estuarine areas or imports them from other countries, including France, most of the seeds of farmed species are supplied from hatcheries. Hatcheries consist of well-developed bases/stations that are operated by corporations, collectives or individuals. The National Fisheries Technology Extension Centre is responsible for guiding breeding techniques and introducing genetic materials from one region to another. The Fish Identification Committee, under the leadership of the National Bureau of Fisheries, is responsible for the identification of genetic materials and the establishment of multiplication centres.

There are about 12 000 feed mills producing various kinds of animal feeds, including fish feed. Of these, about 1 900 have a production capacity exceeding 5 tonnes per hour. The state still plays an important role in the production of feed for aquatic animals and owns slightly more than 47 percent of the mills, down from 99 percent in 1990. Domestic corporations control 47.6

percent of the mills, up from 0 percent in 1990. The contribution of joint ventures has also been increasing, although slowly; in 1999, they accounted for 3.8 percent of the feed mills for aquatic animals, compared with 0.1 percent in 1990.

**Markets and marketing.** Aquaculture products are sold in fresh and processed forms. Although most products are sold fresh, basic fish handling and processing technologies are being progressively replaced by the latest modern technologies to add more value to various fish products. Frozen or cold-stored products are replacing salted ones; large packages are giving way to small ones; and soft tin containers are used in lieu of glass containers.

**Research, education and extension.** The research system consists mainly of national and local fisheries research institutions and universities. In 1999, there were 210 fisheries research institutes in China. National research institutions and universities, most of which are engaged in basic and applied research, are the major power for aquaculture research and technological development. National research institutions are funded by the central government and are under the direct administration of the Chinese Academy of Fishery Sciences within the Ministry of Agriculture. Universities fall under the administration of the Ministry of Education or provincial governments. Local institutions focus on solving the technical problems that affect local aquaculture development. They are more producer-oriented and are sometimes quicker to respond to farmers' needs than are the other two categories. Often, they are also a step ahead of national institutions and universities in terms of practical technological advances. They are funded mainly by provincial and/or municipal governments. Non-fisheries commercial private companies also sponsor aquaculture research, especially in the areas of aquaculture feeds, chemicals (for the control of fish diseases) and breeding and culture technologies of high-value species.

The government has established a system of aquaculture education and training that can



generally meet human resource requirements for the development of the sector.

Education and on-the-job training are fully supported by central and local government. Some 30 universities enrol about 1 000 undergraduate students in aquaculture every year, five universities and research institutions offer doctoral degrees, and nine award master's degrees in aquaculture and closely related areas. There are also about 20 technical secondary schools and a large number of vocational schools with the major task of producing skilled workers for the aquaculture and fisheries sector.

Aquaculture extension has always been strongly supported by the government. The National Fisheries Technology Extension Centre is the national institution responsible for aquaculture extension, and 18 462 fisheries extension stations form a network of services across the country. Extension is jointly funded by central and local government. Research institutions are also starting to extend their findings directly to farmers. As aquaculture develops, a growing number of organizations and commercial companies outside government, especially feed and chemical companies, are showing interest in extension activities. Their motive is profit, as they see extension as an effective means of promoting markets for their products.

Major strengths and constraints. As well as supportive government policies (which are discussed in the following subsection), the main strengths of Chinese aquaculture include well-established seed production technology for freshwater species, a strong and continuing research and development infrastructure, a solid extension service, relatively higher profit and net income per unit of labour, and a strong domestic and international demand for aquatic products. Major constraints include: the continued threat of environmental degradation and disease outbreaks; little improvement in seed supply and genetic conservation; limited suitable land for expansion of land-based aquaculture; and, in many areas, inadequate primary fishery facilities and infrastructure.

## DEVELOPMENT POLICIES

### General sector-specific policies

A rich general policy mix led to the noticeable development of aquaculture at different periods in China.

Self-reliance in fish through the full employment of resources. When the People's Republic of China was proclaimed in 1949, the government developed a highly centralized system of planning, development and management that continued until the implementation of an open-door policy and economic reforms in the late 1970s. During this period, the government's policy was to push for the population's full participation in the economic life of the country, including in the aquaculture sector. The primary goal was fish self-reliance.

Setting aquaculture as a priority in the development of the fisheries sector. Before 1979, the guiding principles for fisheries and aquaculture emphasized marine fisheries and fishing and tended to underrate freshwater fisheries and aquaculture. This policy led to the severe destruction of fishery resources and the slow development of aquaculture. Thereafter, the government issued a series of regulations to protect fishery resources and to make aquaculture development one of its priorities. Targets were set and means of achieving them defined. Guided by these general principles and policies, which were supplemented by other relevant and more specific policies, Chinese aquaculture development recovered from stagnation. By 1985, output from freshwater and marine water aquaculture had reached 3 090 000 tonnes, accounting for about 43 percent of the combined capture fisheries and aquaculture output.

Establishment of aquaculture production bases. Owing to the construction of government aquaculture production bases, aquaculture developed into an important industry for the rural economy. By 1986, the total area covered by the government's aquaculture bases in China had reached nearly 2 400 km<sup>2</sup> and was yielding 1.5 million tonnes, nearly 50 percent of the country's total aquaculture output for that year.

Promotion of sustainable aquaculture development. Ten years after the Instructions on the Release of Restrictions to Expedite the Development of the Aquatic Products Industry were promulgated in 1986, the industry had developed very rapidly. However, many problems emerged alongside the increase in output. Poor management of aquatic seed resulted in high mortality; diseases broke out; the dissemination and transfer of aquaculture technologies was inadequate; and poorly constructed infrastructures and facilities were widespread. In order to foster and boost the sustainable and rapid development of aquaculture, the State Council issued regulations that demanded further reform and liberalization of aquaculture, radical changes to the structure of the sector, adjustment of the species mix and production structure to market conditions, and the development of new technologies to improve the performance of the whole fisheries sector so as to ensure its sustainable development.

Continuous adjustment of the structure of the aquaculture sector. As the industry developed, it soon became apparent that there were serious inherent structural problems, which needed to be addressed if growth was to continue. In the main aquaculture production areas, the supply of some traditional species exceeded demand, resulting in low prices, reduced sector efficiency and depressed producer incomes. In response, in 1999 the Ministry of Agriculture released the Guiding Instrument on Adjusting the Structure of the Fishery Sector, which had the aim of restructuring the fisheries sector, including aquaculture. The guiding principle concerning aquaculture was to increase efforts to develop new markets and expand existing ones, increase the demand for fish through market promotion, develop new value-added products, improve the quality of aquatic products through technological innovation, provide improved infrastructure and facilities, and reform the legal system.

Establishment of a good administrative framework for aquaculture management and creation of a specialized agency. The National Bureau of Fisheries is the functional department in the

Ministry of Agriculture that coordinates the administration of the fisheries sector, including aquaculture. Its main functions are to:

- supervise implementation of the state's general principles, policies and plans for the fisheries sector;
- study and put forward measures for technological advances in fisheries development;
- protect fishery resources and utilize them rationally;
- promote fisheries development;
- organize and supervise the construction of infrastructure in the fisheries sector.

In general, the National Bureau of Fisheries studies and initiates the establishment of general policies and regulations, which are then submitted to the Ministry of Agriculture, the State Council or the People's Congress for approval. Once general policies and regulations have been promulgated, the National Bureau of Fisheries supervises their implementation. The bureau can also set up some specific policies within its area of jurisdiction. Depending on the province concerned, province-level fishery authorities initiate the implementation of the policies/regulations by themselves or after obtaining approval from the provincial government. Other supporting structures for the fisheries sector include: the National Fisheries Technology Extension Centre, which is a semi-governmental institution dealing with implementation of the state's policies on fishery technology and extension services; the Chinese Fishery Academy, which is the national-level academy involved in research on specific subjects, such as the biology of aquatic animals, fishery resources and the socio-economics of fisheries; and the China Society of Fisheries, which is an organization of fishery technicians dealing with technical exchange and promotion. The activities of all of these are coordinated by the National Bureau of Fisheries.

Establishment of a good legal and regulatory framework for aquaculture development. The basic law in fisheries and aquaculture is the

Fisheries Law of the People's Republic of China, which was promulgated by the Standing Committee of the National People's Congress in 1986 and revised in 2000. It first established guiding principles in the development of aquaculture, fishing and processing. Other important parts of the legal system that regulate sustainable development in the fisheries sector, including aquaculture, are the regulations, rules and directive notices that protect fishery resources, provide access to water and areas, protect the environment and control aquaculture production methods and techniques, as well as ensuring the safety of aquatic products. The Fisheries Law is often supplemented by Notices focusing on critical issues facing the industry at the national level.

Emphasis on research, technological development and information dissemination. The rapid development of aquaculture of the past two decades has been strongly supported by research, technology development, education, training and extension, most of which is funded by the government. Scientific research and technological progress, especially the adoption of breeding technologies for different culture species, contributed more than 50 percent to the growth of aquaculture output between 1979 and 1999.

Promotion of high-value species. Prior to the 1970s, the main species cultured in mariculture were seaweeds and molluscs, while herbivorous or omnivorous filter-feeding fish species, such as carps, dominated freshwater aquaculture. There were no feed manufacturers for aquatic animals in China, as there was no supporting demand. When a protein diet was required, trash fish were used as the main ingredient. With the introduction of high-value species such as shrimp in the late 1970s, the home-based feed processing model quickly failed to meet the increasingly high demand for high-quality feed, and this stimulated the development of the fish feed industry. The development of the feed industry further induced the private sector to engage in the farming of more high-value species in both fresh and brackish water, such as the

mitten crab, the soft-shelled turtle, eel and the red seabream in the late 1980s and early 1990s. The diversification of high-value species resulted in expanded aquaculture output.

### **Issue-specific policies**

The government also used policies to address specific issues, such as seeds, feed, technology, land and marketing.

Policies on seed issues. The government addressed the limited availability of high-quality seeds, especially of strong, disease-free and disease-resistant seeds, by encouraging private investment in hatcheries, enacting policies aimed at controlling seed quality, and setting up legal provisions on seed production and dissemination.

Policies dealing with feed issues. Feed-related issues were alleviated through the sponsoring of research in feeds and nutrition, the establishment of a regulatory framework for the development of the feed industry, and the provision of economic incentives to investors, especially preferential tariffs on the raw materials used in feed manufacturing.

Policies dealing with appropriate technologies. The government has continued to apply a multitechnology policy to the development of aquaculture. Thus, national research institutions are distributed across the country's climatic and geographic zones. There are five freshwater fisheries research institutions: one in the subtropics; one in the area close to frigid zones; one in the central eastern part of the country; and two in the inner western part. The three marine fisheries research institutes are also evenly distributed, from south to north along China's coast. Different research institutions have developed broad varieties of production technologies for different regions. The government also strongly promotes the diversification of species, especially through the introduction of foreign technologies and exotic species with good commercial aquaculture potential and the expansion of private sector involvement in technological development,

particularly in such areas as the breeding of high-value species and the enclosure of running water systems.

Policies dealing with marketing issues. Recent government policies in marketing have consisted of breaking the state's market monopoly. Under the centralized planning economic structure prior to 1978, the state had the monopoly for buying and distributing aquatic products. This policy greatly reduced farmers' incentives to expand aquaculture production. Since 1979, the government has been reforming the marketing system for aquatic products by gradually, but drastically, liberalizing and privatizing their production, marketing and distribution. Trade barriers among the country's regions were also abolished. In order to develop China's fisheries and aquaculture further, since 1985 the government has created an enabling environment for market development by issuing a series of policies that allow market forces to determine prices of aquatic products; influence open market dynamics and create and set criteria for the construction, design, organization and management of wholesale markets; establish offices responsible for the management of fish product distribution channels; and promote local wholesale market development. The government has also established seafood market information networks and centres which collect information from various markets and disseminate it to the public, especially to companies for use in their production decision-making and planning.

Land issue policies. Land issues were addressed through the structural reform of farm ownership and property rights policies. Since the early 1980s, the government has encouraged and supported the transfer of farm ownership from the public to the private sector. In contrast to the former collective system, in which ownership and the benefits accruing from farming belonged to the state and/or the collective, under the new land law, the socialistic principle of a collective economy and property rights (particularly ownership and individual rights to farm produce) are guaranteed and given to collective members. Each member has equal rights to the farm and

gets a share of the value of its produce. Investment issue policies. Prior to 1979, government enterprises were the norm. Thereafter, a proportion of the productive capital has changed from government allocation to government loans. The government has also provided grants and subsidies to investors, introduced a tax system whereby the tax burden on investments is shared between central and local government, and encouraged joint ventures between central and local government, on the one hand, and between domestic and foreign private investors, on the other.

### THE WAY FORWARD

The government intends that aquaculture in China should not only be environmentally friendly, but also rational, healthy and sustainable. It is working towards establishing a plan of action and a sound management system to safeguard the environment. Steps have also been made in developing appropriate management strategies through adoption of the precautionary principle approach, as embodied in FAO's Code of Conduct for Responsible Fisheries. Preventive measures for non-point sources of pollution affecting aquaculture, mainly resulting from land wastes, are planned. These will be achieved through suitable awareness building and the implementation of regulatory control programmes by the responsible authorities.

The future of aquaculture in China looks promising. The government's commitment and support of the sector is strong. Aquaculture continues to be a high priority. The private sector is more interested in aquaculture than it is in other agriculture subsectors of the national economy. Output from capture fisheries is unlikely to increase in the foreseeable future. The demand for fishery products is growing, both within China and internationally. China has good potential for increasing the share of its aquaculture products in international markets, helped by its membership of the World Trade Organization (WTO). The development of freshwater integrated farming, paddy-fish culture and marine aquaculture, and the implementation of participatory community extension services are

the main means for achieving these expectations.

As it continues to develop, aquaculture is expected to continue playing an important role in Chinese society by ensuring food supply and alleviating rural poverty, especially through job creation and income generation for the rural poor. Processing, value adding, marketing and the ornamental fish industry are expected to improve, thereby contributing to the well-being of China's urban, suburban and rural population.

Nevertheless, there are some major impediments to further aquaculture development in China. The supply and availability of quality seed in marine aquaculture are still low. In some well-established aquaculture areas, the supply of traditionally cultured species such as Chinese carps greatly exceeds the market demand, and this seriously depresses prices. The high-value or market-preferred species that are in demand in domestic and international markets are not fully exploited on a large scale. Farming technologies are outdated, often resulting in inefficiency. Water is polluted in some areas, leading to disease outbreaks. Suitable land for land-based aquaculture is also limited.

## CONCLUSIONS

China is the world's largest producer of farm-grown aquatic products today. Apart from the country's sheer size and population, this achievement stems mainly from proactive government policies on fisheries, in general, and aquaculture, in particular.

Aquaculture in China has developed through two policy regimes: the egalitarian model under centralized state planning from 1949 to 1978, and the open market economy regime, which started in 1978. The early egalitarian model was primarily responsible for much of the progress achieved in securing food self-sufficiency in fish. Under this model, the government's first priority was to mobilize and organize all the available national resources at its disposal in order to produce more food and raw materials with which to feed and clothe the population. These policies involved the full participation of China's rural communities, which constituted almost 80 percent of the country's total population in the 1950s, and have been highly effective in making

Chinese aquaculture what it is today. In addition, the policies led to the creation and accumulation of real assets and wealth at the national, local and individual levels. Rural incomes and livelihoods significantly improved. The policy of rural communities' full participation in aquaculture also produced skilled aquaculture workers for the development and expansion of the industry. In the open market economy model, in which free market forces are allowed to determine the allocation and transformation of productive resources and to allocate aquaculture output among consumers, food self-sufficiency policy has continued to be the pillar of aquaculture development. Other goals are efficiency and acquisition of the much-needed foreign exchange with which to purchase capital goods for rebuilding the economy.

The main engines of aquaculture growth have been the government's recognition of the sector as a development priority; the full utilization of productive resources, including suitable water surfaces, mudflats and waterlogged lands, as well as people; investment in research and technology; the establishment of a nationwide aquaculture extension network reaching the grassroots level; the promotion of aquaculture for poverty alleviation, food security and employment in poorer provinces; and the establishment and constant improvement of the legal framework and regulatory system.

With continued proactive government policies, adequate advanced planning, scientifically designed production technologies and sound management, aquaculture in China can be, and is likely to be, productively stable, sustainable, equitable and profitable. Responsible aquaculture intensification remains physically feasible and will most likely develop, as the best sites have already been used and there is a growing need to protect and preserve the natural environment.

The main challenges to further aquaculture development in China are the limited supply of good-quality seeds for some species; the oversupply of traditionally cultured species, such as carps, which results in low prices; the underexploitation of high-value species; outdated farming technologies; water pollution; the limited

suitable land for expansion; and frequent fish disease outbreaks. In order to overcome these constraints, it can be expected that the Chinese authorities will:

- consider developing industrialized farming systems by improving the design of and upgrading production systems, employing the latest technology and selecting the best combination of species to respond to market conditions in both domestic and international arenas;
- strive to increase the market share of high-value freshwater species suitable for export, and achieve production efficiency, which in turn suggests large-scale industrial farms;
- give greater emphasis to the production of high-quality seed by making use of modern biotechnology;
- establish an integrated scientific system and network of fish breeding and seed production for high-quality indigenous or endemic species, as well as developing fish health management and disease prevention, diagnosis, control and treatment.

The pursuit of policies of this kind implies allocating additional funds to aquaculture development, particularly to support projects in

appropriate areas and locations, especially in mid-western regions of the country.

The Chinese models and experiences of aquaculture development provide the following valuable lessons to other developing countries in their efforts to promote and develop aquaculture:

- Aquaculture can be developed in a sustainable manner to generate food and jobs and improve the income and livelihoods of rural and urban populations, thus alleviating hunger and poverty.
- The engine for economically resilient and sustainable aquaculture is the government's will and resolve to establish sound policies to support and develop the sector.
- Full employment of productive factors, including human resources, continuous improvements in the legal and regulatory framework for the development of the sector, and scientific breakthroughs in production technologies will strengthen aquaculture and ensure its sustainability, thereby making it a good contributor to the country's overall economic growth through the supply of food, employment and foreign exchange and the creation of infrastructure, especially in rural areas. ♦