MARICULTURE, ENVIRONMENTAL, ECONOMIC AND SOCIAL IMPACTS OF

K. D. Black, Dunstaffnage Marine Laboratory, Argyll, UK

doi:10.1006/rwos.2001.0487

Introduction

The culture of marine organisms requires the supply of environmental resources which vary according to the culture species and method. As culture methods are diverse and a very large and growing number of species are cultured, it is not possible to make many wide generalizations on environmental effects. In broad terms, noncarnivorous species have relatively low environmental demands whereas carnivorous species may make high demands; the culture of autotrophs, e.g., seaweeds, is not considered here. In the case of noncarnivorous species, e.g., bivalves, interactions arise from extraction of nutrients which are largely exported from the system in the product, although there may be a local residual impact through local concentration of wastes. For carnivorous species in open culture systems, nutrition comes from external sources, e.g., from agriculture and capture fisheries, and the local environment is used directly for the processing of waste products. The most obvious environmental resources used for aquaculture include the provision of nutrients and oxygen and the processing of wastes. If a whole system approach is taken then the environmental costs of constructing infrastructure such as cages, nets, boats, roads (often through remote areas) and buildings, as well as the potential ecological costs associated with transmission of diseases and parasites, the effects of escaped culture organisms and conflicts with wild predators, e.g., piscivorous birds should be included.

Artisanal aquaculture is less important in the marine environment than in fresh water so the main drivers of aquaculture expansion are economic rather than social, although the social consequences may be profound. Both the socioeconomic and environmental aspects of mariculture are best understood for the cage production of salmon in high latitudes and for the marine and brackish water pond culture of shrimps in low latitudes. Both culture methods require large inputs of external nutrients and carbon and both are essentially cash crops relying on global markets. The giant tiger shrimp *Penaeus monodon* and the Atlantic salmon *Salmo salar* had ex-farm values of 3.86 and 2.16 billion US$, respectively in 1998. Much of world salmon production takes place in relatively remote areas traditionally dominated by coastal fisheries and small-scale agriculture, taking advantage of a relatively pristine, nonindustrial environment. Similarly, shrimp culture has utilized coastal areas traditionally reliant on artisanal coastal fisheries. In both cases, what was formerly a resource held in common by those exploiting capture fisheries has been transferred to private ownership, although this is more often explicitly a problem in the case of shrimp culture in mangrove fringes. The benefits to remote communities from the employment caused may be considerable although, where companies are not locally owned, profits may also be exported.

Harvesting of Wild Seedstocks

The collection of wild seed is widespread in aquaculture and may be at a range of scales. Where spat are passively collected for bivalve culture on a small scale compared to the total spat abundance, there is likely to be comparatively little impact on sustainability. On the other hand, broodstock for some species are either difficult or expensive to maintain and seed supplies are harvested from the wild either as larvae, fry or berried females. Capture methods are often indiscriminate and very large numbers of by-catch are killed in the process, which may have significant implications for fisheries and ecosystems more generally. It has been estimated that for every giant tiger shrimp captured for pond culture in India and Bangladesh, 160 fish and shrimp fry are discarded. This process may also lead to scarcity of local seed necessitating the importation of foreign stock with attendant risks of disease and parasite transfer.

Feedstocks

The culture of carnivorous species requires inputs of protein, lipids, vitamins, pigments, and other trace components. These are typically fish meal based and this has led to some controversy regarding the actual contribution that this type of culture makes to world food supply. Capture fisheries landings are now around 95 Mt (million metric tonnes) per annum of which around 30 Mt is converted into fish meal and fish oil giving around 6–7 Mt and 1.2 Mt of fish meal and fish oil, respectively. The share of this production that is consumed by aquaculture is increasing over time, from about 10% in 1988 to 33% in 1997, as aquaculture production increases. Some of the fish species used for fish meal production are suitable for human consumption and it is possible that these will, therefore, become unavailable for fish meal production in the future. This may be compensated for by an increased use of fish currently regarded as a by-catch and discarded at sea.

The crucial argument here is whether aquaculture adds to the pressure on wild fisheries. Many wild fisheries are thought to be overexploited but these are mostly for large, high value species, e.g., cod. There is little evidence to support the view that the demand caused by aquaculture has any effect on the sustainability of the fishery which supplies the fish meal industry as most of these species are small, have relatively short life spans, are currently not overexploited and appear to be resilient to even dramatic environmental changes such as El Niño. When supply is reduced, as in El Niño years, the proportion used by aquaculture increases due to a move away from fish meal by the other main consumers, the pig and poultry industries. Nevertheless, it is generally accepted that, in the long term, there will have to be a move to supplement fish meal, and more importantly fish oil, with other protein and oil sources and research in this field is very active.

It takes around 1200 g of fish feed (9% water) to produce 1 kg (weight) of farmed salmon. Salmon feed typically contains 40% protein. If this is all from fish meal and this is derived from wild fish with a 17% protein level then this will require $0.4 \times 1.2/0.17 = 2.82$ kg wild fish per kg salmon. This figure can be considerably reduced if proteins from vegetable sources are used as partial substitutes. Salmon feed typically contains 30% oil. If this is all from fish meal derived from wild fish with an oil content of 7–10% (depending on source) then this will require $0.3 \times 1200/0.07$ or $0.1 =$ 3.6–5.14 kg wild fish per kg salmon. Again this can be substituted with vegetable oils but this will cause a change in the lipid profile of the fish and reduce the health benefits for consumers. Fish oil is presently cheaper than many vegetable oils, which is a disincentive to substitution. A budget of feed utilization is given in **Figure 1**.

Less research has been done on other marine species but many have a higher demand for fish meal than salmon (but often lower oil demands) as their food conversion efficiency is as yet suboptimal,

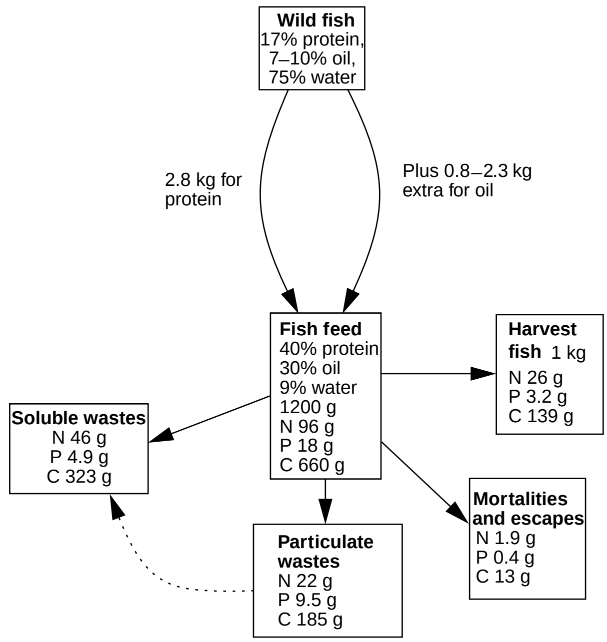

Figure 1 A budget for the flow of nutrients from oceanic wild caught fish to the coastal environment for a harvest of 1 kg of farmed salmon assuming no substitution with vegetable protein or oil and a ratio of fish feed to product of 1.2 : 1.

which may be due to there being less well-developed feeds to meet their specific needs. For example, European sea bass *Dicentrarchus labrax* and gilthead sea bream *Sparus aurata* have typical food conversion ratios (weight of feed to weight of fish product) during on-growing of 2–3:1 compared to 0.9–1.2:1 typical for salmon culture. Shrimps require much lower incorporation of oils in their diets (around 4%).

Wastes from Cage Culture

In cage culture, a variety of methods are used to feed fish, from simple hand feeding to sophisticated computer-controlled activation of automatic feeders with *in situ* sensors to detect uptake. The methods will vary with the size and species and the available technology. Feeding method is important as it can have a direct bearing on two important sources of wastage: overfeeding and mechanical damage to feed pellets. Overfeeding can occur during hand feeding by poorly motivated staff (well trained and motivated staff will observe fish reactions to offered feed), or when an automatic system is wrongly programmed either by an overestimate of the biomass of fish in the cage or by a failure to consider factors which might reduce appetite, e.g., temperature or disease. There are particular problems when feeding diseased fish with medicated feed as many diseases result in reduced appetite. Significant percentages of pelleted feed can be turned into dust by being inappropriately handled by badly set up delivery systems.

A wide range of medicines are used in fish farming to treat infections and parasitic infestations. Ideally these are administered with the feed without overfeeding but bath treatments are also common where the whole fish is immersed in a solution of the medicine. In this case the solution is usually discharged directly to the environment. Antibiotics and antiparasitics have received the most research attention. A wide range of antibiotics is used in aquaculture including oxytetracycline, chlortetracycline, oxolinic acid, furazolidone, sulfadiazene, trimethoprim, sulfadimethioxine, ormetoprim, chloramphenicol, and a host of others although for each species only a subset of these will be used and these will vary by country owing to different regulations. For example, nitrofurans, e.g., furazolidone, are only permitted in countries where regulation is not well developed due to their carcinogenic or mutagenic properties. Many importing countries have monitoring programs which test for the presence of antibiotics and other chemicals. The risk is that the presence of small doses of antibiotics might cause the development of antibiotic resistance but it is probable that this is a relatively minor contributor to this phenomenon compared to the misuse of antibiotics in human medicine.

Antibiotics are typically admixed with the feed and find their way into the environment either directly through feed wastage or indirectly after excretion by the culture organism. Antibiotics differ in terms of their uptake, residence in tissues, stability and clearance rate but in most cases a large percentage of the medicine enters the environment. On entering the environment the fate of an antibiotic medicine will depend on its decay kinetics (half-life) in a particular matrix and its bioavailability. Oxytetracycline is among the best-studied of these products. It appears to have a relatively short half-life in water but can persist in sediments for considerable periods (several months) although it can be rendered unavailable through complexation with divalent cations. Bacterial populations can develop resistance to oxytetracycline although it is not clear whether this presents any human or environmental hazard. Residues have been found in populations of adjacent animals, such as mussels, which could potentially enter the human food chain along with any associated resistant bacteria. Antibiotics have been shown to affect biogeochemical processes in sediment, e.g., oxygen uptake/sulfate reduction rates, but this is a poorly researched area. Vaccines have reduced the routine usage of antibiotics during the 1990s but, as production levels have dramatically increased, it is likely that the total quantities are still significant. In tropical mariculture, it is more difficult to obtain accurate information on usage rates.

Fish feed also ends up in the water column as the products of metabolism and excretion or through remineralization in sediments. These products include inorganic phosphorus and nitrogen compounds and organic carbon, nitrogen, and phosphorus. The former are highly available for autotrophic consumption and the latter may stimulate bacterial production with consequences for microzooplankton bacterial grazers. In many areas, fish farms may represent the largest regional input of nutrients to the marine environment. For example, in Scotland, as a crude estimate, 6900 tonnes of nitrogen and 1240 tonnes of phosphorus enters the marine environment per year from a production of about 120 000 tonnes salmon. Thus, it has been hypothesized that effluents from farms may cause perturbations in algal communities as they are rich in nitrogen, which may be limiting in summer and autumn, and are deficient in silicon, and that this can increase the development of toxins in certain algae. This is generally thought unlikely as advective processes usually lead to the exchange of local water and the dispersion of nutrients on a timescale faster than phytoplankton reproduction, although more research is required in this area. In the more open coastal environment, inputs of nutrients from the ocean appear to swamp inputs from fish farms and only a small percentage of algal production has been attributed to these nutrients. The situation with other more rapidly reproducing organisms, such as bacteria, is less clear. Although only a little work has been done in this area it seems reasonable that for some sites bacterial production will be stimulated by the effluent organic nutrients from cage culture.

The distribution of organic wastes on the seafloor depends on the settling velocity of the waste feed and fecal pellets and the current velocity profile (both of which show temporal variance) and the depth. Input rates will vary over time both on a daily basis depending on feeding regime and throughout the growing cycle of the fish on site. Most large salmon farm sites now operate on a single year class basis to minimize disease transfer between year classes. This effectively means that sites are on a 2-year waste cycle with small fish and a relatively low input at the beginning rapidly increasing until maximum biomass is reached and maintained from the middle of the cycle with harvesting completed at the end of year 2. The distribution of wastes will thus change over time and may be continuously redistributed by resuspension that may be tidal and/or storm driven and which is strongly site specific. The degree of the impact may also vary according to the receiving environment and there is growing evidence that impacts on the sea bed are less than might be predicted at sites in the Mediterranean and the Red Sea. Further work is ongoing in these areas to establish the causes and generality of these observations but this lower than expected impact is probably caused by temperature-enhanced bacterial activity and by the more efficient utilization of waste organics by wild populations, particularly of fish, in oligotrophic environments.

All culture systems require a supply of oxygen. In open systems, e.g., cages, this is supplied by the environment and is brought to the fish by water movements. Thus, the scale of the culture operation must be matched to the lowest expected supply rate, i.e., during slack tides and/or calm weather and high temperatures otherwise problems through hypoxia may result. This may be compounded by organically enriched sediments which themselves may exert a considerable oxygen demand leading to hypoxia or even anoxia in bottom waters. Open culture of carnivorous species essentially uses the coastal environment to oxidize large amounts of highly reduced fish feed input. The main effects on the sediments are simply a consequence of their use as a site for the processing of highly reduced material. The biogeochemistry of sediments beneath marine cages in quiescent environments is dominated by the availability of labile reduced carbon. These sediments therefore exert a strong oxygen demand. When the demand for oxygen exceeds supply from the overlying water for even a few hours, anoxia and azooic conditions are created. Where supply and demand are more balanced the presence of *Begiattoa* sp. bacterial mats is common. These bacteria form part of the sulfide cycle where sulfide released by sulfate reduction in anoxic sediments is re-oxidized to sulfate using oxygen from the overlying water. Sulfate reduction is the main process by which organic material is oxidized in anoxic marine sediments although, in extreme cases, fermentative methanogenesis is likely and is characterized by out-gassing. Such out-gassing is potentially a problem as this can facilitate the delivery of toxic hydrogen sulfide to the water column and to cages moored above.

The benthic ecology of heavily polluted sediments from cage culture is typically described as falling into four zones. Under the cages may be totally azooic but on the next radial zone, typically at the edge of the cage group, a few sulfide-tolerant, opportunist polychaetes species (e.g., *Capitella* sp.) proliferate in huge numbers (of order 10^5 individuals m^{-2}). These play an import role in mixing the substrate and making it more available to bacterial action – experiments have even been done to culture these worms to seed impacted seabed in order to enhance recovery rates. Beyond this, a zone of increased diversity and high biomass takes advantage of the carbon supply and this is succeeded by the fourth zone where benthos typical of the local environment dominates. The areas of these zones vary over time reflecting the changing supply rate from the farm; at well-flushed sites the azooic zone is often absent.

Escaped Cultured Organisms

When cultured organisms escape, a range of outcomes are possible depending on whether there are native wild conspecifics or close relatives in the receiving environment and on whether the escapee is reproductively competent in that environment. Direct ecological risks are possible where escaped organisms may compete for resources with wild populations. This will depend on the number of escapees relative to wild competitors, and on whether the escapees can reproduce to found a new population. Where there are local populations of conspecifics, the possibility for outbreeding depression exists, which might cause a loss of local adaptation. There are many possible permutations and scenarios when considering the genetic interaction of escapees and wild populations and some of these are likely to be either improbable or relatively benign as a consequence of the generally reduced fitness for life in the wild that comes with domestication, i.e., traits selected for during culture are unlikely to be advantageous in the wild but much depends on the scale of the escape. However, there are significant risks. For example, one devastating scenario is that of the so-called Trojan gene, which has been developed through consideration of the possible implications of escaped transgenic fish: if a transgene resulted in a mating advantage (e.g., due to size) but with low reproductive viability it could spread quickly through a wild population leading to extinction. This is purely speculative but there is real concern that the continuous escape of domesticated, maladapted genes into wild populations will result in significant damage. Many species have important population genetic diversity which would be lost if these genes were homogenized with large numbers of escapes. This has two major implications: (1) that wild populations with reduced genetic diversity would be less able to cope with environmental (e.g., climatic) change; and (2) that this genetic diversity is lost to future culturists ultimately leading to inbreeding depression within domesticated stocks, perhaps originating from only a few families.

Transfer of Diseases and Parasites

Problems of disease transfer are probably most commonly experienced from wild populations to farmed rather than vice versa as diseased animals are hard to find in the environment and diseases can spread much more easily through confined animals in high density. However, there are several cases where disease has spread from a farmed stock to a wild population. One notorious example is that of the monogenean parasite *Gyrodactylus salaris* which was transferred with hatchery reared Baltic salmon onto the Atlantic coast of Norway in the 1970s. The Baltic Atlantic salmon race has developed resistance to this parasite, but their Atlantic cousins were very susceptible and many wild populations became extinct. The disease furunculosis, caused by the bacterium *Aeromonas salmonicida,* was believed to have been reintroduced to Norway in 1985 via transfer of cultured stocks from Scotland and led to severe damage to both farmed and wild populations.

Sea lice infestations are endemic in many salmonid culture areas and, in recent years, declines in wild salmonid populations have led to the widespread belief that there is a link with farming. On their first visit to sea in the spring of the year after hatching, sea trout *Salmo trutta* smolts may be confronted with very high numbers of infective sea lice larval stages and quickly become infested with up to several hundred lice. A burden of only 10 adult lice is sufficient to cause mortality, especially in fish which may not have fully developed their osmoregulatory system. Results from Norway indicate that 50–90% of the wild postsmolts of Atlantic salmon were killed as a direct consequence of sea-lice infections during migration from two fiords in spring 1999. Although the relationship between sea-lice infection and the decline of wild populations is striking, there is no definitive proof of a causal link as the origin of lice on wild fish has not been clearly established. There is, however, some genetic evidence that at least some lice on wild fish are of farmed fish origin and further evidence will come if wild populations recover once lice management improves through the use of more efficacious medicines.

Habitat Destruction

Although cage farming causes little habitat destruction apart from the immediate surrounding benthos, the destruction of mangrove forests for the farming of shrimps is of serious concern. Shrimp farming is only a relatively small contributor to global mangrove destruction although locally it can be devastating. Mangroves provide a rich matrix that supports high levels of diversity providing nursery areas for a wide variety of juvenile fish and crustacean species. Mangroves also provide a buffer between the coast and sea protecting the coast from storm erosion and processing material flowing from land to sea thereby improving water quality. In many shrimp farming areas (e.g., in Ecuador and Indonesia) mangroves have been cut for the creation of ponds at densities beyond the carrying capacity of the environment. This is especially so when ponds are emptied at the end of a growing cycle releasing a pulse of highly enriched sedimentary material into the system. Intensive systems also rely on large amounts of chemicals and medicines to maintain shrimp health and these can contaminate the wider environment when discharged either routinely or during pond clearance. Shrimp culture has been dominated by a boom and bust cycle (e.g. in Taiwan, China, and Indonesia) where initial high productivity is replaced by massive mortality caused by disease and reduced water quality. Regulations are now in place in many shrimp-farming countries which prohibit the cutting of mangroves for shrimp farming but, in several cases, the necessary enforcement infrastructure is lacking. There are continued efforts to improve shrimp-farming practices to reduce environmental damage, e.g., reductions in stocking density can lead to improved growth and reduced incidence of disease with less chemical usage.

Interactions with Predators

Cultured animals may represent an attractive food source for predators including seals and birds. These may result in significant losses either directly, by taking or damaging farmed stock or indirectly, such as when seals damage nets allowing fish to escape. Farmers attempt to minimize such losses with a range of deterrents. These include shooting, erecting a barrier, e.g., an antipredator net, or using sonic devices. For example, eider ducks *Somateria mollissima* predate farmed mussels *Mytilus edulis* and may be deterred by submerged nets and by acoustic scarers mounted on floating structures. Similarly, seals may be deterred by nets or by submerged acoustic devices. Such devices may also disturb cetaceans, which are generally more sensitive than seals to underwater noise. Research into the impacts of seal scarers on cetaceans is urgently required. What limited evidence there is suggests that cetaceans may be excluded from areas up to several kilometers from fish farms with high-powered acoustic deterrents. Fish and mammals are shot but it is difficult to quantify the impacts of this activity on wild populations as records may not be accurate. In the developed world, at least, shooting is accepted only as a last resort.

Socioeconomic Aspects

There is no doubt that mariculture can have enormous financial benefits which may run into billions of dollars. For example, the 1998 farm gate value of giant tiger shrimps is given in **Table 1**. **Table 2** shows the value of individual products to nations and includes those products where the national value exceeded 0.25 billion US$ in 1998. Many of these products are sold to export markets although, for some, there are significant internal markets. Wherever the market, the contribution of mariculture is clearly immense and forms a significant proportion of national income for many countries.

The socioeconomic benefits at the local level are, however, highly variable and there are many instances where mariculture comes into conflict with a variety of other stakeholders including inshore fisheries, tourism, and navigation. Different culture methods may also cause conflict, for example, where chemicals are used in fin-fish culture, appropriate separations must be maintained with filter feeding shellfish culture to prevent cross-contamination. There may be serious conflict when local users of a particular common resource, e.g., mangrove forests, are not consulted prior to the development of ponds that may have serious implications for their livelihood. The coastal zone is regarded as the most valuable on earth and it is not surprising coastal aquaculture is at the forefront of such conflicts as it is a relatively new industry. Many countries are now moving towards coastal zone management as an equitable method of allocating resources to avoid conflicts. This involves educating all stakeholders as to the environmental needs of each use type and setting up a framework of regulation and mitigation in order to protect legitimate rights.

Many of the largest mariculture industries are now owned by multinational companies and there is a possibility of the profits being exported from the producing area while the environmental risks are not. Most countries are now moving towards regulations which enhance the sustainability of aquaculture and it is by such regulation, together with monitoring and enforcement, that companies can be obliged to accept responsibility for local impacts. In addition, particularly for exported products, consumer pressure is becoming more sophisticated and there are already campaigns against products from sectors that have poor practice. Although this is a rather blunt instrument, which relies on the availability of clear, balanced information to be truly effective, it is likely to become a major factor in

Table 1 Farm gate value of giant tiger shrimp *Penaeus monodon* for the top 12 producing countries (values in 1000 US$, FAO Statistics)

Producer	*Value (1000 US$) in 1998*
Thailand	1 597 199
Indonesia	754 090
India	585 144
Viet Nam	417 600
Philippines	268 804
Malaysia	72 316
Sri Lanka	53 820
Taiwan	44 245
Madagascar	32 283
Saudi Arabia	13 448
Australia	11 254
Seychelles	7399

Table 2 Mariculture national products that exceeded 250 million US$ farm gate value in 1998 (FAO statistics)

Product	*Producing country*	*Value 1000US$*
Pacific cupped oyster	China	2 549 856
Japanese carpet shell	China	1 825 776
Giant tiger shrimp	Thailand	1 597 199
Japanese amberjack	Japan	1 081 395
Atlantic salmon	Norway	999 641
Fleshy prawn	China	987 293
Yesso scallop	China	881 122
Mandarin fish	China	814 125
Giant tiger prawn	Indonesia	754 090
Whiteleg shrimp	Ecuador	648 000
Giant tiger prawn	India	585 144
Silver seabream	Japan	497 338
Giant tiger prawn	Viet Nam	417 600
Atlantic salmon	Chile	374 731
Penaeus shrimps	Bangladesh	351 083
Marine crabs	China	348 949
Atlantic salmon	United Kingdom	332 751
Razor clams	China	332 026
Yesso scallop	Japan	295 392
Coho salmon	Chile	292 425
Giant tiger prawn	Philippines	268 804
Milkfish	Indonesia	266 220
Pacific cupped oyster	Japan	251 406

controlling the production of cultured organisms from the sea.

See also

El Niño Southern Oscillation (ENSO). Fishery Management, Human Dimension. Mangroves. Mariculture Diseases and Health. Mariculture Overview. Salmonid Farming.

Further Reading

Baird D, Beveridge M, Kelly L and Muir J (1996) *Aquaculture and Water Resource Management*. Oxford: Blackwell Science.

Bartley DM and Hallerman EM (1995) A global perspective on the utilization of genetically-modified organisms in aquaculture and fisheries. *Aquaculture* 137: 1–7.

Beveridge MCM, Ross LG and Kelly LA (1994) Aquaculture and biodiversity. *Ambio* 23: 497–502.

Black KD and Pickering AD (1998) *The Biology of Farmed Fish*. Sheffield: Sheffield Academic Press.

Black KD (ed.) (2001) *Environmental Impacts of Aquaculture*. Sheffield: Sheffield Academic Press.

Folke C, Kautsky N and Troell M (1994) The costs of eutrophication from salmon farming – implications for policy. *Journal of Environmental Management* 40: 173–182.

Kaiser MJ, Laing I, Utting SD and Burnell GM (1998) Environmental impacts of bivalve mariculture. *Journal of Shellfish Research* 17: 59–66.

Naylor RL, Goldburg RJ, Mooney H *et al.* (1998) Ecology – Nature's subsidies to shrimp and salmon farming. *Science* 282: 883–884.

Naylor RL, Goldburg RJ, Primavera JH *et al.* (2000) Effect of aquaculture on world fish supplies. *Nature* 405: 1017–1024.

Pearson TH and Rosenberg R (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Reviews* 16: 229–311.

Wu RSS (1995) The environmental impact of marine fish culture – towards a sustainable future. *Marine Pollution Bulletin* 31: 159–166.

MARINE FISHERY RESOURCES, GLOBAL STATE OF

S. M Garcia and I. De Leiva Moreno, Food and Agriculture Organization of the United Nations, Rome, Italy

doi:10.1006/rwos.2001.0445

Introduction

The fisheries department of the Food and Agriculture Organization (FAO) monitors the state of world marine fishery resources and presents every two years to the FAO Committee on Fisheries (COFI) a report on The State of Fisheries and Aquaculture (SOFIA). This article draws significantly from a section of SOFIA 2000 on the state of world fisheries and uses the information available from 1974 to 1999 (the last year for which information is available).

With the view to offering a comprehensive description of the global state of world stocks, the analysis provided below considers successively: (1) the relation between 1998 and historical production levels; (2) the state of stocks, globally and by regions according to data collected up to 1999; and (3) the trends in state of stocks since 1974, globally and by region.

Relative Production Levels

The data available for 1998 for the 16 FAO statistical regions (**Table 1**) of the world's oceans indicate that four of them are at their maximum historical level of production: the Eastern Indian Ocean as well as the Northwest, Southwest and Western Central Pacific Oceans. All other regions are presently producing less than their historical maximum, for various reasons (**Figure 1**). Although this might result, at least in part, from natural oscillations in productivity (e.g., due to El Niño 1997 in the Southeast Pacific Ocean), the lowest values observed may indicate that a high proportion of the resources are overfished (e.g., in the Antarctic, as well as in the Southeast and Northwest Atlantic Oceans).

Global Levels of Exploitation

At the end of 1999, FAO had some information on 590 'stock' items. For 441 (or 75%) of them, there was some more-or-less recent information on the state. These 'stock' items are classified as underexploited (U), moderately exploited (M), fully exploited (F), over exploited (O), depleted (D), or recovering (R) depending on how far they are from 'full exploitation' in terms of biomass and fishing