ISSN 1198-6727

Production Systems in Fishery Management

Fisheries Centre Research Reports
2002 Volume 10 Number 8

ISSN 1198-6727

Fisheries Centre Research Reports

2002 Volume 10 Number 8

Production Systems in Fishery Management

Fisheries Centre, University of British Columbia, Canada

Production Systems in Fishery Management

Edited by
Daniel Pauly and Maria Lourdes D. Palomares

A Research Report from the
Sea Around Us Project
Sponsored by the Pew Charitable Trusts,
Philadelphia, USA

Fisheries Centre Research Reports Volume 10 Number 8
28 pages © published 2002 by
The Fisheries Centre, University of British Columbia
2204 Main Mall
Vancouver, B.C., Canada

ISSN 1198-6727

PRODUCTION SYSTEMS IN FISHERY MANAGEMENT

Edited by

Daniel Pauly and Maria Lourdes D. Palomares

2002 Fisheries Centre Research Reports 10(8): 28 pages

CONTENTS

A Research Report from the Sea Around Us Project

Supported by the Pew Charitable Trusts of Philadelphia, USA

FISHERIES CENTRE RESEARCH REPORTS ARE ABSTRACTED IN THE FAO AQUATIC SCIENCES AND FISHERIES ABSTRACTS (ASFA)

DIRECTOR'S FOREWORD

Use your loaf and fish

Someone forgot to pack food for the picnic. In addition, far too many people turned up. Only a miracle could overcome such poor logistics. The Christian parable of the 'feeding the multitude' depicts a solution. The different gospels are a bit hazy on detail: was it five or seven loaves, two or a few fishes, seven or twelve baskets, four or five thousand men; and what about the women and children? And in Matthew's gospel, a second multitude is fed.

Well, all the variants qualify for miracle status. The loaves and fishes image, apparently symbolizing the mass, is common among the earliest archeological remains from mid-2nd century Christian catacombs in Rome. The fishy secret symbol of early Christians shares this origin with the famous acrostic of 'ichthus'.

The *Parable of the Loaves and Fishes* as painted in 1578 by Tintoretto (Jacopo Robusti; 1518—1594), a Venetian named 'little dyer' after his father's profession: his images inspired the 17th century baroque movement. The 'feeding of the five thousand' story is the only parable found in all four Gospels (*Mark 6:32-4; Matthew 14:13-21; Luke 9:10-17; John 6:1-16*). Tintoretto's painting depicts the miracle as described in *John*, showing Jesus handing Andrew one of the five loaves and two fishes to be distributed to the crowd.

Scuola di San Rocco, Venice, oil on canvas, 538 x 325 cm

Ensuring a useful outcome from messy logistics is the origin of the papers published in this report, although whether the result qualifies for the epithet 'miraculous' I will let readers decide, by using their own loaf. This report presents, in just a few pages, a broad coverage of capture fisheries including vital issues of size and scale, economic factors, aboriginal fisheries, and aquaculture issues. We learn that small-scale fisheries (rather like those operated by Jesus' disciples) have a number of attractive features in equity of benefits and employment, lower environmental costs, although at the end of the day, they may be equally hard to control. Aboriginal fisheries deserve prime allocation rights, partly as restitution for past wrongs and partly in recognition of the need for today's economic activity. Aquaculture is alright if the right type of fish is farmed and its environmental impacts are minimized.

The overall message of the papers published here, perhaps, is to use your loaf when you fish. Students, and others in the Pacific Northwest, may find the report a useful starting point for description of many topics covered by Fisheries Center faculty and associates. Perhaps this basket of such issues can keep five thousand satisfied.

The Fisheries Centre Research Reports series publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focusses on the multidisciplinary problems of fisheries management, and aims to provide a synoptic overview of the foundations, themes and prospects for current research. Fisheries Centre Research Reports are recorded in the Aquatic Sciences and Fisheries Abstracts and are distributed to appropriate workshop participants or project partners. A full list of the reports is published at end of this issue. All papers are available as free PDF downloads from the Fisheries Centre's Web site *www.fisheries.ubc.ca*, while paper copies of a report are available on request for a modest cost-recovery charge.

Tony J. Pitcher
Professor of Fisheries
Director, UBC Fisheries Centre

PREFACE

The contributions in this report were originally prepared for inclusion as a section of a CD-ROM encyclopedia devoted to production systems, both land-based and aquatic. Conflicting commitments and miscommunications led to this work not being included in the encyclopedia in question, leading to four orphan contributions.

Upon re-reading these, however, we realized that their specific format suits them rather well as background reading for introductory fishing and aquaculture courses at under or graduate levels. Thus, while updating and preparing these contributions for publication through this report, we have added recent related references that can be freely downloaded from the Fisheries Centre web site (www.fisheries.ubc.ca), notably from amongst the products of the *Sea Around Us* Project (www.saup.fisheries.ubc.ca). The authors' biographies, a quirky requirement of those who originally commissioned these contributions, were retained (page 28), if only to show students who is behind writings of this sort.

Daniel Pauly

and

Maria Lourdes D. Palomares

Vancouver, December 2002

FISHERIES MANAGEMENT: SUSTAINABILITY VS. REALITY

Daniel Pauly
Fisheries Centre, University of British Columbia, Vancouver, Canada

CONTENTS

GLOSSARY

Biomass: The combined weight of all the members of a given population or stock.

Catch: The number or weight of all fish killed by fishing operations, whether the fish are landed or not.

Discard: Fish that are caught by fishing, but not landed, i.e., that are thrown overboard.

Overcapitalization: Excessive numbers of boats and/or gear deployed to exploit a fish population, relative to the fishing pressure that this population can sustain.

Overfishing: Catching more fish than the maximum that a multispecies population can produce, thus inducing a decline in their abundance.

Trophic level: A number, usually ranging from 1 to 6, expressing the position of organisms within food webs, with plants having a trophic level of 1, herbivores 2, first order carnivores 3, etc.

SUMMARY

Fisheries have a long history, marked mainly by lack of sustainability. This has become worse since the Industrial Revolution, which added industrial fishing vessels to the smaller crafts and fixed gear that had so far been used to exploit coastal fish populations. The added fishing effort led globally to a massive increase of catches from offshore and/or distant areas previously not exploited. Also, this added effort led in many countries to the marginalization of small-scale fishers, and especially of aboriginal people. However, present levels of effort are unsustainable, if only because of the ecological damage they generate, and which research has so far largely ignored. Reestablishing a semblance of sustainability will require a massive reduction of fishing effort in most parts of the world. This may be achieved, at a minimum of social cost, by replacing, wherever possible, large and invariably subsidized industrial (and/or distant-water) fleets, by ecologically more benign small-scale operations.

1. INTRODUCTION: FROM FORAGING TO INDUSTRIAL FISHING

The earliest evidence of fishing by humankind so far identified is sophisticated bone harpoons, recovered, along with middens and related evidence, by archeologists digging at a site estimated to be 90 000 years old, in present day Congo (formerly Zaire). The main species that was targeted is a now extinct, 2 m long, freshwater catfish; most probably, the fishers in question moved on to other species. This pattern of fisheries exterminating the population upon which they originally relied, and then moving on to other species, has been going on since.

The last major step in fisheries was the development, during the Industrial Revolution, of vessels of unprecedented fishing power, such as stream trawlers. Added to the substantial fishing effort of the traditional, small-scale fleet that operated inshore and tended to target juveniles, these industrial vessels, targeting stocks of adult fishes further offshore, quickly reduced populations that had previously been perceived as immune to the effects of fishing.

2. LARGE-SCALE VS. SMALL-SCALE FISHERIES

The developments of a dual sector, consisting of a few large vessels competing usually for different life stages of the same shared resources with a multitude of small coastal vessels, or fixed gear (or 'industrial' *vs*. 'artisanal'), as occurred in Europe at the end of the 19th Century, was quickly duplicated in other parts of the world, either via local industrialization (US, Canada, Japan, Korea, etc.), via import of vessels (India, Southeast Asia), or via distant-water fleets operating with or without the agreement of the coastal country, as often occurs along West African coastlines. Overall, fishing effort is now at least two or three times what would be required to harvest world catches, and this may be explained as a result of profit maximizing firms competing against each other while exploiting largely open-access resources.

Besides this problem of global overcapacity, the duality of the fisheries sector illustrated in Figure 1, and almost everywhere in the world, in pitting artisanal fishers against the operators of industrial fleets, is one of the greatest problem besetting fishing enterprises.

Indeed, the two problems are closely interrelated. Thus, 'buy-back' programs aiming at reducing fleet overcapacity often have the perverse result of eliminating relatively harmless small-scale craft, while subsidizing the modernization of industrial fleets.

Moreover, the duality of fisheries, and the within-sector competition it entails, also makes it very difficult to address issues of sustainability, as each subsector believes all would be well if the other were not operating. Indeed, it took two World Wars, and the recovery of major fish stocks from fishers and fishing vessels drafted into the war effort, for the notion of sustainable fishing to become widely accepted, at least in theory, by the industry as a whole. Sustainable fishing, and its converse, overfishing, imply that fisheries have strong impact on the abundance and biological productivity of fish stocks, and that therefore, there should be, for each fishery/resource complex, a level of fishing effort such that its yield is optimized.

Fisheries research, in the three decades following the Second World War, turned this costly insight into quantitative fish population dynamics, and 'stock assessments,' based mainly on the mathematical models of R. J. Beverton, S. J. Holt and J. A. Gulland in England, M. B. Schaefer in the US, and W. E. Ricker in Canada. However, the demonstration, though these models, of the benefits of limiting fishing effort, did not stop the relentless expansion of industrial fleets. Rather, during this same period, they expanded throughout the world, to Latin America, the shores of newly independent states of Asia and Africa, and into the subpolar and polar seas. Global landings in this period climbed from 20 million in 1950 to 70 million tonnes in 1975 (Figure 2).

None of these fisheries came even close to being sustainable, even by the standard of their time, and only a few stock collapses were strong enough to induce reflection. One of these was the 1972/73 collapse of the Peruvian anchoveta, *Engraulis ringens*, visible even in the highly aggregated trend of Figure 2. However, as this collapse was associated with an El Niño event, it sent to managers and scientists the (misleading) message that fisheries are typically at the mercy of environmental fluctuations. Thus, the collapse, in the 1970s, of the demersal resources of the Gulf of Thailand was far more representative of fisheries in general, in that it showed how a modern fleet could reduce a coastal multispecies stock, within a decade, to less than one tenth of its original biomass. Indeed, the Gulf of Thailand trawl fishery reenacted the destruction of coastal stocks that occurred in the North Atlantic at the end of the 19th Century.

In the 1980s and 1990s, the technological and geographic expansion of industrial fleets continued, but led to relatively small increases in global marine landings, then to stagnation and decline (Figure 2). This, however, went along with a massive increase of discarding unwanted by-catch, now estimated at nearly 30 million tonnes, and of widespread cheating, along with the accompanying degradation of catch statistics. The latter, also due to government staff and cost-cutting measures led, in many areas of the developed world, to largely unreliable catch statistics, not to speak of developing countries, where the multitudes of species caught, and of places where they are landed, accentuates the lack of resources devoted to monitoring the fisheries.

During this period, fisheries research went on, much of it along traditional lines, i.e., performing assessments for single-species fisheries, in view of estimating their Total Allowable Catch (TAC), while fighting off claims by conservationists asserting, with increasing public support, that industrial fisheries systematically destroy their resource base.

Yet the scientific evidence for large-scale ecosystem impacts of industrial fishing is extremely strong, and it is hard to conceive how fisheries research will be able to continue as a credible activity if it cannot restructure itself around that evidence. One reason why this should be possible is that multispecies models derived from standard, single-species models, do in fact predict pervasive ecosystem impacts of exploiting single species.

FISHERY *BENEFITS*	**LARGE SCALE**	**SMALL SCALE**
Number of fishers employed	about ½ million	over 12 million
Annual catch of marine fish for human consumption	about 29 million tonnes	about 24 million tonnes
Capital cost of each job on fishing vessels	$30,000 - $300,000	$250 - $2,500
Annual catch of marine fish for industrial reduction to meal and oil, etc.	about 22 million tonnes	Almost none
Annual fuel oil consumption	14 – 19 million tonnes	1 – 3 million tonnes
Fish caught per tonne of fuel consumed	= 2 – 5 tonnes	= 10 – 20 tonnes
Fishers employed for each $1 million invested in fishing vessels	5 - 30	500 – 4,000
Fish and invertebrates discarded at sea	16 – 40 million tonnes	None

Figure 1. Schematic illustration of the duality of fisheries prevailing in most countries of the world, using numbers raised to global level (based on an original graph by David Thompson, updated with FAO data). This duality of fisheries, which largely reflects the misplaced priorities of fisheries 'development,' offers the opportunity for reducing fishing mortality on depleted resources while maintaining social benefits, by reducing mainly the large-scale fisheries.

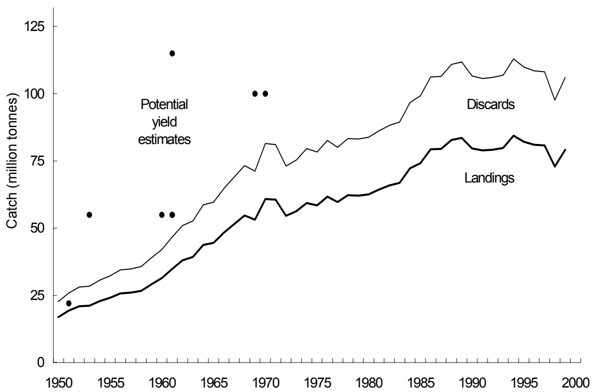

Figure 2. Marine global fisheries catches (1950s to 1990s). Estimates of discards are based on a study from the early 1990s, scaled to landings for the other periods. Some potential yield estimates are also plotted above their year of publication.

3. CASES OF ABSENT SUSTAINABILITY

3.1 Hypothesis: Resources are Inevitably Overexploited

It can be argued that the sustainability of fisheries is a myth because improved technology and geographic expansion has caused fishing to actually induce serial depletions leading to the exploitation of previously spurned species lower in the food web. The consistent and global decline in catches starting from the late 1980s and the further continuation of present trends will lead (and in some cases already has) to the general collapse of marine resources.

We suggest that such consistency is due to the following common features:

- Wealth or the prospect of wealth generates political and social power that is used to promote unlimited exploitation of resources;
- Scientific understanding and consensus is hampered by the lack of controls and replicates, so that each new fishery involves learning about a new system;
- The complexity of the underlying biological and physical systems precludes a reductionist approach to management. Optimum levels of exploitation must be determined by trial and error;
- Large levels of natural variability mask the effects of overexploitation. Initial overexploitation is not detectable until it is severe and often irreversible.

This contention is illustrated here through three examples of ecosystem impacts by fisheries, indicating a lack of sustainability for their operations.

3.2 Case I: Fishing down Marine Food Webs

The first of these is the demonstration that fisheries landings increasingly originate from the lower part of marine food webs, due mainly to the fact that the populations targeted by fisheries function as part of food webs, both as consumers and as preys. Within food webs, the fish of different species occupy distinct trophic levels (TL), each defining a certain distance from the plants (algae) at the basis of marine food webs, which have a definitional TL of 1. Thus, fish feeding on algae has TL = 2, while fish feeding on herbivorous zooplankton would have TL = 3, etc. Important here is that the fish of various ecosystems usually have intermediate TL values (2.7, 3.5, 4.1, etc.), reflecting the catholic nature of their diet. Fisheries, by removing biomass, necessarily modify food webs, forcing predators to shift towards alternative preys, if any. Such fisheries-induced adjustments were previously not distinguishable from natural fluctuations. They have gradually become highly visible, however, because they change the mean trophic level of the catches extracted from different stocks. Moreover, these changes induced by fishing are not, as was long believed, of a random nature, with decreases in one area matched by decreases in another. Rather, they are directed, with a clear downward trend, due to the fact that large fishes with high TL values tend to have low rates of natural mortality (see Figure 3). Thus, in large fish, even a low level of fishing mortality, generated by what may appear a well-managed fishery, will quickly exceed the (low) level of total mortality (i.e., natural + fishing mortality) that can be accommodated without the stock collapsing. Moreover, it does not matter whether the large fish in question are targeted by the fishery, or caught incidentally, as by-catch of another species, and then discarded. In fact, most declines of large fish are nowadays induced by nonselective gear targeting valuable resources such a nearshore shrimps, and which discard at sea from 70 to 90% of their catch, especially the juveniles of large and potentially valuable fish species.

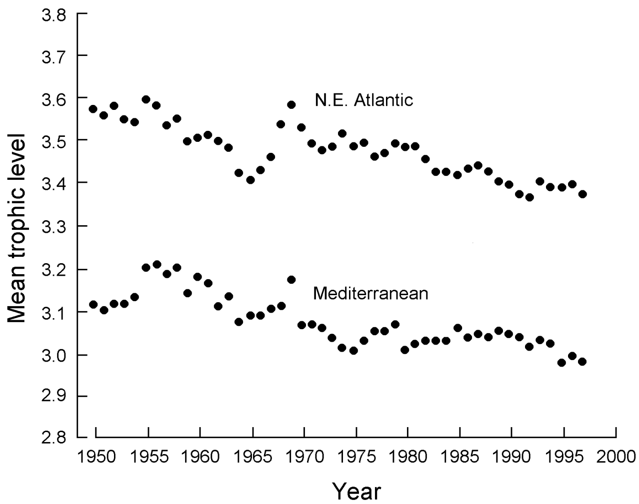

Figure 3. Trends of mean trophic level in landings from the Eastern North Atlantic and the Mediterranean, i.e., encompassing the waters around Europe. Note that the trends in the Mediterranean started from a lower base, suggesting that high-level carnivores were depleted in earlier times. Similar trends occur in most parts of the world. The declining trend of mean trophic level associated with the process of 'fishing down marine food webs' provides a clear indication that globally, fisheries generate levels of effort well past those allowing sustainability, however defined.

3.3 Case II: Bottom Trawling

The second example of fisheries impacts on ecosystems is the demonstration that globally, trawling, which involves dragging a heavy, chain-studded, broad net on the sea bottom, plows over an area that is 150 larger than the forest area that is clear-cut every year. This form of fishing—often compared to harvesting corn with bulldozers—is almost entirely confined to shelves, i.e., to the productive areas down to 200 m depth around the continents, from which about 90% of all fisheries landing originates. The problem here is not only the enormous waste that ensues—although it is trawling which contributes the bulk of the 30 or so million tonnes of by-catch that is discarded annually. Rather, the problem is the destruction of sea bottom structure, which is now known to provide shelter to young fishes, i.e., to contribute to the recruitment of the very stocks upon which the fisheries depend. Here again, sustainability, the alleged goal of most fisheries management plans, does not even begin to be approached.

3.4 Case III: Northern Cod off Canada

The third example, containing elements of the previous two, and concerning the collapse of the northern cod (*Gadus morhua*) stock off Newfoundland/Labrador, Canada, also highlights the nefarious effects, on research and management, of the duality, alluded to above, of the fisheries sector.

The stock in question had been sustainably exploited for centuries by small-scale operators who used fixed traps, and who were, therefore, unable to access the old, large and highly fecund fish of deeper waters. These fish, which produced the recruits that had kept the fishery sustainable for centuries, began to be exploited in the early 1960s by distant water fleets based in Europe. While biomasses plummeted, catches surged at first, from the (sustainable) baseline of about 200,000 tonnes per year to 810,000 in 1968. In 1997, Canada's extension of its jurisdiction to 200 miles, and the elimination of foreign fleets, provided an opportunity to reestablish the cod fishery on a sustainable basis. Instead, the Canadian federal government subsidized the launching of a new, national deep-sea trawler fleet. For a few years, catches increased again, while the biomass and recruitment declined further (Figure 4). The biomass reduction led to a collapse of the distribution range of northern cod. The inshore trap fishers did notice the range collapse: fewer of their immobile gears were catching cod. The trawl fishery, capable of tracking the remaining fish, was able to maintain its catch per unit of effort, and its representatives remained convinced of the population's resilience. Incredibly, so were most the government scientists working on this stock, who relied on data supplied by the trawl fishery, and largely ignored the contradictory signals of the trap fishers. The stock collapsed in 1992, and the ensuing moratorium on cod fishing threw 40 000 fishers and fish workers out of gainful employment.

This catastrophe occurred in a rich country with one of the most sophisticated fisheries research tradition in the world. Now, some attribute the collapse to particularly cold waters, some to the growth of the seal population, a cod predator. However, it is the lack of a historical dimension that manifests itself in these pseudo-explanations: low temperatures and high seal populations did not decimate the stock in the hundreds of years before the advent of industrial fishing, and the ensuing removal of the older age groups from the cod population.

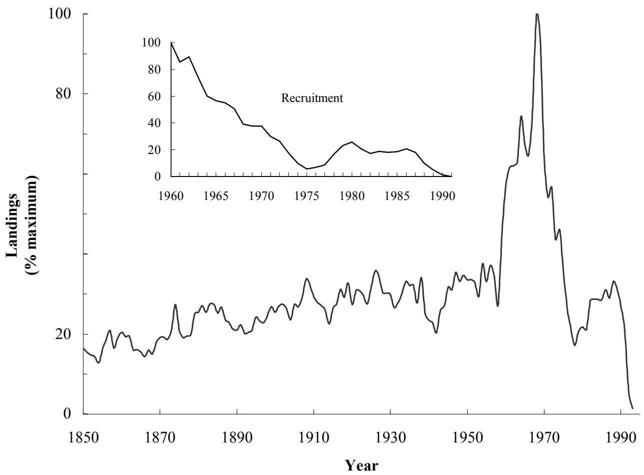

Figure 4. Time series of landings of northern cod off Newfoundland and Labrador, Canada, documenting the sustainable, inshore small-scale fishery that caught 150–250,000 tonnes per year over centuries (only 100 years shown here), until foreign deep-sea trawlers (1960s to mid 1970s) and the local trawl fleet that succeeded them (1980s) drove catches up, recruitment down (see time series in insert), and the fishery into collapse.

Interestingly, while many out-of-work fishers in Newfoundland and Labrador still hope for a full-fledged cod fishery to reopen, an extremely lucrative trawl fishery for bottom invertebrates has started, notably for snow crabs and northern shrimps, the latter being one of the prey organisms released from the predatory pressure of cod. This typical case of fishing down a food web can be safely assumed to delay the full recovery of the cod stock, if not to preclude it.

3.5 Shifting Baselines as an Aggravating Factor

These three examples document why, throughout the world, the biomasses of commercial stocks are much reduced from their pristine abundances, usually by factors ranging from 10 to 100—this not considering local extirpation, notably of rays in various areas, e.g., of the North Atlantic, the South China Sea, or other areas exploited by trawl fisheries.

Unfortunately, these numbers usually fail to impress fisheries scientists and managers; dealing with past abundances (as occurred, e.g., in the 19th Century) is not part of their worldview, nor of their organizations' research program, and it seems easier to dispute these numbers, or to blame seals, or the environment, than to follow up on their implications. Indeed, one result of this lack of a historical dimension in fisheries research is that the very baseline used to assess the status of various stocks shifts downward with each new generation of fisheries scientists. This further undermines the notion of sustainability.

4. Beyond Sustainability: Towards Rebuilding Healthy Ecosystems

The key problem with sustainability as a goal for fisheries management is that it must be expressed in negative terms. Thus, for a population that is already exploited (as nearly all are), sustainability aims to avoid further decline. If that population is brought further down by uncontrolled fishing, the goal of only sustaining that population invariably implies setting our sights lower, to the new, lower level, and so on, until the baseline has shifted and the population is lost, along with the memory that it ever existed. Because of this dynamic, there is, indeed, a very real danger for the continued existence of many populations targeted by fisheries, for the populations indirectly affected by these fisheries, and for the ecosystems in which these species are embedded.

Addressing these issues requires reformulating the goal of fisheries research and management, from sustainability to rebuilding. Moreover, it is not only depleted populations that will have to be rebuilt, but the ecosystems themselves. For this, it will be necessary to reestablish firmly anchored baselines, representing earlier states of the population and ecosystems in questions. This makes the reconstruction and description (or simulation) of earlier states of ecosystems important and new areas of research, which will have to be multidisciplinary if they are to be successful.

This may lead to reformulating fisheries research as a branch of conservation biology, dealing with the maintenance of exploitable fisheries resources, embedded in healthy ecosystems. As a key element of this reformulation, fisheries scientists and managers would have to see themselves as being responsible to more 'clients' than the two they now serve, i.e., government agencies and the fishing industry, especially its large-scale component. Indeed, reallocation of access away from large-scale enterprises, toward artisanal (including aboriginal) operations would go a long way in addressing the problems illustrated in Figure 1, in countries as diverse as South Africa, or India, or the Canadian East (see above for the case of cod) and West coast. Moreover, fisheries scientists and managers will have to accept as legitimate the concerns of the broader public, interested not so much in private enterprises extracting the maximum possible of what is, after all, a public resource, but in maintaining it in the long term, inclusive of its biodiversity.

As another important change, Marine Protected Areas (including no-take components or marine reserves) will have to be perceived not as scattered and small concessions to conservationist pressure, but as a legitimate and obvious management tool, required to prevent the entire distribution area of various exploited species from being accessible to fishing. Indeed, preventing species extinctions should become a major task of future management regimes. This would link fisheries scientists with the vibrant community of researchers now working on marine biodiversity issues. The formal adoption of the FAO Code of Responsible Fishing by virtually all fishing nations has created favorable conditions for this, by shifting the burden of proof onto those who claim that fishing has no deleterious effects on stock and ecosystem. Time will tell if 'responsible fishing' is sufficient to halt the decline of marine fisheries resources, or whether more of these will suffer the fate of the giant catfish mentioned in the Introduction.

BIBLIOGRAPHY

Alcala, A. C. and G.R. Russ. (1990). A direct test of the effects of protective management on abundance and yield and yield of tropical marine resources. J. Cons. int. Explor. Mer 46: 40–47. [One of the first quantitative evaluations of the benefits of marine protected areas for fisheries.]

Alverson, D.L., M. Freeberg, S.A. Murawski and J.G. Pope. (1994). A global assessment of fisheries by-catch and discards. FAO Fisheries Technical Paper No. 339. FAO, Rome. 223 pp. [The first sound, global evaluation of the amount of fish that is discarded annually.]

Bonfil, R., G. Munro, U.R. Sumaila, H. Valtysson, M. Wright, T. Pitcher, D. Preikshot, N. Haggan and D. Pauly. (1998). Impacts of distant water fleets: an ecological, economic and social assessment, p. 11–111. In: The Footprint of Distant Water Fleets on World Fisheries. Godalming, Surrey, UK: Endangered Seas Campaign, WWF International. [A comprehensive review of the advantages and disadvantages of distant water fleets, with case studies from different parts of the world. Available online at www.fisheries.ubc.ca.]

Brander, K. (1981). Disappearance of common skate *Raja batis* from the Irish Sea. Nature 290: 48-49. [Demonstrating an unanticipated effect of bottom trawling.]

Casey, J.M. and R.A. Myers. (1998). Near extinction of a large, widely distributed fish. Science 281: 620–692. [One of the first rigorous demonstrations of an effect of fishing so far widely denied.]

Cushing, D.H. (1988). The Provident Sea. Cambridge University Press, Cambridge. 329 pp. [A comprehensive account of the history of fishing, documenting *inter alia* the effect of the introduction of steam trawlers into the North Sea.]

Mace, P.M. (1997). Developing and sustaining world fisheries resources: the state of fisheries and management, p. 1–20. In: D.H. Hancock, D.C. Smith, A. Grant, and J.P. Beumer (eds.) Proceedings of the 2nd World Fisheries Congress. CSIRO Publishing. Collingwood, Australia. [A comprehensive review, with emphasis on overcapacity.]

Pauly, D. (1988). Fisheries research and the demersal fisheries of Southeast Asia, p. 329–348. In: J.A. Gulland (ed.) Fish population dynamics. 2nd Edition. Wiley Interscience. Chichester, UK. [Describes the expansion of the Gulf of Thailand trawl fishery, and the depletion of its resource base.]

Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10(10): 430. [Describes the process by which depleted resources are forgotten.]

Pauly, D. (1997). Small-scale fisheries in the tropics: marginality, marginalization and some implication for fisheries management, p. 40–49. In: E.K. Pikitch, D.D. Huppert and M.P. Sissenwine (eds.) Global trends: fisheries management. American Fisheries Society Symposium 20. Bethesda, Maryland. [Describes the process leading to use of destructive gear (e.g., poisons, dynamite) by fishers that are too numerous relative to their resource base, or 'Malthusian overfishing.']

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F.C. Torres, Jr. (1998). Fishing down marine food webs. Science 279: 860–863. [Presents the definition and first description of this important ecological process. Available online at www.saup.fisheries.ubc.ca.]

Pauly, D., V. Christensen, S. Guénette, T.J. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson and D. Zeller. (2002). Towards sustainability in world fisheries. Nature 418: 689-695. [Review emphasizing the lack of sustainability in historic fisheries and the need to now invent it.]

Pitcher, T.J. (2001). Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. Ecological Applications 11: 601-617. [Documents numerous cases of lost resources and makes a lucid case for rebuilding fisheries and their underlying ecosystems.]

Smith, T.D. (1994). Scaling fisheries: the science of measuring the effects of fishing. Cambridge University Press. Cambridge. 392 pp. [A history of a field that tends to forget that it has one.]

Stringer, C. and R. McKie. (1996). African exodus: the origins of modern humanity. Henry Holt. New York. 282 pp. [An account of where the origins of humankind were, with a brief account of past fishing practice.]

Walters, C. and J.J. Maguire. (1996). Lessons for stock assessment from the northern stock collapse. Reviews in Fish Biology and Fisheries 6(2): 125–137. [Concludes that overfishing, and not environmental cause, led to the demise of cod off Newfoundland/Labrador.]

Watson, R. and D. Pauly. (2001). Systematic distortion of global catch statistics. Nature 414: 534-536. [Shows that global catches, contrary to official statistics, have been declining since the late 1980s; available online at www.saup.fisheries.ubc.ca.]

Watling, L. and E.A. Norse. (1998). Disturbance of the seabed by mobile fishing gear: a comparison to forest clear cutting. Conservation Biology 12(6): 1180–1197. [Demonstrates that trawling has a tremendous impact on fishing grounds.]

THE FISHING ENTERPRISE AND FISHERIES MANAGEMENT

Ussif Rashid Sumaila
Chr. Michelsen Institute, Bergen, Norway, and Fisheries Centre, University of British Columbia, Vancouver, Canada

CONTENTS

GLOSSARY

Externality: environmental cost of an activity (e.g. overfishing), imposed on society, and not paid by the person(s) or firm(s) which caused that cost.

Subsidy: transfer of economic resources from one sector of the economy to another. In overexploited fisheries, (government) subsidies contribute to further overfishing.

Open access: the state prevailing in a fishery when they are now effective barriers to entry of new fishers and/or new gear.

Overfishing: deploying more fishing assets (boats, gear) than is required to generate the best possible (aggregate) economic returns from a resource (i.e., Maximum Economic Yield).

SUMMARY

This paper focuses on how the motives and behavior of fishing enterprises may impact on the sustainable use of fishery resources. A simple description is given of what an enterprise is and how it is expected to behave in the course of its activities. It is demonstrated that the usual tendency of fishing enterprises to act as profit maximizers puts the long-term sustainability of fisheries in great danger. A key challenge for managers is to devise and implement incentive systems that make fishing enterprises more responsible for the long-term well being of the industry, and its resource base.

1. INTRODUCTION: THE ECONOMIC DIMENSION OF FISHERIES

Fisheries are economic and social activities involving an estimated 12.5 million fishers operating from more than 3 million vessels globally. Most of these fishers are organized into fishing firms or enterprises that land around 90 million tonnes of fish per year, and discard an unwanted 'by-catch' of about 30 million tonnes. Note that aquaculture, the farming of fish and aquatic invertebrates, is not considered here, but elsewhere in this volume.

To design appropriate fisheries management regimes one needs to understand the reasons why fishing enterprises or firms go out fishing. This contribution is thus structured around four questions. First, what is an enterprise? Second, how do enterprises behave? Third, how does this behavior impact on the long-term sustainability of fishery resources? Fourth what challenges confront fisheries managers because of the way enterprises operate and behave?

2. WHAT IS AN ENTERPRISE AND HOW DOES AN ENTERPRISE BEHAVE?

Most economic definitions of the firm share the idea that a firm or enterprise should be able to produce (or sell) more efficiently than would its constituent parts acting separately. Hence, economic definitions of the firm entail very explicit optimizing approaches. For instance, the firm is usually regarded as a synergy between different units, jointly exploiting economies of scale. However, describing the behavior of the firm is not a simple matter. In general, economic theory prescribes profit-maximizing behavior as the typical behavior of the firm or enterprise. But clearly this is not a complete description, since there is empirical evidence to show that business executives may occasionally deviate from profit-maximizing behavior. This caveat notwithstanding, economists generally believe that the profit-maximization hypothesis is still a useful guide for predicting, in most sectors, the behavior of the firm or enterprise. The next question is: do enterprises of the fisheries sector also behave according to the profit-maximization hypothesis? The evidence at hand suggests that this is the case for firms involved in commercial and distant-water (deep sea) fishing, i.e., for the firms contributing the bulk of the world fisheries catches. However, this may not apply in the Aboriginal fisheries discussed elsewhere in this volume.

3. How does the behavior of enterprises affect fishery resources?

3.1. Market vs. non-market values

Given, thus, that fishing enterprises generally seek to maximize their discounted profits from their fishing activities, what are the chances that the goal of sustainable fisheries will be achieved?

One can categorize the benefits from marine ecosystems into market and non-market benefits. Even though economic theories, especially of the Rawlsian and to some extent the utilitarian variety, are broad enough to conceive of non-market benefits, it is almost always the case, in practice, that economic actors put more weight on market benefits when they go out to exploit resources embedded within marine ecosystems. This leads to the ecosystems being treated as 'mines' for products that are traded in the market. As expected these results in the degradation of the ecosystem. Economists attribute this degradation to what they call an 'externality,' that is, a situation in which economic agents impose external costs upon society at large. With no market values to provide incentives for the preservation of those features of ecosystems that provide non-market values and services, the inevitable result is the misuse of ecosystems by enterprises each separately seeking to maximize its profit.

For most economists, the source of an externality is typically to be found in the absence of fully defined property rights, whether to a group such as a community, a country or an individual or firm. Hence, the further discussion in this section is structured around open access and common or private property.

3.2 Enterprises operating under open access

Open access describes a situation in which fishing enterprises may use the marine ecosystem under no controls, and where no-well defined property rights, whether individual, communal or state, exist and/or are enforced. It has been shown by economists and other students of fisheries that in an open access situation, the sustainability of the flow of market values is in great danger, not to mention non-market values. The reason is what has been commonly known as the 'race for the fish' (Figure 1). Thus, if fishers are free to harvest the resource at any time, and they know that anyone can harvest the resource at will, individual fishers come to the conclusion that if they were to restrain themselves (e.g., by allowing fish to escape, so they can grow and reproduce before being caught), then other fishers would catch the fish instead. This perfectly rational kind of thinking is what usually pushes economic agents into 'mining' marine ecosystems. This then leads to the degradation of the ecosystem, and the depletion of the resources, and to waste - not only of non-market values and services, but also of market values, notably in terms of collapsed commercial fish stocks. Clearly, under these circumstances, it is vain to hope that profit-maximizing enterprises left to their own devices will ensure the sustainability of a given fishery (Figure 1).

3.3. Enterprises operating under common and private property

Under a property regime, groups, communities or the state (in the case of common property), or firms and individuals (in the case of private property) are assigned the rights to the exclusive use of the ecosystem resources. Hence, potential competitors from outside the group can be excluded. In the case of common property, individuals in the group may work together in a cooperative manner in their use of the fishery resources. Alternatively, they may opt to exploit the resource non-cooperatively. Such non-cooperative behavior by members of a group usually degenerates into a situation akin to open access, i.e., the profit-maximizing enterprises again will be ill placed to deal with concerns of sustainability. On the other hand, when members of the group work cooperatively to sustain and enhance their overall benefit from their use of the resource, this generates a situation similar to private property.

Assuming that the private rights owners, be they a community, a firm, the state or an individual, wants to maximize their long-term discounted economic benefit from their use of the resource, it can be asserted that they will take into account all aspects of the ecosystem that will enhance the expected future streams of market values from the ecosystem (note in Fig. 1B that the fishing effort that maximizes profits is less than the open-access equilibrium effort). However, they will do this only to the extent that discounting, prices and cost levels allow. With a very large discount rate, for instance, the stream of discounted future market values could be reduced to next to nothing.

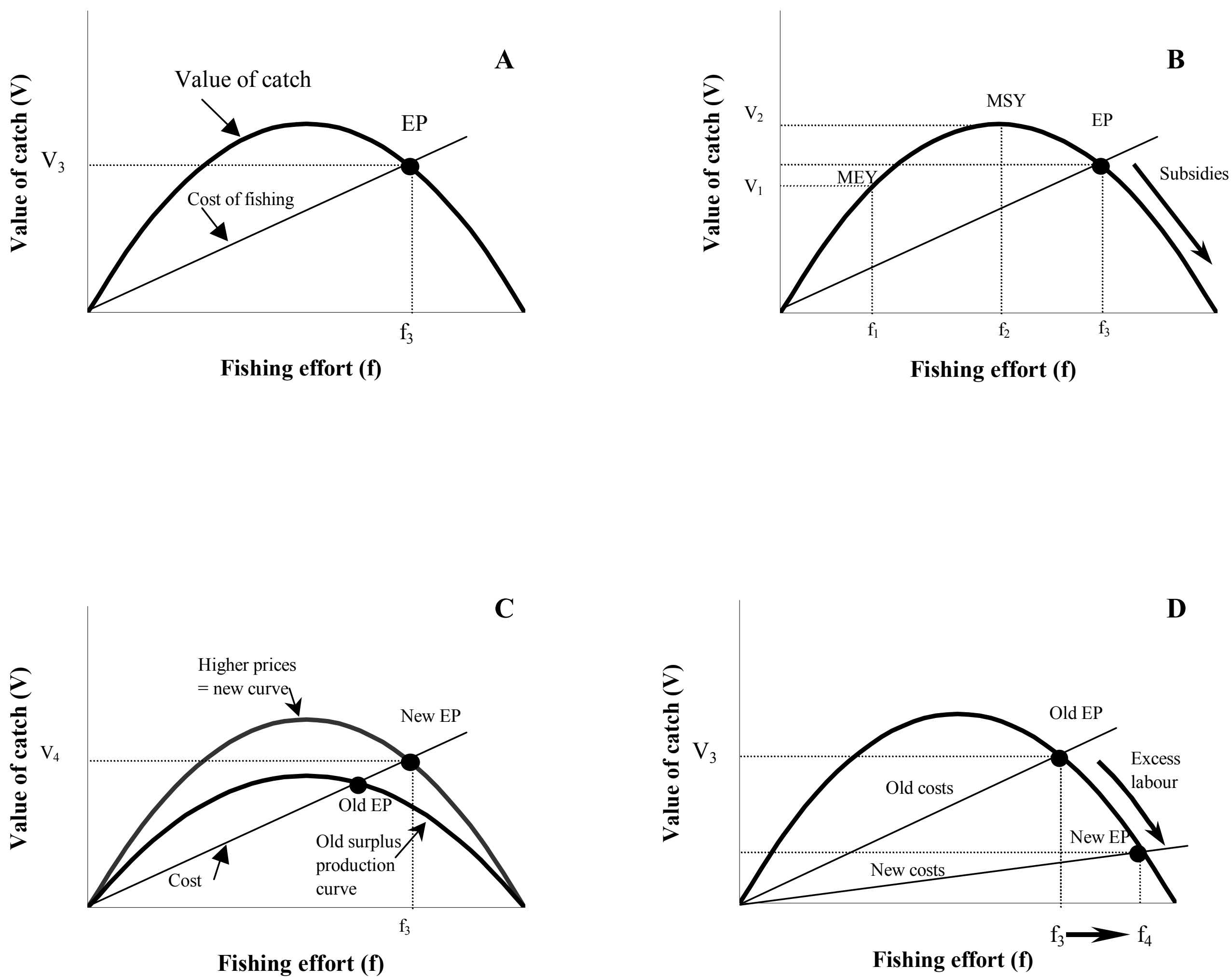

Figure 1. Schematic representation of the key economic factors affecting open-access fisheries: A: Basic model, in which fishing costs are assumed proportional to fishing effort (f), and gross returns proportional to catches (parabola). B. Under open access, f will increase past Maximum Economic Yield at f_1 (where the economic rent, i.e., the difference between total costs and gross returns is highest), and past Maximum Sustainable Yield (at f_2), until the equilibrium point (EP, at f_3), where costs and returns are equal, i.e., where the economic rent is completely dissipated. In this situation, subsidies, by reducing costs, increase the level of effort at which EP occurs, and thus decrease catches. C. Price increases, by increasing gross returns, increase the level of effort at which the rent will be dissipated (i.e., from f_3 to f_4), and hence foster overfishing. just as subsidies do. D: In small-scale fisheries, labor is a major cost factor; when its value tends toward zero (as occurs when there is a large excess of rural labor), resources may become severely depleted, leading to Malthusian overfishing. [Graphs from D. Pauly, pers. comm.]

One would expect the enterprise, as rights owner, concerned with maximizing discounted economic benefits from its use of resources, to be concerned with maintaining those features of ecosystems that enable catches to be sustained in the long run. Conversely, the rights owners can be expected to protect non-target species and their habitat only if they are convinced that these have a direct positive effect on the target species. The problem here is that the enterprises may fail to see the ecological links between non-market species or habitats to the well-being of the market species, which may result in ignoring, and even in destroying those links.

4. Challenges to fisheries management

4.1 Conditions for meeting the challenges

From the foregoing discussion, it is clear that fisheries managers face big challenges. In effect, they need to design and put in place policies that force profit-maximizing enterprises to carry out their activities in a sustainable manner. Two necessary, but not sufficient conditions, for meeting this challenge are: (i) a good understanding of the resource and their ecosystem, and (ii) a good knowledge of the fishing industry, of its operations, of the system of values of its members, and of how this affects their decision to fish. Item (i) entails an understanding of the key features of the ecosystem within which the resource are embedded. On the other hand, item (ii) includes aspects of fisheries management, such as the economic and social motives dictating the actions of fishers; and how these determine the development of legal and institutional structures; and the choice of the technology deployed the exploitation of the resource. Further discussion of the challenges to fisheries management is carried out under the subtitles below.

4.2 Use of best the available science

Subsidies to fisheries are extremely high, e.g., 2.5 billion dollars per year for the North Atlantic alone, and probably around ten times that figure for the world as a whole. Clearly, policy-makers have failed to implement the advice from fisheries scientists and economists, which has generally been geared toward reducing fishing capacity. Indeed, it is common for fisheries managers and their political master, to avoid the implementation of the best available science because of their concern for political rather than scientific realities. This is what has been behind many of the management failures around the globe, where scientific knowledge was wasted, rather than translated into action.

4.3. Regulation and control

Enforcement of fishery laws and regulations is a difficult task because fishers are good at circumventing them; also, effective enforcement is costly. To address this, managers must use economic, social and cultural incentives to generate self-enforcing regulatory mechanisms. This entails changing the incentive structure for fishers so as to make it in their own interest to exploit the resource in a sustainable manner. Second, managers must have access to advanced technology for monitoring, control, and for fisheries data collection and analysis. Third, in some cases, new governance arrangements need to be developed, notably to overcome the marginality of some small-scale fishers' communities. Anthropologists and other social scientists have a contribution to make here.

4.4. Over-capacity and subsidies

Over-capacity plagues most of the world's capture fisheries, even though limited entry or license limitation programs have been attempted for a couple of decades. There are two reasons for this state of affairs. First, the high level of subsidies given to the fishing industry over the years (see above) provided an incentive for firms to over-capitalize, mainly by acquiring too many vessels of excessive size. Second, fishing effort has often been equated to a single input, the vessel. Thus, it was thought that once you limit the number of vessels that enter the fishery, you solved the problem of over-capacity. This has turned out to be wrong: fishing effort is made up of a bundle of inputs (including e.g. acoustic fish finders, complexly rigged gear, etc.), which are much more difficult to control. Clearly, over-capitalization is a perfect prerequisite for over harvesting because large underutilized fleets can easily push the authorities towards granting them generous quotas, thereby exacerbating problems of sustainability.

4.5 Technology: problems and opportunities

There are at least two ways in which technological progress impacts on fisheries. First, during the course of the last decades, fishing gear and vessel technology have achieved the capacity to impact radically on the earth's ecosystem. From the perspective of fisheries, fleets have become powerful enough to over-exploit basically all stocks in the world. Second, improvement in fish product conservation and transportation technology has remarkably increased the scope of international trade in fish products, especially from poorer, 'low demand' countries to the markets of rich countries such as Japan, the USA or the members of the European Union. This situation is not necessarily bad in economic terms, granted that the exporting countries use the foreign exchange thus gained to support their development. However, the challenge here is how technological improvements can continue without causing stock collapse and depletions in countries that have few alternative sources of revenues.

5. Conclusions: getting the incentives right

As a way of conclusion, it must be reiterated that the best chance for the sustainable use of marine resources is for managers to devise and implement incentive systems that make fishing enterprises more responsible for the long-term well being of the industry and the resource upon which it depends. The current high level of overcapacity in the world's fleet must be dealt with.

Subsidies to fishing fleets must be stopped, and in general the special treatment given to the fishing sector vis-à-vis other sectors of the economy must also come to an end. An important point here is that managers and policy-makers need to recognize the fact that the extracting sector, that is, fishing enterprises, are not the only stakeholders with legitimate claims to fishery resources. Society at large has a stake in the resources, as well. For instance, those who express concerns for conservation, economic efficiency, and the needs of future generations also have legitimate interests. In any event, there is evidence to show that neither subsidies nor preferential treatment given to the fishing sector are in the best interest of either the fish or the fishing enterprises themselves in the long run.

Additional ways to enhance sustainable fisheries is for management to focus on the opportunities offered by technology in monitoring, control, data collection and dissemination. Finally, the availability of computational methods from applied mathematics, and the huge increase in computer power is an opportunity that fisheries scientists and managers should seize to get more empirical insights for practical fisheries management.

Bibliography

Baumol, W.J. and W.E. Oates (1988): The theory of environmental policy. Cambridge University Press. New York. [Elaborates on the economic concepts in this contribution.]

Gordon, H.S. (1954): The economic theory of a common property resource: the fishery. Journal of Political Economy, 62: 124-42. [A classic paper that grafted basic economic consideration onto a simple fisheries production model.]

Jentoft, S. (1989): Fisheries co-management: Delegating government responsibility to fishermen's organizations. Marine Policy, April: 137-154. [A major paper on a necessary element of fisheries management.]

Munro, G.R. and U.R. Sumaila. (2001). Subsidies and their potential impact on the management of the ecosystems of the North Atlantic, p. 10-27. In: T. Pitcher, U.R. Sumaila and D. Pauly (eds.) Fisheries impacts on north Atlantic ecosystems: evaluations and policy explorations. University of British Columbia Fisheries Centre Research Report 9(5). Vancouver. [Building on an OECD study, this work estimates total subsidies of 2.5 billion US$ for the North Atlantic fisheries; available online on www.fisheries.ubc.ca.]

Pauly, D. (1997). Small-scale fisheries in the tropics: marginality, marginalization and some implication for fisheries management, p. 40-49. In: E.K. Pikitch, D.D. Huppert and M.P. Sissenwine (eds.) Global trends: fisheries management. American Fisheries Society Symposium 20. Bethesda, Maryland. [Describes the process leading to use of destructive gear (e.g., poisons, dynamite) by fishers that are too numerous relative to their resource base, or 'Malthusian overfishing'.]

Sumaila, U.R. (1999). A review of game theoretic models of fishing. Marine Policy, 23(1): 1-10. [Identifies the condition under which incentives for collaboration and compliance with fisheries regulations can emerge.]

Sumaila, U.R. (2001). Generational cost benefit analysis for evaluating marine ecosystem restoration, p. 3-9. In: T. Pitcher, U.R. Sumaila and D. Pauly (eds.) Fisheries impacts on north atlantic ecosystems: evaluations and policy explorations. University of British Columbia Fisheries Centre Research Report 9(5). Vancouver. [Proposes a clock whose setting varies between sensation as an approach to estimate discount rates that allow for intergenerational equity; available online on www.fisheries.ubc.ca.]

Tirole, J. (1989). The theory of industrial organization. The MIT Press. Cambridge, Massachusetts. [Discusses the role of the firm, as followed up in this contribution.]

ABORIGINAL FISHERIES ISSUES: THE WEST COAST OF CANADA AS A CASE STUDY

Nigel Haggan
Fisheries Centre, University of British Columbia, Vancouver, Canada
and
Pamela Brown
Museum of Anthropology, University of British Columbia, Vancouver, Canada

CONTENTS

GLOSSARY

First Nations: a term used in Canada to refer to the country's original inhabitants and their descendants; also: Aboriginals.

Aboriginal: The original, surviving, inhabitants of countries whose population largely consists of recent immigrants (as, e.g., in the Americas, Australia and New Zealand). Aboriginal are often marginalized, especially with regard to access to natural resources.

Aboriginal rights: rights flowing from the original occupancy of the territory. Such rights are now recognized in Canada's Constitution and Supreme Court decisions.

Hereditary Chiefs and Elders: The leaders of Pacific Northwest Aboriginal societies; also responsible for transmitting oral history from one generation to another – the 'corporate memory' of First Nations.

Indian Act: Canadian legislation that replaced traditional forms of government with elected officials with a 2-year term of office.

Potlatch: Institution of Aboriginal government where, *inter alia*, responsibilities for lands and resources were transferred from one generation of hereditary chiefs to another.

Traditional ecological knowledge: The knowledge acquired through living in contact with the natural resources of a particular area over many generations.

Traditional territory: The lands, waters, natural and spiritual attributes of the area occupied by an Aboriginal people.

SUMMARY

A brief account is given of the major fisheries-related issues facing Aboriginal societies along the Pacific coast of Canada. This includes the implementation of traditional access rights, now increasingly recognized by Canadian authorities, in spite of wrenching cultural change, a declining resource base, and the overwhelming impacts of commercial fisheries. Increased consultations between Canadian authorities and Aboriginal communities would benefit all. Also, it is suggested that granting increased and, in part, exclusive, resource access to Aboriginal fishers would generate numerous social benefits, for both the Aboriginal communities and society at large.

1. INTRODUCTION

This brief account concentrates on British Columbia (BC), Canada, and on the issues that confront Aboriginal peoples in salmon and other fisheries, but is meant to illustrate problems of resource access and management affecting Aboriginal people in other parts of the World.

BC Aboriginal peoples today describe themselves as 'First Nations' so indicating both original occupancy and nationhood. Aboriginal rights, including fishing, are increasingly recognized in Canadian law. In 1992 the federal government of Canada, the provincial government of BC and the First Nations' Summit established a process of modern-day treaty making to resolve issues of ownership of traditional territories and clarify access and management authority. The issue is complicated, i.e., most of BC's fisheries resources are fully exploited and some are clearly overexploited.

2. TRADITIONAL ABORIGINAL RESOURCE MANAGEMENT

Aboriginal peoples of the Pacific Northwest derive their culture and identity from traditional territory. They are anchored to place in a way that is difficult to fully understand for those who were brought up in a culture characterized by high geographic mobility. For most aboriginal peoples, moving away permanently is not an option.

Indeed, for coastal peoples in general, fisheries are not just the main source of subsistence and wealth. The seasonal cycle of fisheries resources has also shaped their social and cultural life. Thus, anything that affects the availability of fish has social and cultural as well as economic repercussions.

Respect for territory and for all natural resources is the foundation of Aboriginal society, culture and economy. Until contact with European explorers and traders, the hereditary chiefs had an ownership right and management responsibility to ensure the survival of all stocks of salmon and other species. Resource harvest was based on a seasonal round that involved traveling to different sites at different times of year. Pre-contact management systems were grounded in traditional ecological knowledge (TEK) of a wide range of species from different places and habitats. In effect, pre-contact fisheries were based on a rigid 'area licensing' system.

3. Impact of Colonization on Traditional Resource Management

After contact, fisheries based on traditional territories were replaced by European-style industrial fisheries where fish are a common property resource available to any licensed fisher. At first, Aboriginal fishermen dominated the new commercial fishery while women and children provided a pool of labor for a network of canneries along the coast. This lasted only until improvements in vessel and freezer technology made it more economical to concentrate the canning industry in cities such as Vancouver and Prince Rupert. The disappearance of local canneries had a catastrophic effect on Aboriginal communities who depended on the canneries as a market for their fish and as a source of employment.

The advent of modern industrial fisheries had several major impacts on Aboriginal society. Important food and trade resources were lost as industrial fleets depleted coastal stocks and moved offshore. Where Aboriginal people participated, as in the early BC salmon fishery, traditional subsistence economies were disrupted. First, by concentration on one fishery instead of a wide range of traditional foods; second, the advent of a cash economy created individual entrepreneurs. Licenses were granted to hereditary chiefs. Skilled fishers were able to acquire boats and licenses. It is worth reflecting on the difference between Aboriginal rights and commercial licenses.

3.1 Aboriginal Rights vs. Fishing Licenses

Firstly, Aboriginal rights are 'recognized and affirmed' in section 31(1) of the Constitution of Canada. In the 1990s, two Supreme Court of Canada decisions, 'Sparrow' and 'Delgam'uukw', provided further clarification of what is meant by Aboriginal fishing rights and Aboriginal title. Prominent among these is the requirement to avoid 'traditional English common law interpretations' and to be 'sensitive to the Aboriginal perspective on the meaning of the rights at stake.'

More specifically, commercial fishing licenses originated from the European common property resource concept. There is no constitutional protection or requirement to be sensitive to Aboriginal concerns. Secondly, Aboriginal rights cannot be extinguished or defined by regulation, while the Minister of Fisheries can cancel or change the conditions attached to commercial licenses. Thirdly, Aboriginal rights are communal, while commercial licenses are owned by individuals or, increasingly, held by large corporations. Fourthly, First Nations' Aboriginal rights are restricted by tradition to their tribal territory (unless by formal agreement with another First Nation), while commercial fishing licenses can be used in any First Nation's tribal territory in BC without their permission. This infringes on the Aboriginal rights and sovereignty of the First Nation concerned.

3.2 Access vs. Management Authority

Much emphasis has been placed on loss of access, but from an Aboriginal perspective, loss of management authority is equally problematic. The status of chiefs in the hereditary government or Potlatch system, derived from the wealth they were able to give away as a result of their good stewardship of the lands and waters they had been trained from childhood to manage. Replacement of management authority by central government authority and diminishing harvest opportunity sidelined the hereditary chiefs and elders. While not fisheries related, new educational requirements further marginalized chiefs and elders as educators and role models. Canada's Indian Act formalized this process by replacing hereditary systems linked to land and resources with elected governments with a two-year term and virtually no administrative support system.

The view of fisheries as a common property resource and consequent failure of government agencies to appreciate the vital role of place in traditional management systems has led to tragic and occasionally ludicrous situations. In the 1950s, Canada's Department of Fisheries and Oceans (DFO) dynamited a rock in Hagwilget Canyon on the Bulkley River, thinking that it was a barrier to migrating salmon. What the DFO didn't know was that the rock was the only fishing station of the Hagwilget people. In consequence, DFO were obliged to provide the Hagwilget with canned salmon from elsewhere, much of it not to their taste.

3.3 Compounded Effects Leading to Depletion of Fish Stocks

The immediate effect of industrial fishing is depletion of the target species. This is followed by targeting other species leading to sequential depletion, and vanishing alternatives. Consequences for Aboriginal people include loss of major subsistence and trade commodities, the cost and danger of going further out to sea in small and sometimes unreliable boats and disruption of cultural and spiritual life. The lasting consequence of the centralization of fishing and processing has been very high levels of unemployment in Aboriginal communities.

The loss of access and management authority and the replacement of local knowledge of many species by highly-quantitative fisheries management science accounts, in the writers' view, for the very small number of Aboriginal people seeking careers in fisheries science and management.

The recent failure of modern quantitative fisheries management science and realization that the warnings of coastal fishing communities had a basis in fact and recent work on the ecosystem effects of fisheries has renewed interest in TEK. Also, new precautionary ecosystem management approaches are being developed that use the traditional knowledge of past diversity and abundance to help in setting restoration goals.

Taking a broader view, the dispossession of BC Aboriginal peoples was almost inevitable. As the realization dawned that salmon were finite, Aboriginal people were demonized for taking the 'last' salmon off the spawning beds. It is now obvious that the displacement of Aboriginal people was only the first stage in a process of corporate concentration that has eliminated most small owner-operators, Aboriginal and non-Aboriginal alike, from coastal communities throughout BC. If stocks continue to decline and management costs to industry go up, there will be very little left to stop large corporations moving offshore.

4. Policies Toward Restoration

Canada's commitment to social justice in recognizing Aboriginal rights in the Constitution and legislation and the new treaty-making process in BC points a way to restore place-based management. It is suggested that the government of Canada could give consideration to a vessel and license buyback program that, in effect, reverses the effects of corporate concentration. The first task would be to establish an area licensing system that makes sense in terms of marine ecosystems and coastal communities. The second element would be to purchase licenses from large corporations and re-allocate them to coastal communities. While this re-distribution would not be restricted to Aboriginal communities, it could deal first with a down payment on the treaties being negotiated. As a start, Canada could commit $ 1 billion the next 5 years.
We note here that this sum, although large, pales into insignificance when compared to the $ 3.5 billion that Canada spent up to 1998 to mitigate community impacts of the 1992 closure of the Atlantic cod fishery.

On the credit side, the expenditure would advance the development of 'place-based' ecosystem management, as indeed required by Canada's new Oceans Act, 1996. It would provide coastal communities, native and non-native, with a long-term vested interest in the health of local stocks. It would stem the loss of lifestyle and the loss of a store of traditional knowledge garnered over thousands of years. It would win and hold public support by addressing British Columbians' concern about conservation and go a long way to defuse opposition by non-Native interests who fear that implementation of Aboriginal fishing rights will further erode their position. In the long-term, it is likely that reduction of transfer payments to coastal communities and creation of new wealth will make a larger contribution to Canada's and BC's tax base than the large corporations do at present.

BIBLIOGRAPHY

Codere, H. (1990). Kwakiutl: traditional culture, p. 359-377. In: W. Suttles (ed.) Nortwest coast. Vol. 7 of Handbook of North American Indian. Smithsonian Institution. Washington, D.C. [Basic description of the cultural groups mentioned in the text.]

Newell, D. (1993). Tangled webs of history: Indians and the law in Canada's Pacific coast fisheries. University of Toronto Press. Toronto. 306 p. [A history of the British Columbian fisheries, with emphasis on the gradual dispossession of Aboriginal communities.]

Richardson, M. and Green. (1989). The fisheries co-management initiative in Haida Gwaii, p. 247-269. In: E. Pinkerton (ed.) Cooperative management of local fisheries: new directions for improved management and community development. University of British Columbia Press. Vancouver. [An account of the cooperation that emerged between Canadian authorities and the Haida Nation, of the Queen Charlotte Islands/Haida Gwaii.]

Pauly, D. (1999). Fisheries management: putting our future in places, p. 355-362. In: D. Newell and R. Ommer (eds.) Fishing places, fishing people: traditions and issues in Canadian small-scale fisheries. University of Toronto Press. Toronto. [An account of the importance of small-scale fisheries for sustainable resource exploitation.]

TRENDS IN FRESHWATER AND MARINE AQUACULTURE PRODUCTION SYSTEMS

Michael B. New
Wroxton Lodge, Marlow, Bucks, UK

CONTENTS

GLOSSARY:

Aquaculture: the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants.

Fish meal: the dried, ground up bodies of fishes (usually anchovies, sardines, menhaden, etc.), used as 'aquafeed', i.e., as feed or feed complements (along with fish oils) in aquaculture.

Mariculture: the farming of marine organisms, including fish, mollusks, crustaceans and plants.

Tilapia: small to medium-sized, generally herbivorous fishes of the Family Cichlidae, widely used in semi-intensive aquaculture, notably in Asia.

Transgenics: organisms into which genes from unrelated species have been introduced using techniques other than breeding.

SUMMARY

Aquaculture, the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants is an ancient industry that is now expanding rapidly, especially in developing countries, from which 80% of total production originates, and where growth, especially in South America is fastest.

In 1996, the top fourteen countries producing food fish (i.e., fin-fish, crustaceans and mollusks for direct human consumption) through aquaculture included nine Asian and three European countries, as well as one each in South and North America. However, China contributes a disproportionately high aquaculture production (67%), or 17.7 million tonnes, compared with 8.7 million tonnes for the rest of the world.

Seaweed and mollusk culture expanded faster than the average for all species from 1987 to 1996, while crustacean farming was the poorest performing sector. The culture of some species, including Mediterranean seabass and seabream, Atlantic and Pacific salmon, scallops, crabs and clams, expanded more than 200% in the last decade. Tilapia farming expanded faster than the average for all finfish.

Two of the most important technical topics and issues for aquaculture firms in the 21st Century are the use of genetically modified organisms and non-indigenous species, which need to be introduced with care, according to strict codes of practice. Another issue is that aquaculture firms will be using most of global fish meal and fish oil supplies by 2010, though research has demonstrated the potential for fish meal replacement.

Three major means of increasing output from aquaculture firms without massive environmental impact exist, viz.: fisheries enhancement, recirculation technology and offshore aquaculture. However, issues of ownership associated with culture-based fisheries need resolution, and methods for increasing productivity from existing water resources need to be used more widely. The technological challenges facing offshore aquaculture can be met but this form of aquaculture may remain suitable only for luxury finfish production.

Aquaculture is facing increasing criticism from a public sensitized by organizations which lobby on behalf of environmental, food safety, and animal welfare concerns. The emergence of voluntary codes of conduct and guidelines will have a major impact on the activities of private firms, but other initiatives, such as the development of certification systems, also have an important role to play.

Achieving the global potential of aquaculture will thus depend on well-directed research and development, the development of appropriate efficiency indicators for balancing aquaculture with other types of resource use; and the public and private promotion of responsible aquaculture practices.

1. INTRODUCTION: ORIGINS AND PRESENT SCOPE OF AQUACULTURE

The Food and Agriculture Organization of the United Nations defines aquaculture as "the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries."

Aquaculture is an ancient activity, with roots in ancient Egypt, China, India, and in various provinces of the Roman Empire. Except for China, where it always played an important role in the rural economy, aquaculture is a rather recent industry, and indeed, some countries have recently become major producers which had no tradition of aquaculture whatsoever, often based, as well, on species not previously cultivated.

In 1996, global aquaculture production exceeded 34 million tonnes, including seaweeds, with a value exceeding US$ 46.5 billion (Table 1). Of this, 'food fish' (meaning fin-fish, crustaceans and mollusks for direct human consumption) contributed 26.4 million tonnes. However, China's dominance skews the global total. Moreover, Table 1 demonstrates that aquaculture in the rest of the world is not expanding so fast as in China. The food fish produced through aquaculture in the rest of the world expanded by an average of only 50% during the decade 1987-1996, whereas China's output increased by 264%. A similar, but less pronounced differential occurred in the average value of food fish produced through aquaculture, which increased by 168% in China but 102% elsewhere. Including China, global aquaculture production in 1996 was nearly 2.5 times greater by weight and 2.3 times greater in value in 1996 than a decade earlier (Table 1).

Table 1. Aquaculture production and value 1987 and 1996, as estimated by FAO.

Production (millions of tonnes)	**1987**	**1996**	**1996 - 1987**
All countries (including seaweeds)	13.5	34.1	2.5
China only (including seaweeds)	6.0	23.1	3.9
All countries (food fish only)	10.6	26.4	2.5
Chinese production (food fish only)	4.9	17.7	3.6
Value (1000 of millions US $)			
All countries (including seaweeds)	20.7	46.5	2.2
China only (including seaweeds)	7.7	21.2	2.8
All countries (food fish only)	18.4	41.5	2.3
Chinese production (food fish only)	6.7	17.9	2.7

Mariculture, principally mollusk culture, has expanded faster than brackishwater or freshwater aquaculture, and the proportion of global aquaculture production originating from each continent changed significantly during the decade 1987-1996 (Table 2). Aquaculture in South America and Oceania, though a small (but increasing) proportion of the global production total, expanded faster than in any other continent except Asia. The fastest expansion rate in any continent, including Asia, was in South America.

In 1987-1996, the culture of seaweeds (172%) and mollusks (also 172%) expanded faster, on a global scale, than the average for all species (153%). Though it doubled in the decade, crustacean farming was the poorest performing sector in terms of production. Cultured shrimp production in 1996 (nearly 915,000 tonnes) declined by 2.3%

Table 2. Global aquaculture production[a] by continent, as estimated by FAO.

Continent	**1987 share (%)**	**1996 share (%)**	**Change (%)**
Africa	0.5	0.4	- 0.1
North America	4.6	2.3	- 2.3
South America	0.9	1.6	+ 0.7
Asia	80.2	88.9	+ 8.7
Europe	10.2	6.0	- 4.2
Oceania	0.3	0.4	+ 0.1
Former USSR	3.3	0.4	-2.9

[a] Excluding seaweeds

from 1995, the only time this has occurred in the past decade. Though production is low in absolute terms, the culture of European seabass and gilthead seabream in the Mediterranean is notable for its expansion rate, over 2,500%. Crab culture also took off, expanding by more than 1,150% in the decade. Rapid expansion also occurred in the farming of Atlantic salmon (>700%), scallops (nearly 550%), Pacific salmons (>370%), other marine finfish (>310%), seabass (*Lates calcarifer*) (nearly 310%), and clams (>250%). Tilapia farming (>170%) also expanded faster than finfish culture as a whole (nearly 150%). More than 9 out of every 10 oysters, Atlantic salmon and cyprinids consumed are now products of aquaculture. 4 out every 5 mussels and 3 out of 4 scallops are cultured and 27% of shrimps are farmed.

The global expansion of aquaculture continues to outpace growth in the capture fisheries sector. Aquaculture in inland waters, heavily dominated by Chinese and other Asian production, now achieves more than twice the output of freshwater fisheries. In marine waters the contribution of aquaculture nearly trebled, from 4% in 1987 to 11% in 1996.

There are many who hope that aquaculture can bridge the gap between the increasing world-wide demand for fish and other aquatic products and the stagnating catches of capture fisheries. However, bearing in mind the constraints to further development, it is not certain that the aquaculture potential (or targets) set by various authors or organizations, say for the year 2035 can be attained, as this would involve a production of nearly 62 million tonnes to sustain current per capita food fish availability, or of 124 million tonnes if per capita availability is to increase by 1% per year from a 1993 baseline.

Technologies for increasing aquaculture productivity, while minimizing resource use and environmental impacts are being developed. A major step towards promoting the use of these technologies in a responsible manner has been the publication, in 1995, of the FAO Code of Conduct for Responsible Fisheries and a series of technical guidelines on its application, also issued by FAO. Issues which are crucial to aquaculture enterprises and the expansion of their operations in the 21st Century include:

- use of genetically modified organisms and introduced species;
- reliance of aquaculture on the marine capture fishery industry;
- wisdom of diversifying into new species;
- use of new production technologies;
- importance of fish health and human food safety; and
- minimization of environmental impacts.

Some of these issues are briefly discussed below.

2. USE OF GENETICALLY MODIFIED ORGANISMS AND INTRODUCED SPECIES

Compared to livestock (particularly poultry) production, aquaculture has yet to fully exploit the potential of genetics to increase growth rates, improve disease resistance, broaden the environmental range within which species can be cultured, and create new products. However, this situation is rapidly changing, as illustrated by the production of genetically male and genetically improved tilapia (especially *Oreochromis niloticus*, Family Cichlidae), explicitly for increasing the income of small-scale farmers, and the development of transgenics for use in more capital-intensive settings. However, the precautionary approach is essential here, not only because of potential damage to the environment and diversity, but also to the public image of farmed aquatic produce.

Though there are difficulties in transferring such technology to smallholders, the potential of genetic improvement is now obvious to commercial-scale aquaculture producers. For example, a US$2.4 million pedigree salmon breeding and research unit was opened in the late 1990s by a Scottish aquaculture company with interests in Chile. Social disruption may be expected when production is intensified and production shifts towards the use of improved strains and the supply of small, but cheap fish to urban markets patronized by poor people decreases.

The introduction of non-indigenous species for aquaculture purposes has been blamed for unacceptable competition and cross-breeding with indigenous species, following their escape into the wild. Similar concerns exist in relation to the escape of transgenic fish. Approaches to preventing the reproduction of escaped trangenics appear rather important. Indeed, emphasis now needs to be placed on the testing of the products of genetic technology, rather than on further research on the technology itself.

3. REDUCING THE RELIANCE OF AQUACULTURE ON THE MARINE CAPTURE FISHERY INDUSTRY

It was estimated that the total use of fish meal by aquaculture enterprises will rise from 1.1 million tonnes in 1994 to 1.5 million tonnes in 2010, while fish oil use will expand from 0.4 million to 1.1 million tonnes. Overall, aquaculture is likely to utilize about 25% of the total fish meal supply and over 80% of the fish oil supply by 2010. However, there is a need for aquaculture to mature from being a net consumer of food-grade fishery resources into a net contributor, i.e., to use of feed ingredients not otherwise usable as human food. Also aquaculture firms should use feeding and water management systems that minimize waste and maximize the nutrient retention and health status of the cultivated organisms.

However, considering the growth of the Chinese aquafeed industry, fish meal usage by aquaculture might rise even higher than suggested above. In this case, and in spite of optimistic forecasts by the fish meal and fish oil industry, it is not certain how long supplies will be sufficient to support expansion in the culture of 'luxury' carnivorous species. Unless marine feed ingredients are diverted from use for other animal feeds, or fish meal is reserved only for aquaculture, or more discards and fish processing wastes are utilized in its manufacture, or expansion in the direct human use of fish oil slows down, fish meal substitution will become a necessity rather than only a desirable goal.

4. THE WISDOM OF DIVERSIFYING INTO NEW SPECIES

Broadening of the species mix in global aquaculture is frequently encouraged and is certainly occurring: scallop and *Pecten* culture has increased at over twice the global average for all mollusks; Japanese seabream production expanded, though slowly; Arctic char culture soared from only 3 tonnes in 1987 to 631 tonnes in 1996; sturgeon and bastard halibut farming increased by about three times the average finfish expansion rate; turbot and Atlantic cod culture each expanded by a factor of nearly 40 between 1987 and 1996, etc.

This diversification is expected to continue but it is debatable whether it should be encouraged or not. The culture of new species, as a reaction of entrepreneurial farmers to a perceived local, domestic, or export market, may seem reasonable but is often based on wild-caught juveniles or spat, or requires considerable research to develop the hatchery rearing technology. There is also a tendency for scientists seeking new challenges, publications, and research funds, to concentrate their efforts towards diversification. Drawing parallels from terrestrial livestock production, it would seem more sensible to concentrate development effort and scientific research on a relatively few species.

5. USING NEW PRODUCTION TECHNOLOGIES

Further research and development into new production technologies is essential if existing resources are to be used more efficiently, and new sites, with resources and space, brought into production. The most promising new opportunities are in the fields of fisheries enhancement (culture-based fisheries, both marine and inland) and aquaculture in recirculation systems and offshore sites. While fisheries enhancement mainly requires the solution of ownership problems rather than further research, recirculation technology does require further research effort. Aquaculture production from recirculation systems forms only a very small proportion of the global total, though it has been the subject of considerable research. This investment is bound to pay off, at least in developed countries, where the competition for water and suitable sites should make these techniques an essential component of aquaculture.

While increasing the efficiency of current methods and locations for aquaculture production in a responsible but cost-effective way can probably help it to keep pace with demand in the short to medium term, further expansion will ultimately be constrained by lack of space and water, and increased competition for other resources. However, if cost-effective technology can be developed, off-shore aquaculture has the greatest potential for increasing the area available for production. This topic is currently attracting great interest from entrepreneurs, equipment manufacturers, and academic and research institutions, but poses many technological challenges. Fish appear to grow faster and healthier off-shore, where better water exchange enhances the supply of dissolved oxygen and more effectively disperses wastes. Off-shore aquaculture units create less conflict with other coastal resource users, such as urban, industrial, recreational and tourism developments, and have a reduced visual footprint. The development of this type of aquaculture would enable more of the countries which do not have protected sites, such as fjords or lochs, to move into marine fish farming. However, the many technical challenges include the need to develop equipment to withstand wave action, solving the difficulties in farm management (including feed and other consumables supply and staffing for maintenance and monitoring duties), ensuring safety and protection against poaching, etc.

6. THE IMPORTANCE OF FISH HEALTH AND HUMAN FOOD SAFETY

The most important limiting factor for shrimp farmers appears to be disease problems. Indeed, the risk of aquaculture diseases spreading to wild stock receives particular attention from environmental lobby organizations and recreational fishers. The frequent emergence (or recognition) of new aquatic diseases means that health management will continue to be one of the most critically important topics in the 21st Century. Fortunately, the need for a 'systems management approach' to disease prevention has been recognized and new tools to combat or control diseases (including quality controls on inputs of water, feed and seed, nutrition, harnessing defense mechanisms, new vaccines, immunostimulants and non-specific immune-enhancers, new assay procedures, and genetic technologies to increase disease resistance) are being developed and applied.

The FAO Code of Conduct for Responsible Fisheries calls for food safety in aquaculture products. Food safety assurance programmes, based on HACCP (Hazard Analysis Critical Control Points) principles and the SPS (Sanitary and Phytosanitary Measures) of the World Health Organization (WHO) are increasingly being applied to aquaculture products as an essential alternative to the imposition of import embargoes. The relevant international organization is the FAO/WHO *Codex Alimentarius* Commission. HACCP principles have been included in an FAO draft for a Code of Hygienic Practice for the Products of Aquaculture, which is being reviewed by the CAC Committee on Fish and Fishery Products.

The US government and industry have developed comprehensive HACCP plans for selected aquaculture products, and similar initiatives are being taken in Australia, Chile, New Zealand, Norway, Thailand and EU member countries. It is expected that these principles will increasingly be applied to aquaculture products on a global basis. However, some of the requirements of this approach will be hard to meet by to small-scale fish farmers.

7. MAINTAINING ACCEPTABLE ENVIRONMENTAL CONDITIONS

While certain forms and locations of aquaculture have definitely resulted in negative impacts (both environmental and social), some of this criticism may have been unfair, with aquaculture operators being assessed more harshly than other activities, notably cities and their industrial and human wastes, agriculture, and mangrove logging. Nevertheless, the public perception of aquaculture as a major polluter continues to hamper its further development.

The potential for aquaculture to contribute further to enhanced food supplies and incomes, particularly in developing countries, may be reduced because of increasing pressure on aquatic environments and competition for finite resources from non-aquaculture resource users. Aquaculture also suffers from negative public perceptions caused by the relatively few (but well publicized) cases of severe local environmental degradation and social disruption caused by some forms of aquaculture. To deal with this, an 'enabling environment' for sustainable aquaculture development should be created as a responsibility of governmental, non-governmental and financial organizations, as well as the industry itself.

In any case, the aquaculture sector, and particularly the individual enterprises are likely to come increasingly under closer public scrutiny. The activities of the private sector in seeking to implement responsible aquaculture practice may counter, in the media, the influence of groups opposed to aquaculture development. One of the most publicized private sector initiatives so far is the formation of an organization called the Global Aquaculture Alliance by the shrimp farming industry, which participated in public fora such as the World Aquaculture Society Annual Meetings in Seattle (1997) and Las Vegas (1998). GAA has published codes of practice for responsible aquaculture and mangrove use, which aim at averting stricter government regulation.

However, doubts may be expressed about the consumer acceptability of self-regulation. 'Eco-labeling' may only be effective if it is monitored by independent organizations whose activities are acceptable to producers, environmental animal welfare groups, and consumers alike, and if a confusing plethora of industry-driven labels is avoided. It is therefore encouraging that the efforts of the Marine Stewardship Council (MSC) to develop a certification system for the products of capture fisheries (see www.msc.org) are being extended to aquaculture products.

8. TRADE ISSUES

'Industrial' methods of aquaculture production have substantially increased the availability of some aquatic products formerly in the luxury category, such as salmon, Mediterranean seabass and seabream, and shrimp. In the case of Atlantic salmon, and to a lesser extent seabream and seabass, one result has been a reduction in unit market price, thus considerably broadening the consumer profile. This does not bring salmon anywhere near the 'aquatic chicken' goal sought by proponents of tilapia farming in terms of price, and it does not make salmon farming a responsible user of feed resources. However, it does mean that farmed salmon has enormously expanded the market.

Globally, most aquaculture products are consumed domestically. However, many countries have been able to export valuable commodities, such as marine shrimp, salmon, and mollusks, and this could contribute to food security in developing countries if the foreign exchange earned is used to import greater quantities of less costly protein foods. While further expansion of the trade in (European) seabass and seabreams may be confined principally to Mediterranean countries, there appears to be considerable potential for much wider trade in tilapia in the next decades. By 1996, tilapia was already the third largest aquaculture import into the USA (after shrimp and salmon), having increased 17% by weight and 26% in value from 1995. The principal tilapia exporters are currently Central American countries to the USA, and Taiwan to Japan and the USA. Thailand and Indonesia are also exporting tilapia, and Viet Nam and China are recent entrants to this trade. Tilapia prices, though not yet the 'chicken-of-the-sea,' are expected to decrease, thus leading to further exports, not only to the USA but also to Europe.

9. THE IMPORTANCE OF RESEARCH AND TECHNOLOGICAL DEVELOPMENT

The delicate balance between food security and the environmental cost of production, and between food production and revenue generation and the protection of the environment (for its intrinsic value and its capacity to promote material and other benefits for future generations), can only be achieved through a better understanding of the system in which we live. Reductions in research effort in the natural and social sciences would narrow our choice. Continued support for research and development will be critically important if our efforts to expand aquaculture production in the next decades are to be achieved.

Further, one of the most obvious means of ensuring the promotion of responsible aquaculture within an 'enabling environment' is through the development of appropriate regional and national policies, regulations and plans. Existing government regulations are often perceived as unnecessarily constraining aquaculture activities, or failing to protect them. However, where the consultation process is satisfactory, they may be welcomed by the industry.

Developing a comprehensive regulatory framework for aquaculture is often legally and institutionally complex, particularly because aquaculture is frequently controlled by several agencies under a variety of laws and regulations.

The closer integration of aquaculture with other activities using the same resources, notably crop and livestock production, forestry, irrigation and water supply systems must serve to induce greater responsibility and sustainability. Besides the integration of systems, greater vertical integration (either financially or collaboratively) within the aquaculture industry, from resource supply through to the marketing of aquaculture products, may be beneficial. Governments need to exert their influence towards greater integration of aquaculture into agriculture. For example, rice-fish farming needs active governmental support as part of processes designed not only to improve food security but also to ensure sustainable rural development.

10. CONCLUSIONS: A FUTURE FOR AQUACULTURE

During the 21st Century, relatively affluent people, including the bulk of the citizens of so-called 'developed countries', will have to make some uncomfortable choices, and examine their ethics more closely. Mouthing platitudes about increasing food supply for the starving billions in the developing world without decreasing consumption of food and resources in the developed world will not work. Thus, if those presently too poor to purchase fish are to have access to fish, consumption in developed countries will probably have to decline, even if aquaculture succeeds in filling the gap between capture fisheries supply and increasing global population and demand. At present, we continue to delude ourselves that increasing (average) affluence justifies the use of less responsible forms of aquaculture, such as those which are net consumers of fish products (fish meal and fish oil), for example.

Indeed, finite fisheries resources, and our responsibility to ensure that they are used to create the maximum quantities of food, mean that we should discourage present trends toward less responsible forms of aquaculture, both by our private and corporate actions and, if necessary, by government regulation. If we can increase productivity without increasing resource consumption (i.e., by a more intensive and efficient use of finite resources) then we may be able to postpone the day when the rich of every country will have to deny themselves the variety of luxury food items so far available.

Although there remain many ethical and humanitarian questions to be resolved during the 21st Century concerning food security, global aquaculture production is likely to continue expanding, no matter who consumes it.

BIBLIOGRAPHY

Bardach, J.E., J.H. Ryther and W.O. McLarney. (1972). Aquaculture: the farming and husbandry of freshwater and marine organisms. John Wiley & Sons. New York. 868 p. [This is a classic and comprehensive, if somewhat dated review of aquaculture systems and species up to the late 1960s.]

Barg, U.C., D.M. Bartley, A.G.J. Tacon and R.L. Welcomme. (1997). Aquaculture and its environment: a case for collaboration, p. 462-47. In: D.A. Hancock, D.C. Smith, A. Grant and J.P. Beumer (eds.) Developing and sustaining world fisheries resources. The state of science and management. Proceedings of the 2nd World Fisheries Congress, Brisbane, Australia, 28 July - 2 August 1996. CSIRO. Collingwood, Australia. [A cogent argument for sustainable aquaculture.]

Huet, M. (with the assistance of J.A. Timmermans). (1986). Textbook of fish culture: breeding and cultivation of fish. Fishing News (Books) Ltd. West Byfleet and London. [A classic aquaculture text, translated from French, and updated.]

New, M.B. (1998). Global aquaculture: current trends and challenges for the 21st Century, p. 9-57. In: Proceedings of Aquicultura Brasil '98, 2-6 Nov. 1998, Recife, Volume 1. World Aquaculture Society. Latin American Chapter, Baton Rouge. [A comprehensive review, providing the details behind the various issues raised in this contribution.]

Pullin, R.S.V., H. Rosenthal and J.L. McLean (Editors) (1993). Environment and Aquaculture in developing countries. ICLARM Conference Proceedings 31. ICLARM. Manila, Philippines. 390 p. [The chapters in this edited volume review a wide range of environmental issues raised by present aquaculture practices, and propose mitigations.]

Ruddle, K. and G.F. Zhong. (1988). Integrated agriculture-aquaculture in South China: the dyke-pond system of the Zhuijian Delta. Cambridge University Press. Cambridge. 173 p. [Detailed description of an old and sustainable integrated aquaculture system.]

Tacon, A.G.J. (1997/8). Global trends in aquaculture and aquafeed production 1984-1995, p. 5-37. In: International Aquafeed Directory and Buyers' Guide. Turret RAI, Uxbridge, UK. [A review by the authority on feed requirements of various species and aquaculture systems, with a description of major trends.]

Biographical Sketches

Pamela Brown. *Curator of Ethnology and Media, Museum of Anthropology, University of British Columbia, 6393 Marine Drive, Vancouver, BC V6T 1Z2, Canada. Tel. No.: +1 (604) 8226587. Fax: +1 (604) 8222974. Email: pbrown@interchange.ubc.ca*. Pam is a member of the Heiltsuk Nation whose traditional territory is in the central coast area of BC, and was born and raised in Bella Bella. Her early experience includes commercial fishing on the east and west coast of Canada and work in the Namu Salmon cannery. Pam received her B.A. in 1990 and graduated with her M.A. in Anthropology at UBC in 1994. As part of her M.A. thesis program, she curated the Museum of Anthropology's (MOA) exhibit *Cannery Days: a chapter in the lives of the Heiltsuk* (1933-1994) that described the life and work experience of women and men in the Namu salmon cannery. Pam is now curator of Ethnology and Media at MOA. Her area of interests include cultural representation, ethnographic authority, First Nations protocol, developing partnerships between First Nations communities and museums, virtual museums, treaty negotiation support, and First Nations training.

Nigel Haggan. *Research Associate, Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC V6T 1Z4, Canada. Tel. No.: +1 (604) 8226939. Fax: +1 (604) 8228934. Email: n.haggan@fisheries.ubc.ca*. Nigel grew up in Northern Ireland with connections on both sides of the doctrinal divide. Perhaps in consequence, his main area of interest is in exploring ways for people from different cultural, religious and educational backgrounds to collaborate. He moved to Canada in 1981 and spent twelve years helping to develop cooperative fisheries management concepts and programs between British Columbia First Nations, government, science and industry. He joined the Fisheries Centre at UBC in 1994 with the idea of using the university as a neutral forum where diverse interests in the Pacific Fishery might be sufficiently comfortable to pursue their common interest in healthy ecosystems and fisheries. Current work includes ways to integrate traditional environmental knowledge with 'mainstream' science and a suite of initiatives to make university fisheries science more accessible to Aboriginal communities. He was also involved in projects in Hong Kong and Indonesia designed to maximize the ecological, social and economic benefits from marine ecosystems.

Michael New. *President, European Aquaculture Society. Wroxton Lodge, 25 Institute Road, Marlow, Bucks SL7 1BJ, UK. Email: Michael_New@compuserve.com*. Michael entered the field of aquaculture in 1969 after extensive experience in the animal feedstuff industry. After conducting research on freshwater prawn culture in the UK and North America, he worked both as an international consultant in finfish and crustacean culture, with clients that included major public companies, private individuals, governments, and aid organizations, and for various international organizations, notably the United Nations Development Programme, the European Commission, and the Rome-based Food and Agriculture Organization of the United Nations, where he was Senior Aquaculturist. Michael has aquaculture experience in Australia, Bangladesh, Belgium, Brazil, Brunei Darussalam, Canada, China (PRC and Hong Kong), Colombia, Dominica, Egypt, Germany, Greece, Guam, Indonesia, Italy, Japan, Kuwait, Malaysia, Martinique, Mexico, Morocco, Namibia, Nepal, Nigeria, Norway, Pakistan, the Philippines, Portugal, Saudi Arabia, Singapore, Sri Lanka, Switzerland, Thailand, Tunisia, UK, USA and Zambia. He has authored more than 100 technical manuals, scientific papers and popular articles on aquaculture, and has chaired or been a keynote/plenary speaker at numerous international conferences. He was President of the World Aquaculture Society (1997-1998), which appointed him as an Honorary Life Member in 2002. In 1999 Queen Elizabeth appointed him an Officer of the British Empire (OBE) for services to aquaculture in developing countries.

Daniel Pauly. *Principal Investigator, The Sea Around Us Project, Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC V6T 1Z4, Canada. Tel. No.: +1 (604) 8221201. Fax: +1 (604) 8228934. Email: d.pauly@fisheries.ubc.ca*. Daniel is a French citizen who grew up in the French-speaking part of Switzerland. He completed high school and university studies in the Federal Republic of Germany, where he acquired a 'Diplom' (= M. Sc.) in 1974 and a Doctorate in Fisheries Biology in 1979 at the University of Kiel. In 1979, he joined the International Center for Living Aquatic Resources Management (ICLARM), in Manila, Philippines, as a Postdoctoral Fellow, and gradually took responsibilities as Associate, and Senior Scientist, then Program and Division Director. In 1985 he obtained the 'Habilitation', again at Kiel University. In 1994, he became a professor at the Fisheries Centre, University of British Columbia, Vancouver. His scientific output, covering fish biology, fisheries management and ecosystem modeling, comprise 500 items, including books, scientific articles, and software used throughout the world.

Ussif Rashid Sumaila. *Assistant Professor, The Sea Around Us Project, Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC V6T 1Z4, Canada. Tel. No.: +1 (604) 8220224. Fax: +1 (604) 8228934. Email: r.sumaila@fisheries.ubc.ca*. Rashid is an economist – a senior research fellow at the Chr. Michelsen Institute, Bergen, Norway and an Assistant Professor at the Fisheries Centre, UBC. His research interests include multi-agent modeling of fisheries, the evolution of global fish catches and prices and ethical issues in the use of common property resources. A selection of Rashid's recent publications are, *viz.*: (1) A review of game theoretic models of fishing, *Marine Policy*; (2) Protected marine reserves as fisheries management tools: a bioeconomic analysis, *Fisheries Research*; (3) Cooperative and non-cooperative exploitation of the Arcto-Norwegian cod stock in the Barents Sea, *Environmental and Resource Economics*; (4) Strategic dynamic interaction: the case of Barents Sea Fisheries, *Marine Resource Economics*.