HomePage FAO HomePage Highlights Site Map Glossary Search Email us

Back to main page

GESAMP REPORTS AND STUDIES No.47

IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP

Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)

REDUCING ENVIRONMENTAL IMPACTS OF COASTAL AQUACULTURE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1991

NOTES

1. GESAMP is an advisory body consisting of specialized experts nominated by the Sponsoring Agencies (IMO, FAO, Unesco, WMO, WHO, IAEA, UN, UNEP). Its principal task is to provide scientific advice on marine pollution problems to the Sponsoring Agencies and to the Intergovernmental Oceanographic Commission (IOC).

2. This report is available in English from any of the Sponsoring Agencies.

3. The report contains views expressed by members of GESAMP who act in their individual capacities; their views may not necessarily correspond with those of the Sponsoring Agencies.

DEFINITION OF MARINE POLLUTION BY GESAMP

"Pollution means the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities".

For bibliographic purposes, this document should be cited as :

GESAMP (IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution), 1991. Reducing Environmental Impacts of Coastal Aquaculture. Rep. Stud. GESAMP, (47):35p.

PREPARATION OF THIS STUDY

This document is based on the work of the GESAMP Working Group on Enironmental Impacts of Coastal Aquaculture. The Working Group met from 7 to 11 January 1991 in Kiel, Germany. The meeting was attended by Margarita Astralaga (UNEP), Brian Austin, Uwe Barg (Technical Secretary), Chua Thia-Eng (Chairman), Richard J. Gowen, Heiner Naeve (FAO), Harald Rosenthal, Heye Rumohr and Philipp Tortell. Written contributions were received from Louise Fallon and Hillel Shuval.

The Working Group was jointly sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization (Unesco), the World Health Organization (WHO) and the United Nations Environment Programme (UNEP). The secretariat was provided by FAO.

EXECUTIVE SUMMARY

1. There have been substantial socio-economic benefits arising from the expansion of coastal aquaculture. However, in some coastal regions, this has caused significant ecological changes.

2. The type and scale of any ecological change associated with coastal aquaculture development will depend on the method of aquaculture, the level of production and the physical, chemical, and biological characteristics of the coastal area. Ecological change has been associated with the large-scale production of bivalves and seaweeds and the release of dissolved and particulate waste from fish, shrimp, and bivalve culture. Destruction of productive wetland habitats has resulted in the disturbance of wildlife and uncontrolled introductions and transfers have altered or impoverished the biodiversity of the receiving ecosystem. Some ecological change, such as the impact of organic waste on the seabed ecosystem, can limit production.

3. The indiscriminate use of bioactive compounds, including pesticides and antibiotics, has caused concern about their release into the aquatic environment. The health implications of the use of chemicals and the consumption of seafood grown in contaminated waters are problems of growing concern, especially in relation to intoxication by phycotoxins and infectious diseases such as typhoid fever, cholera, and hepatitis.

4. Some of the ecological and socio-economic problems encountered are due to the market failure to reflect the true cost of resource depletion and environmental change. The solution to this problem requires policy intervention at national and local level, particularly in regard to the issues of common property rights and economic incentives and deterrents needed to minimize environmental change.

5. Sustainable coastal aquaculture requires adequate consideration of the interactions among the social, economic and ecological changes. This can be achieved through an integrated approach to planning and management of coastal aquaculture within the framework of integrated coastal zone management.

6. Specific actions are essential to effectively utilize the environmental capacity of the coastal ecosystem for food production and generation of income, reducing resource use conflicts, and minimizing health risks to human consumers and adverse ecological impacts. These activities include the formulation of coastal aquaculture development and management plans, application of environmental impact assessment to aquaculture proposals, development of criteria for site selection, determination of the carrying capacity of ecosystems, establishment of guidelines governing the use of mangrove wetland, bioactive compounds, transfers and introductions, improvements in farm operation and management, regulation of farm discharges, and monitoring ecological changes, and application of regulatory measures and economic incentives or deterrents to promote sound environmental management.

TABLE OF CONTENTS

1. INTRODUCTION

Aquaculture is the farming of aquatic organisms, including fish, molluscs crustaceans and aquatic plants (see FA0, 1990). The geographical area covered by the term "coastal" includes the shoreland influenced by the sea, the water column and the seabed extending to the edge of the continental shelf (Sorensen *et al.*, 1984). In this report the term "coastal aquaculture" covers land-based and water-based brackish-water and marine aquaculture practices.

Aquaculture production is rapidly increasing worldwide and at present constitutes approximately 12% of the world's fishery production. FAO (1990a) estimated that 56% of the 14.47 million tonnes of aquaculture production in 1988 came from the brackish and marine environment. Over 90% of molluscs, crustaceans and seaweeds were derived from coastal aquaculture, with 95% of this production being derived from 20 nations. Total world production through aquaculture is expected to attain 22 million tonnes by the turn of the century (FAO, 1989) with a substantial proportion of this derived from coastal aquaculture.

Small-scale coastal aquaculture has been a traditional and sustainable practice in many countries. The levels and patterns of coastal aquaculture practices vary according to the species cultured, sites and methods of farming. There is, however, a trend towards intensification which is usually driven by market forces and competitive use of the resources. This trend is expected to continue for the forseeable future although at present a large proportion of coastal aquaculture is still extensive or semi-intensive. In Asia most brackish-water farms collectively cover a large area, but are individually small and poorly managed. The majority of existing coastal aquaculture is undertaken for profit rather than subsistance farming. It is clear that there has been substantial benefits arising from the expansion of coastal aquaculture.

However, the rapid expansion in some coastal regions has caused ecological impacts such as enrichment and changes in the biodiversity of coastal ecosystems which in turn have had important socio-economic consequences. In general, ecological impact results from a lack of adequate coastal planning, management and consideration of the environmental compatibility of particular sites. Often, mitigating measures have not been considered or have proven to be ineffective and/or prohibitively expensive. In some cases ecological change is irreversible or recovery from an impact slow.

While most of the coastal aquaculture activities are located in Asia, North America and Europe, a substantial number of heavily financed projects are being implemented in Latin America and also, to some extent, in Africa. The potential negative impact due to badly planned and unco-ordinated development in these regions may soon become obvious.

It should be noted that existing aquaculture has been seriously affected by pollution caused by land-based and coastal developments. Furthermore, in some countries, further expansion of coastal aquaculture is limited by the availability of suitable sites.

Some of these problems may be overcome by improvements in technology (such as the development of offshore fish farming), nonetheless, there is an increasing need for coastal zone management to ensure that aquaculture developments are fully integrated into ecological and socio-economic structures of coastal regions. This report analyses the impacts of coastal aquaculture practices and provides guidelines for environmentally sound management of coastal aquaculture.

2. ECOLOGICAL IMPACTS OF COASTAL AQUACULTURE DEVELOPMENTS

The type and scale of any ecological change associated with coastal aquaculture development will depend on the method of aquaculture, the level of production and the biological, chemical and physical characteristics of the coastal area.

Some impacts such as enrichment of benthic ecosystems have been studied in detail, others for example, the genetic interaction between farmed and wild salmonids and the ecotoxicology of the many chemical compounds used in aquaculture are either poorly understood or perceived as potential impacts. Reviews by Austin and Austin, 1987; Rosenthal *et al.*, 1988; Gomez *et al.,* 1989; Sen Gupta *et al.*, 1989; Gowen *et al.,* 1990 and Gowen *et al.,* 1990a provide general discussions of many of these impacts.

2.1 Enrichment

The release of soluble inorganic nutrients (nitrogen and phosphorus) from intensive fish and shrimp farming has the potential to cause nutrient enrichment and eutrophication (increase in primary production) of a water body. It has also been suggested that the release of dissolved organic compounds together with other components of the diet such as vitamins could influence the growth or toxicity of particular species of phytoplankton (Gowen and Bradbury, 1987, and references cited therein). There are examples of eutrophication of lacustrine waters as a result of fish farming, but few examples from coastal waters. At the present level of coastal fish farming, nutrient enrichment and eutrophication of open coastal waters is unlikely, but could occur in semi-enclosed coastal embayments (fjords, inlets and lagoons) which have restricted exchange of water with more open coastal waters. One example of an increase in phytoplankton biomass attributed to nutrient enrichment by fish farming is from a sheltered archipelago in Finland (Isotalo *et al*., 1985). Increasing eutrophication can lead to ecologically undesirable consequences and there is the possibility that waste released from fish farms could stimulate the growth of species harmful to farm stock (Nishimura, 1982). During the last decade, there have been many instances of mass mortality of farmed fish caused by the occurrence of harmful algae (see for example Tangen, 1977; Jones *et al.,* 1982). There, is however, no evidence that the occurrence of these harmful events was due to the release of waste-compounds from the fish farms.

The equilibrium increase in dissolved nutrients can be estimated using a simple mass balance approach and relating the output of nutrients to the volume and flushing time (dilution rate) of the water body (Gowen *et al.*,1989). Such estimates must be regarded as approximate because the method assumes complete dispersal (which is often not the case in large embayments) and also fails to account for incomplete exchange for example, Gowen *et al.*, 1983 estimated that approximately 50% of the water leaving a small sea-loch on the ebb tide returned on the flood.

The deposition of organic fish farm and bivalve waste has been shown to cause enrichment of the benthic ecosystem in the vicinity of the aquaculture operation. The changes which take place include: the formation of anoxic sediments (Brown *et al.*, 1987) with, in extreme cases, the release of carbon dioxide, methane and hydrogen sulphide; increased oxygen consumption by the sediment (Kaspar *et al.*, 1985) and efflux of dissolved nutrients (Enell and Löf, 1983; Blackburn *et al.,* 1988); and changes in the community structure of the benthic macrofauna (Brown *et al.,* 1987; Ritz *et al.*, 1989; Weston, 1990). With respect to changes in the macrofauna the effects range from a reduction in diversity and increase in opportunistic, pollution tolerant species (Weston, 1990) to the complete absence of macrofauna (Brown *et al.*, 1987). The release of hydrogen sulphide gas, together with hydrogen sulphide dissolved in the water has been held responsible for a deterioration in the health of farmed fish (increased stress, reduced growth, gill damage and even mortality) and loss of production (Braaten *et al.*, 1983). A high level of enrichment leading to what has been termed souring of sites has been reported from a number of fish farms in several countries. For example, it has been estimated that 30% of oyster and mussel farms in France are periodically abandoned or relocated because of the accumulation of biodeposits (Sornin, 1979). These are clear examples of how production can exceed the capacity of the site to assimilate the amount of waste generated and how ecological change can limit the long-term viability of a site.

Lumb (1989) provides guidelines on the siting of fish farms which can be used to gain a qualitative assessment of the impact of organic fish farm waste on the benthos. However, Hagino (1977) and Gowen *et al*. (1989) present predictive models which have been specifically formulated to predict the dispersal and input to the benthos of organic waste from cage fish farms. In a more general context GESAMP (1986) provide a discussion of the pathway for assessing the impact resulting from the discharge of sediment.

2.2 Interaction with the food web

The large scale, extensive cultivation of bivalves can interact with the marine food web in two ways. Firstly, by the removal of phytoplankton and organic detritus and, secondly, by competing with other planktonic herbivores.

Imai (1971), for example demonstrated that the culture of 50,000 - 60,000 oysters reduced the amount of seston (predominantly phytoplankton) by between 76 and 95%. It is therefore possible that the siting of bivalve farms in coastal embayments could reduce the natural productivity of the embayment.

Bivalve grown by suspended culture methods will compete with other planktonic herbivores. For example, Tenore *et al.* (1985) found that in the Ria de Arosa of Spain mussels have replaced copepods as the main pelagic grazing organisms. In addition, the culture structures provided a substrate for the crab *Pisidia longicornis*, the larvae of which also competed with copepods as a planktonic herbivore.

The carrying capacity of a natural ecosystem is the maximum production of a species which can be maintained by naturally available food resources (Rosenthal *et al.*, 1988). This particularly applies to the production of bivalves. Carrying capacity can be assessed by evaluating historical records of bivalve culture (Héral, 1988), measuring the availability of phytoplankton biomass or undertaking more sophisticated studies of carbon flux through the food web (Rodhouse *et al.*, 1985). Furthermore, models have been formulated to predict the carrying capacity of some coastal areas (see for example Héral *et al.*, 1989), the general principles of which hold true for any coastal area.

2.3 Oxygen consumption

Aquacuture production can be limited by the availability of oxygen (Rosenthal *et al.*, 1988). An assessment of this limit for an embayment can be obtained by establishing a mass balance. That is, comparing the oxygen demand of the stock to the pool of available oxygen and the rate of supply. With respect to oxygen, there have been some attemps to model the production potential in relation to aquaculture development (Black and Carswell, 1989; Aure and Stigebrandt, 1989).

In addition to the oxygen demand by the cultured species, wastes and biodeposits released by a farm have a high biochemical oxygen demand. Deposition of organic waste increases the consumption of oxygen by the sediment and can result in oxygen depletion of the bottom water (Tsutsumi and Kikuchi, 1983). A reduction in the concentration of dissolved oxygen in water passing through cage farms has also been reported (Rosenthal, 1983). In general, however, large-scale depletion of oxygen in coastal waters is unlikely. While the small, short term reduction in the concentration of oxygen in water passing through cage farms is important to the farmer, it is probably not ecologically significant.

One possible exception to the above is in low energy coastal environments such as the deep basins of some fjords and inlets. In such locations the retention of deep water within the basin for a period of time (months to several years) results in a natural depletion of oxygen (Gade and Edwards, 1980). The deposition of waste would increase the oxygen deficit. This potential problem has been recognised in several countries. In Norway for example, only a low level of aquaculture production is allowed in fjords with deep isolated basins and this is restricted to the shallow, relatively well flushed near shore areas.

2.4 Disturbance of wildlife and habitat destruction

All forms of aquaculture have the potential to affect wildlife. Human activity can be disruptive in the vicinity of important breeding colonies and feeding grounds, while the aquaculture facility itself can attract predatory species. For example, in Germany cormorant populations have increased as a result of pond farming. However, there have been few detailed studies of the ecological effects of aquaculture operations on wildlife.

The impact of some forms of aquaculture on wildlife habitat is better documented (Paw and Chua, in press). For example 200,000 hectares of mangrove have been destroyed in the Philippines (Gomez *et al.*, 1989) and in Thailand an estimated 25% of the mangrove resource has been lost as a result of aquaculture development.

Coastal wetlands are amongst the most productive ecosystems and are important in sustaining the ecological integrity and productivity of adjacent coastal waters. Mangrove areas, for example, are important nursery grounds for many commercial fish and shrimp species (Linden, 1990, and references cited therein).

2.5 Interaction between escaped farmed stock and wild species

The rapid development of marine cage farming of salmonids in Europe has raised concerns about the impact of escaped fish on natural populations. It has been suggested that farmed fish have been selected for traits which make them suitable for farming (for example, rapid growth and placid behaviour) but less well adapted to the natural ecosystem. Thus, escaped fish could initially outcompete native stocks, but then decline, or the progeny resulting from inter- breeding could be poorly adapted to the ecosystem.

There is insufficient information available to judge whether the interaction discussed above is a serious ecological impact. It is known that farmed fish do escape and that the numbers of escapees can be large. Some countries have initiated studies to address this issue and in recognition of the potential problem Norway prohibits the siting of salmon farms within 30 km of important salmon rivers.

2.6 Introductions and transfers

A number of fish, invertebrate and seaweed species have been transferred or introduced from one region to another for aquaculture purposes. A distinction has been made between the two kinds of movements which differ in their purpose and potential effect (Welcomme, 1988).

Transfers take place within the present geographical range of a species and are intended to support stressed populations, enhance genetic characteristics or re-establish a species that has failed locally.

Introductions are movements beyond the present geographical range of a species and are intended to insert totally new taxa into the flora and fauna.

The problems associated with transfers and introductions have been well studied and recorded (Rosenthal, 1976;

Hoffman and Schubert, 1984; Welcomme, 1988a; Munro, 1988; Turner, 1988). These movements can pose risks to human health, the integrity of ecosystems, agriculture, aquaculture and related primary industries. The ICES/EIFAC Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms (Turner, 1988) discusses each of these risks in detail. Transfers and introductions may alter or impoverish the biodiversity of the receiving ecosystem through interbreeding, predation, competition for food and space and habitat destruction (Folke and Kautsky, 1989).

Examples of the type of disease problem which have arisen in the past from such movements are illustrated by the transfer of salmon smolts from Sweden to Norway and Finland, the introduction of infected ova of coho salmon *(Oncorhynchus kisutch)* from the USA and the introduction of Japanese oysters *(Crassostrea gigas)* to France (Munro, 1988).

2.7 Bioactive compounds (including pesticides and antibiotics)

Bioactive compounds should be considered as part of overall disease control strategies. However, it is accepted that many bioactive compounds, including pesticides and antibiotics, are used extensively in coastal aquaculture as the sole means of disease or pest control (see Austin and Austin, 1987). Indeed, the success or failure of aquaculture may in certain circumstances depend on the timely use of such bioactive compounds to combat infectious diseases and parasites. In general, the use of such compounds in aquaculture is haphazard, often reflecting the whims of the aquaculturist or disease adviser. Environmental issues centre on:

- The longevity of inhibitory compounds in animal tissues;

- The fate of bioactive compounds in the aquatic environment;

- The development and transfer of resistance in microbial communities.

2.7.1 Longevity of inhibitory compounds in animal tissues

There is an increasing literature indicating that bioactive compounds linger in animal tissues for greater periods than had hitherto been recognized. For example, McCracken *et al.* (1976) established that the antibiotic trimethoprim remained in rainbow trout muscle for 77 days after the cessation of treatment. After statistical modelling, Salte and Liestøl (1983) recommended that for rainbow trout maintained at a water temperature of >1Õ C a withdrawal period of 60 days is necessary when using antibiotics such as oxytetracycline and potentiated sulphonamides. This period is much longer than normally practiced in aquaculture.

2.7.2 Discharge of inhibitory compounds in the aquatic environment

The widespread use of inhibitory compounds in aquaculture has generated fears about the potential release of the bioactive component into the aquatic environment. In the case of antibiotics, this could damage biological filters in recirculating systems. Recent published data suggest that only 20-30% of antibiotics are actually taken up by fish from medicated food; thus, approximately 70-80% reaches the environment (Samuelsen, 1989), notably from uneaten medicated food (Jacobsen and Berglind, 1988). With oxytetracycline in seawater, it has been established that degradation proceeds rapidly (Samuelsen, 1989). However, most oxytetracycline becomes bound to particulates, and is deposited at the bottom of (or beneath) the fish holding facilities in the case of marine cage sites. Within the sediments, oxytetracycline may remain in concentrations capable of causing antibacterial effects for 12 weeks after the cessation of treatment (Jacobsen and Berglind, 1988). Such antibiotic containing sediment affects the fauna. For example, detectable levels of oxytetracycline have been found in blue mussels (*Mytilus edulis*) which were located 80 m from a fish farm using this antibiotic (Møster, 1986).

The problem with pesticides is incompletely understood. Certainly, large quantities of a diverse range of natural and synthetic chemicals, including dichlorvos, malachite green, derris root, and tea seed cake, are used in coastal aquaculture worldwide. To illustrate the extent of the problem, it has been determined that during 1989 3,488 kg of dichlorvos was used in Norwegian fish farms to control infestation by salmon lice. Evidence for some compounds, such as dichlorvos, has shown that some of these chemicals have adverse environmental effects, and, therefore their use in coastal aquaculture must be carefully assessed. The fate of such compounds should be properly addressed.

2.7.3 Development of antibiotic resistant microbial communities

A problem is the development and spread of antibiotic resistance among members of the native aquatic microbial communities. It has been determined that the administration of medicated food has a dramatic effect on the microbial populations within the digestive tract of the aquatic animals (e.g. Austin and Al-Zahrani, 1988).

Plasmids (= extrachromosomal self-replicating elements of DNA), conferring antibiotic resistance properties, abound in fish pathogens and native aquatic bacteria, particularly those in the vicinity of fish holding facilities (Austin and Austin, 1987). Workers have provided evidence of a widespread resistance to antimicrobial compounds (including numerous cases of multiple resistance; see Aoki, 1989) among fish pathogens, notably *Aeromonas hydrophila*, *Pasteurella piscicida*, *Streptococcus* spp. and *Vibrio anguillarum* (Aoki, 1989). It is conceivable that plasmid-mediated antibiotic resistance could be transferred to bacteria of human and veterinary significance. Initial unpublished work has suggested that antibiotic resistance may indeed be transferred between related bacterial groups. Fortunately, cessation of treatment appears to lead to a rapid decline in the levels of antibiotic resistant micro-organisms in the aquatic environment.

2.8 Chemicals introduced via construction materials

Some construction materials release substances into the aquatic environment (e.g. heavy metals, plastic additives). Their presence is unknown to most of the farmers, although awareness is increasing. Frequently preservatives have been intentionally used assuming that they are relatively harmless to the cultured species. These include antifoulants, of which the broad ecological effects of tributyltin (TBT) is a good example (GESAMP, 1989). Plastics contain a wide variety of additives including stabilizers (fatty acid salts), pigments (chromates, cadmium sulphate), antioxidants (e.g. hindered phenols), UV absorbers (benzophenones), flame retardants (organophosphates), fungicides and disinfectants. Many of these compounds are toxic to aquatic life, although some protection is provided by their low water-solubility, slow rate of leaching and dilution. Mortalities in coastal aquaculture have resulted from toxicant leaching from construction materials, and the environmental effects of these toxicants remain largely unresolved. At the present time there are few standards regulating the composition of materials used in aquaculture facilities.

2.9 Hormones and growth promoters

An increasing number of hormones and growth promoters are used to alter sex, productive viability and growth of culture organisms. Although many studies have been undertaken to describe their physiological effect in the target organism, studies of their wider ecological impact have not been undertaken.

3. IMPLICATIONS FOR HUMAN HEALTH

The implications of aquaculture development for human health assume importance in some geographical areas, but may gain further significance in the future. Many outbreaks of human diseases have been associated with marine fishery products, especially those from wild stocks. Similar problems can result from aquaculture due to poor management.

Much of aquaculture is practised in coastal waters which are subjected to organic pollution. Toxic algal events (blooms) are common in many parts of the world. The consumption of raw or partially cooked fish and shellfish from affected areas is likely to cause diseases due to pathogens or toxins (Shuval, 1986).

3.1 Outbreaks of disease associated with the consumption of shellfish

3.1.1 Typhoid fever

Many epidemics of shellfish-associated typhoid fever occurred in Europe and the USA at the turn of the century. The recognition of shellfish as a vehicle for enteric agents resulted in some modifications of sewage disposal practices, with the lessening of marine pollution. The clear risk of transmission of typhoid fever by bivalves growing in sewage contaminated water was well-established during the early years of this century and served as the basis for the establishment of shellfish sanitation programmes in the UK and in the USA. These programmes were based on approved, clean harvesting areas and shellfish self-purification in clean-water holding tanks, termed "depuration". The subsequent disappearance of epidemics of typhoid fever, transmitted by shellfish, may partially be a result of the success of these programmes (Mosley, 1974).

3.1.2 Infectious hepatitis and other viral diseases

Mosley (1974) reviewed the epidemiological aspects of transmission of infectious hepatitis (IHA) and other virus diseases by shellfish. Epidemics of IHA have occurred in Germany, Sweden and the USA. These outbreaks occurred despite simple sanitary improvements which were sufficient to eliminate shellfish-associated typhoid-fever. The occurrence of shellfish-associated hepatitis is not confined to eating raw molluscs, because steaming as usually practiced fails to raise the internal temperature sufficiently to inactivate the viral agent (Koff and Sears, 1967).

Another concern is that of the possible transmission of type B hepatitis by accumulation of hepatitis B virus (IHB) in oysters and clams (Mahoney *et al.,* 1974). The only demonstration of mollusc contamination, however, was in samples taken from a shellfish bed adjacent to a hospital's sewage outfall. Many other samples along the coast were negative for IHB. Mosley (1974) considered that seafood was not a significant route for transmission of IHB, since occurrence of the agent in faeces was doubtful, and oral infection of serum was low.

Metcalf and Stiles (1967) demonstrated enteroviruses in oysters harvested from contaminated waters closed to harvesting, and Denis (1973) reported frequent recovery of Coxsackie A viruses in market samples in France. Furthermore, Di Girolamo *et al.* (1972) have demonstrated that West Coast (USA) shore crabs accumulated poliovirus both in artificially contaminated seawater and when allowed to feed on virus-contaminated mussels.

Goldfield (1976) reported five outbreaks of gastro-enteritis of unknown aetiology in which shellfish including clams and oysters were implicated. He suggested that some of these outbreaks of "non-bacterial" aetiology may have been caused by parvovirus. The first well documented shellfish-associated epidemic caused by the Norwalk-like virus was a massive gastro-enteritis outbreak in all areas of Australia, in which approximately 2,000 cases (possibly 10 to 20 times that number of people were actually infected) were reported. This outbreak was associated with the consumption of raw shellfish harvested from sewage contaminated areas (Murphy *et al.,* 1979).

In addition to clear epidemics of virus disease associated with consumption of raw or partially cooked shellfish, there is growing evidence that shellfish consumption is strongly associated with the endemic transmission of infectious hepatitis (e.g. Ọ Mahany *et al.*, 1983). Reports have implicated shellfish as a source of non-A, non-B hepatitis. For example in a study of patients in five hospitals in Baltimore (USA), Alter *et al.* (1982) found that eating raw shellfish was associated with 12.5% of the cases on non-A, non-B hepatitis. This was the third most common risk factor after parental drug use and history of blood transfusions. It is possible that different non-A, non-B hepatitis viruses were associated with the shellfish than with parental drug use and blood transfusions.

In the USA, the first case of shellfish-associated gastro-enteritis attributed to Norwalk virus occurred in 1980 after individuals consumed oysters from Florida (Gunn *et al.,* 1982). In addition, a group of small round viruses have been reported as the cause of numerous outbreaks of shellfish-associated gastro-enteritis. These viruses do not appear to be serologically related to the Norwalk virus. More recently the Snow Mountain virus has been reported as the cause of several outbreaks of gastro-enteritis associated with the consumption of clams (Dolin *et al.*, 1987).

3.1.3 Survival of enteric viruses in the marine environment

Numerous studies have been conducted on the survival of viruses in marine waters. Laboratory studies have shown that enteric viruses can survive from 2 to 130 days in seawater, which is generally longer than coliform bacteria (Melnick and Gerba, 1980). A number of variables, including temperature, salinity, microbial antagonism, solar radiation, and association of viruses with solids, have been found to affect virus survival. Of these factors temperature is the most important, and below 1õ C enteric viruses could be expected to survive for several months (Gerba and Goyal, 1986). When sediment is present, the inactivation rates of viruses in seawater-moistened sand tended to be 4.5 fold slower than in seawater alone (Gerba and Goyal, 1986).

There is now ample evidence that shellfish, particularly molluscs grown in sewage polluted water are very effective carriers (and concentrators) of IHA virus and Norwalk virus and have on numerous occasions caused infection in humans.

3.1.4 Cholera

It was clear from the result of a major cholera epidemic in Italy during 1973 that contaminated molluscs can be effective vectors of *Vibrio cholerae* (Baine *et al.,* 1974). The cholera epidemic in Naples, the coastal regions of Campania and Puglia and in Sardinia resulted in 278 confirmed cases, probably many more non-laboratory confirmed cases, and 25 fatalities. In addition, major economic losses due to a reduction in tourism and trade resulted from the compulsory international quarantine notification of the outbreak. It should be noted that prior to the much publicized Naples outbreak there was an explosive outbreak of cholera in the Philippines in 1961, in which Joseph *et al.* (1965) identified the consumption of raw shrimps as the main mode of transmission. Laboratory studies have indicated that *V. cholerae* persists in fish and shellfish at room temperatures from 2-5 days and under refrigerated conditions for 1-2 weeks (de Araoz *et al.*, 1970).

Naples-type outbreaks could occur anywhere, especially as El Tor cholera is pandemic and airline travel permits the rapid dissemination of pathogens throughout susceptible populations. It has been estimated that a human cholera patient may excrete 10^{13} organisms/day. These organisms could contaminate shellfish beds via improperly treated or raw sewage.

3.1.5 The influence of fish pathogens on human health

Some bacterial fish pathogens have been implicated with outbreaks of human disease. However, it should be emphasized that the published literature is restricted to a few documented cases; the extent of the problem is largely unknown. Nevertheless, it is appreciated that *Aeromonas hydrophila, Mycobacterium* spp. and *Nocardia asteroides* have been associated with isolated cases of skin/wound infections, mycobacteriosis (fish tank granuloma) and nocardiosis, respectively (Austin and Austin, 1989).

3.2 Phycotoxins

The occurrence of toxic species of phytoplankton represents a considerable threat to the economic sustainability of coastal aquaculture development in many countries. A relatively small number of algal species produce a range of toxins, the effects of which include mortality of stock (larval and adult), and human illness and even death (WHO, 1984; see also Shumway, 1990 and references cited therein).

Several toxins are responsible for paralytic shellfish poisoning (PSP) (Sullivan, 1988) which is perhaps the most well documented group of phycotoxins. The toxins are produced by several armoured dinoflagellates, including *Alexandrium tamarense*, *Gymnodinium catenatum* and *Pyrodinium bahamense*. Human illness and occasionally death results from the consumption of bivalves which have accumulated the toxin. Human illness has also been attributed to the consumption of fish containing saxitoxin. The presence of the toxin in the fish was assumed to be the result of its transfer through the food chain (Ting and Wong, 1989). There is, however, no evidence of human illness as a result of consumption of farmed fish containing phycotoxins.

A group of toxins (including okadaic acid, dinophysis toxins DTX1, 2 and 3 and Yessotoxin) are responsible for diarrheic shellfish poisoning (DSP). These toxins are thought to be produced by the armoured dinoflagellates of the genus *Dinophysis* and *Prorocentrum*. Human illness (sickness and diarrhoea) result from the consumption of bivalves which have accumulated the toxin. There is no evidence that DSP toxins have caused human deaths.

The causative agent for neurotoxic shellfish poisoning (NSP) is *Ptychodiscus breve*. Consumption of shellfish containing this toxin causes symptoms similar to PSP, but paralysis leading to death has not been recorded.

Amnesic shellfish poisoning (ASP) has been so-named because one of the effects is memory loss. In 1987, 30 people were taken ill and three died in eastern Canada as a result of consuming bivalves which had accumulated domoic acid, a neurotoxic amino acid. In this incident the source of the compound was traced to the diatom *Nitzschia pungens*. There were some unusual features associated with this event. Firstly, the algal species producing the toxin was a diatom when, prior to the event shellfish toxicity had been associated with dinoflagellates. Secondly, the event took place during winter. Thus, the event occurred during the season of low phytoplankton growth; normally most toxic events occur during the period of maximum phytoplankton growth.

Ciguatera toxins are produced by the benthic dinoflagellate *Gambierdiscus toxicus* and can accumulate in several tropical and subtropical herbivorous fish and predators which feed on the herbivores. At present this is not a problem in the context of coastal aquaculture, but may become important if ranching of reef fish is practised (Maclean, 1989).

In some coastal regions the occurrence of toxic species and toxicity in bivalves is almost an annual event and this has necessitated the establishment of extensive programmes to monitor bivalve stocks. For example, most European countries have routine monitoring programmes for PSP and DSP. The detection of toxins at a pre-determined level usually results in a ban on harvesting which is enforced until the level of toxin in the stock falls below the action level. It is therefore possible to safeguard human health and manage farms to mitigate the effects of toxic events. The duration of closure can, however, affect the economic viability of bivalve culture as a result of loss of markets due to failure to provide the product or loss of consumer confidence in the product (often the result of misinformation). Furthermore, the value of the product can be reduced if harvesting is not permitted before the stock begins to mature sexually and the quality of the meat declines.

3.3 Depuration

Microbiological standards have been devised to counter the possible presence of pathogens in aquatic invertebrates. For example, the EC Shellfish Directive adopts a provisional value of <300 faecal coliforms/100 ml of shellfish tissue (see also Pike and Ridgway, 1985). However, the definition of a faecal coliform is vague (see Austin *et al*., 1981), and there is a dubious relationship to the number of viral particles (Gerba *et al.*, 1979; Tyler, 1985). In short, viral counts do not coincide with the number of faecal coliforms (Tyler, 1985). Moreover, it is often difficult to isolate viruses from seawater and filter feeders. Therefore, current microbiological standards for shellfish are of questionable value.

Depuration is commonly used to reduce the risk of microbiologically contaminated filter feeding invertebrates being sold for human consumption. Thus, the animals are transferred to tanks with several changes of "clean" water whereupon pathogens are supposedly eliminated. The effectiveness of such procedures is possibly illustrated by the virtual elimination of typhoid fever by this route in the industrialized nations of the western world (Pike and Ridgway, 1985). Yet, problems ensue with the cleanliness of the water used in depuration systems. Firstly, without adequate disinfection systems, depuration may serve to spread pathogens from a few contaminated animals to many others in the depuration system. Secondly, harsh disinfectants, such as high levels of chlorine, may well inactivate many pathogens, but the presence of such chemicals in the water has an adverse effect on the animals. In the presence of some disinfectants the invertebrates close-up and, therefore, do not depurate. For effective depuration, it is essential to use systems which encourage the animals to void/eliminate the pathogens into the water, while ensuring that there is adequate disinfection to kill them. Experience has suggested that ozonation which is extensively used in France, is an effective tool in depuration. In particular, residual ozone in the water does not adversely affect the filter-feeders, and results in the inactivation of viruses, including poliovirus (Richard, 1984), bacterial fish pathogens (Austin, 1983) and parasites, e.g., *Naegleria* and *Acanthamoeba* (Perrine *et al*., 1984).

4. SOCIO-ECONOMIC CONSIDERATIONS

The full socio-economic benefits of coastal aquaculture development can only be achieved by adopting the principle of sustainable development, which is defined by FAO (1988) as:

> "Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal

genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable"

It is clear, however, that inadequate planning and inefficient management of coastal aquaculture has been the case, and has resulted in serious socio-economic consequences. Some examples are:

- Large-scale mangrove conversion for shrimp and fish farming in Ecuador and many southeast Asian countries have displaced rural communities which traditionally depended on mangrove resources for their livelihood. In addition to the negative social consequences, the cost of disrupting the ecosystem includes coastal erosion, saltwater intrusion into groundwater and agricultural land, acidification, and a reduction in a range of goods and services produced from the mangrove forests (Bailey, 1988).

- The economic disaster resulting from the collapse of the shrimp industry due to disease outbreaks in Taiwan province in which shrimp production dropped from 90,000 to 20,000 tonnes between 1987 and 1989 (Liao, 1990).

- Land subsidence (sinking) in Taiwan Province caused by excessive pumping of groundwater for shrimp and eel culture resulting in significant social costs in terms of salinization of underground water and land due to salt-water intrusion (which reduce agricultural productivity), reduction of freshwater-supply (for agricultural, industrial and municipal/domestic uses) and damage to transportation and other infrastructure (Huang, 1990).

- Financial losses to the Norwegian cage-farming industry due to outbreaks of Hitra disease (Austin and McIntosh, in press).

- The public health consequences of red-tide outbreaks in areas where shellfish are grown (Maclean, 1989).

Some of the problems outlined above result from the market failing to reflect the true cost of resource depletion and environmental change. For example, the true costs related to the deterioration of coastal water quality are not usually borne by coastal aquaculturists. Such costs are often spread onto other users of coastal waters.

Likewise, the cost of land subsidence is borne not just by those in the aquaculture industry, but also by others who are engaged in other productive activities which depend on the availability of groundwater.

The solution to this problem requires policy intervention at national and local level, particularly to address the issues of common property rights and economic incentives and deterrents needed to minimize ecological change. The use of common resources such as water and public land for coastal aquaculture development should take into account traditional use and the potential consequences of over-use.

The idea of economic incentives and deterrents such as subsidies and taxes is to encourage aquaculturists to make more efficient use of resources and take full responsibility for mitigating or minimizing ecological changes caused by their culture operation. For example, if aquaculturists in Taiwan Province had to pay for the scarcity value of water and the environmental cost of land subsidence the industry would have developed differently and may have had less of an environmental impact.

Policy intervention may also include a requirement for regulatory control of the establishment, operation and management of coastal aquaculture. It is clear therefore that to ensure sustainable development, the positive and negative socio-economic effects of coastal aquaculture, including its ecological effects, must be evaluated in the context of the society's social and economic goals. Analysis of any coastal aquaculture project should take into account both the local and the wider social and ecological costs and balance this against the benefits and costs of the project, which should not be undertaken unless there are net social benefits.

The assessment of wider environmental impacts (socio-economic and ecological) is necessary in an evaluation of the social benefits. Thus, the impacts have to be identified, measured and where possible, a monetary value placed on them so that they can be included in a formal analysis (Dixon *et al.*, 1988). However, quantitative evaluation of the impacts of aquaculture on the environment have only recently been seriously attempted, and most of the biophysical relationships involved have yet to be firmly established. Most research on the environmental impacts of aquaculture has been focussed on intensive production systems for finfish and molluscs in developed countries (ICES, 1989, 1990) and little is known regarding the impact of shrimp culture. Furthermore, in many cases a monetary value cannot be placed on ecological change. In such cases the acceptability of the levels of ecological change associated with coastal aquaculture development lies with society.

Sustainable coastal aquaculture requires adequate consideration of the interactions among the social, economic and ecological changes, which accompany development. This can be achieved through an integrated approach to planning and management of coastal aquaculture within the coastal system.

5. GUIDELINES FOR THE DEVELOPMENT OF ENVIRONMENTALLY ACCEPTABLE COASTAL AQUACULTURE

The ecological and socio-economic benefits and costs of aquaculture activity are potentially so significant that action oriented policies are necessary. In order to ensure that financial gain is not at the expense of the ecosystem or the rest of society, aquaculture developments must follow established principles.

The formulation of strategies will provide the focus for an equitable balance between those seeking a simple livelihood, those wanting to make a profit, the quality of the environment and the interests of local people, the wider community and, where appropriate, the international community.

5.1 General principles

- Coastal aquaculture has the potential to produce food and to generate income contributing to social and economic well-being.

- Planned and properly managed aquaculture development is a productive use of the coastal zone if undertaken within the broader framework of integrated coastal zone management plans, according to national goals for sustainable development and in harmony with international obligations.

- The likely consequences of coastal aquaculture developments on the social and ecological environment must be predicted and evaluated, and measures formulated in order to contain them within acceptable, pre-determined limits.

- Coastal aquaculture activity must be regulated and monitored to ensure that impacts remain within pre-determined limits and to signal when contingency and other plans need to be brought into effect to reverse any trends leading towards unacceptable environmental consequences.

5.2 Strategies

Strategy 1. The sound utilization of the ecological capacity of the coastal zone to produce aquatic products and generate income.

Strategy 2. The development of policy and management mechanisms to reduce conflict with other coastal activities.

Strategy 3. The prevention or reduction of the adverse environmental impacts of coastal aquaculture.

Strategy 4. The management and control of aquaculture activities to ensure that their impacts remain within acceptable limits.

Strategy 5. The reduction of health risks from the consumption of aquaculture products.

5.3 Actions

Action 1: Formulate coastal aquaculture development and management plans

A coastal aquaculture development and management plan at national or local level is an essential first step towards achieving the above objectives. Such a plan must be integrated into the overall coastal zone management plans discussed below.

The allocation of potential sites and the selection of forms of coastal aquaculture practice must be preceded by adequate survey and evaluation. Not all the sites found to be technically suitable will be utilized for aquaculture since they will also need to be economically viable and socially and culturally acceptable and their impacts must be within the assimilative capacity of the particular ecosystem. Such planning procedures provide the framework for an orderly development of aquaculture practices including the use of species and culture systems reflecting the physical, chemical and biological characteristics of the site. The scale and level of operation will often depend on societal and economic objectives and investment opportunities. The plans also provide the framework for institutional and legislative arrangements to administer, regulate and monitor the development of aquaculture farms.

Action 2: Formulate integrated coastal zone management plans

Within the general framework of integrated coastal zone management, policy and management guidelines must be established for the allocation of coastal resources to various economic development needs. The zonation approach is one effective means of assigning priorities and limiting development activities to specific areas or zones. The priority activity in a particular zone acquires "predominant use" status. Other "permitted uses" can be accommodated, but only as long as they do not jeopardize the predominant use. Integrated coastal zone management requires institutional and legislative provisions if it is to succeed in achieving multiple use. This includes zoning regulations and regulatory measures to control effluents. Continued monitoring and evaluation form an important part of integrated coastal zone management programmes. Remote sensing and geographical information systems can be effectively used for this purpose, especially to determine changes in resource use over time.

An example of steps for developing an integrated coastal zone management plan is given in Appendix 1.

Action 3: Apply the environmental impact assessment (EIA) process to all major aquaculture proposals

EIA is a process whereby the potential impacts of a proposal on the social, biological, chemical and physical environment are assessed and justified, and the means sought to minimize or eliminate negative effects. Appendix 2 illustrates the EIA process as applied in New Zealand with the various actions numbered sequentially. The process starts when the developer lodges an application (1) with the Permit-granting Authority which informs (2) the Environmental Agency and consults on whether the application is significant enough to require EIA processing. If such a process is deemed justified, the Environmental Agency convenes (3) a scoping conference attended by the Developer, the Permit-granting Authority and itself, and the scope of the EIA document is agreed to (4). The Developer then undertakes the necessary research and consultations and produces (5) the EIA document. This is conveyed (6) to the Environmental Agency which publishes it and invites (7) submissions. Depending on the prevailing system in the country, submissions may be sent (8) to the Environmental Agency which evaluates the application in the light of the submissions received (9) and its own research and produces an audit (10). The audit is made available publicly (11) with advice to the Permit-granting Authority which, after also taking into account other considerations, approves or declines the application (12).

Action 4: Select suitable sites for coastal aquaculture

In selecting an appropriate site for aquaculture it is essential to consider, in addition to the socio-economic consideration, the biophysical requirements of the cultured organism, the characteristics of the site and the culture methods to be used. In evaluating the characteristics of the site, essential physical, chemical and biological variables should be considered. These include coastline morphology and bathymetry, water temperature and salinity, flushing time, sediment particle size, water movement (current speed and direction), dissolved oxygen, dissolved inorganic nutrient, sedimentary redox-potential and organic content, natural resources and their use, wildlife, planktonic biomass and species composition, and bacterial population.

Action 5: Improve the management of aquaculture operations

Properly sited and managed aquaculture activities should not result in unacceptable ecological change. Nevertheless, should change occur, a number of measures can be used to minimize it.

For example, ensuring good health of the stock will reduce wastage of feed and the use of bioactive compounds. Techniques, though costly, are also available to collect or disperse waste to reduce the severity of the impact beneath cages. Longer-term measures to reduce waste output from intensive fish and shrimp farms include improvements in the formulation of diets to increase digestibility and the development of techniques to monitor the biomass and health of stock.

Action 6: Assess the capacity of the ecosystem to sustain aquaculture development with minimal ecological change

The concept of environmental capacity can be applied to the control of pollution and assumes that coastal ecosystems have differing quantifiable capacities to assimilate the discharge of a contaminant and provide trophic and non-trophic resources (GESAMP, 1986). Thus, in the context of the ecological impact of some coastal aquaculture development in which there can be a net loss or reduction in a variable (as well as the discharge of a contaminant) ecological change can be limited by ensuring that the scale of development does not exceed the availability of a trophic or non-trophic resource or the capacity of the ecosystem to assimilate the changes resulting from production.

Action 7: Establish guidelines governing the use of mangrove wetland for coastal aquaculture

The use of mangroves along the shore front or fringing river banks for aquaculture should be discouraged in view of their significant contribution to coastal stability preventing soil erosion, and their role as valuable habitats. Unlike extensive shrimp farming in mangrove swamps utilizing tidal energy for water exchange and shrimp larvae supply, modern intensive shrimp farming uses mechanical pumps for water supply and seeds from hatcheries. As such there is no justification in the use of mangrove swamps for shrimp culture. Traditional use of mangrove wetland for extensive aquaculture has minimal negative ecological impacts. The use of river basin mangrove should be guided by the recommendations from national mangrove committees which have been established in some nations with rich wetland resources.

Action 8: Establish guidelines for the use of bioactive compounds in aquaculture

The use of bioactive compounds, including antibiotics and pesticides should be controlled to prevent misuse. A suggested code of practice for the use of inhibitory compounds in aquaculture is included as Appendix 3.

Action 9: Assess and evaluate the true consequences of tranfers and introductions of exotic organisms

Transplantation of exotic species beyond their natural range to new habitats for aquaculture and stocking purposes should be carefully and rigidly controlled. The Codes of Practice, Standard Guidelines and Protocols governing the introduction of exotic species developed by ICES and EIFAC should be strictly followed and implemented (Turner, 1988). Adequate inspection services and quarantine facilities should be made available in both the exporting and importing country before any transfer and importation is authorized. The flow-chart of the review and decision model of the ICES/EIFAC Code of Practice is attached in Appendix 4.

It should be emphasized that every movement of species to and from aquaculture sites, even within the same general area, should be strictly controlled through inspection and certification.

Action 10: Regulate discharges from land based aquaculture through the enforcement of effluent standards

The accumulating effects of discharges on the coastal environment could be greatly reduced by the enforcement of site- and contaminant-specific effluent standards (e.g. for suspended solids, nutrients, and BOD). Levels to be adopted should be within the assimilative capacity of receiving ecosystems (GESAMP, 1986).

Action 11: Establish quality control measures for aquaculture products

All aquaculture products should conform with safety standards for seafood before they are allowed for human consumption (WHO Expert Committee, 1974; FAO/WHO Codex Alimentarius Code of Hygienic Practice for Products of Aquaculture, in preparation). A Directive from the European Community adopts a provisional value of <300 faecal coliforms/100 ml of bivalve tissue. Therefore, it is essential to ensure an adequate sanitary standard for waters in areas supporting aquaculture. Improved water treatment techniques and effluent standards would help to minimize human health risks. Monitoring by the health authority should be established to ensure that the growers comply with such requirements. Depuration and appropriate storage and preservation facilities need to be established to ensure the adequate quality of products.

Action 12: Increase public awareness of the safety aspects of consuming seafood

Better public awareness of the need for good seawater quality in the production of marine aquaculture products will provide pressure for the control of undesirable inputs to the local environment. A knowledge of the specific risks associated with handling, processing and consuming seafood including aquaculture products could help reduce the incidence of food poisoning and infections from food-borne organisms. Consumer awareness is an effective way to compel fish farmers to produce hygienic products. The appropriate use of the news media, avoiding the spread of misinformation, can help to increase consumer confidence and to support those seafood industries which are not affected by contamination.

Action 13: Apply incentives and deterrents to reduce environmental degradation from aquaculture activities

Incentives such as concessionary lease of wetlands, tariff exemption on feeds and equipment, energy subsidies and depreciation allowances on facilities and deterrents such as taxes on land and water uses and effluent discharge can be used to encourage aquaculturists to make more efficient use of resources and take full responsibility for mitigating or minimizing environmental change (see Van Houtte *et al.*, 1989).

Action 14: Monitor for ecological change

There are existing monitoring protocols which have been developed to monitor ecological change in coastal waters and in the vicinity of effluent discharge points (ICES, 1989a; ICES, 1989b). However, given that the nature and scale of an ecological impact will depend on the type of aquaculture practice and the location of the operation it is likely that existing protocols will have to be modified according to local requirements.

The purpose of monitoring for regulatory control of aquaculture development is ecological protection. The aim is to identify the level of, or trend in a particular variable and ensure that it does not fall below or exceed a predetermined value related to the natural conditions for the area. Identification of the spatial and temporal trend in a particular variable will be aided by reducing variation due to seasonality and sampling and method error. Validation of a trend will require statistical analysis and this requires that a sufficient number of samples are collected. Since monitoring is only a means to an end, the results obtained must be used to modify the operation if the change in a variable exceeds or falls below the predetermined.

6. REFERENCES

Alter, M.J. *et al.,* 1982. Sporadic non-A, non-B hepatitis frequency and epidemiology in an urban U.S. population. J.Infect.Dis., 145:866-93

Aoki, T., 1989. Ecology of antibiotic-resistant determinants of R plasmids from fish pathogenic bacteria. In Recent advances in microbial ecology, edited by T. Hattori *et al.*. Tokyo, Japan, Japan Scientific Societies Press, pp. 571-6

Araoz, J. de *et al.*, 1970. Principles and practice of cholera control. WHO Public Health Pap., (40):139p.

Aure, J. and A. Stigebrandt, 1989. On the influence of topographic factors upon the oxygen consumption rate on sill basins of fjords. Estuar.Coast.Shelf Sci., 28:59-69

Austin, B., 1983. Effectiveness of ozone for the disinfection of laboratory effluent. Fed.Eur. Microbiol.Soc.,Microbiol.Lett., 19:211-4

Austin, B. and A.M.J. Al-Zahrani, 1988. The effect of antimicrobial compounds on the gastrointestinal microflora of rainbow trout, *Salmo gairdneri* Richardson. J.Fish Biol., 33:1-14

Austin, B. and D.A. Austin, 1987. Bacterial fish pathogens: disease of farmed and wild fish. Chichester, Ellis Horwood

Austin, B. and D.A. Austin (eds.), 1989. Methods for the microbiological examination of fish and shellfish. Chichester, Ellis Horwood, 319p.

Austin, B. and D. McIntosh, in press. New bacterial fish pathogens and their implications for fish farming. Rev.Med.Microbiol., (in press)

Austin, B., *et al*., 1981. Numerical taxonomy analysis of bacteria from the completed "most probable numbers" test for coliform bacteria. J.Appl.Bacteriol., 51:101-12

Bailey, C., 1988. The social consequences of tropical shrimp mariculture development. Ocean Shoreline Manage., 11:31-44

Baine, W.R. *et al*., 1974. Epidemiology of cholera in Italy in 1973. Lancet, December 7, 1974:1370

Black, E. and B.L. Carswell, 1989. Sechelt Inlet water quality model. Seattle, University of Washington, Institute of Environmental studies, Northw.Environ. J.,Inst.Environ.Stud., Univ.Wash., 5

Blackburn, T.H., B.A. Lund and M.D. Krom, 1988. C- and N- minerilization in the sediments of earthen marine fish ponds. Mar.Ecol.Progr.Ser., (44):221-7

Braaten, B. *et al.*, 1983. Pollution problems in Norwegian fish farming. Copenhagen, International Council for the Exploration of the Sea, Mariculture Committee, F:26

Brown, J.R., R.J. Gowen and D.S. McLusky, 1987. The effects of salmon farming on the benthos of a Scottish sea loch. J.Exp.Mar.Biol.Ecol., 109:39-51

Chua. T.-E., 1989. Will coastal area managment programmes work in Southeast Asia. ICLARM Conf.Proc., (19):231-40.

Denis, F.A., 1973. Coxsackie group A in oysters and mussels. Lancet, 1973 (Vol 1):1262

Di Girolamo, *et al*., 1972. Preliminary observations on the uptake of poliovirus by West Coast Shore crabs. Appl.Microbiol., 23:170

Dixon, J.A. *et al*., 1988. Economic Analysis of the environmental impacts of development projects. London, Earthscan Publ. Ltd.

Dolin, R., J.J. Treanor and F.M. Meyer, 1987. Novel agents of viral gastroenteritis. J.Infect.Dis., 155:365-76

Enell, M. and J. Löf, 1983. Environmental impact of aquaculture - sedimentation and nutrient loadings from fish cage sulture farming [in Swedish]. Vatten, 39:364-75

FAO, 1988. Aspects of FAO's policies, programmes, budget and activities aimed at contributing to sustainable development. Document to the ninety-fourth Session of the FAO Council, Rome, 15-25 November 1988. Rome, FAO. CL 94/6

FAO, 1989. Review of developments in aquaculture. Rome, FAO, COFI/89/Inf.5

FAO, 1990. Aquaculture production (1985-1988). FAO Fish.Circ., (815) Rev.2:136p.

FAO, 1990a. Aquaculture Minutes No. 8. Rome, FAO(FIRI), 4p.

Folke, C. and N. Kautsky, 1989. The role of ecosystems for a sustainable development of aquaculture. Ambio, 18 (4):234-43

Gade, H.G. and A. Edwards, 1980. Deep water renewal in fjords. In: Fjord oceanography, edited by H.J. Freeland, D.M. Parker and C.D. Levings. New York, Plenum Publ. Comp., pp.453-89

Gerba, C.P. and S.M. Goyal, 1986. Development of a Qualitative Pathogent Risk Assessment Methodology for Ocean Disposal of Municipal Sludge. Cincinnati, OH, U.S. Environmental Protection Agency, ALAO-CIN-493

Gerba, C.P. *et al*., 1979. Failure of indicator bacteria to reflect the occurrence of enteroviruses in marine waters. Am.J.Public Health, 69:1116-9

GESAMP (IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution), 1986. Environmental Capacity. An approach to marine pollution prevention. Rep.Stud.GESAMP, (30):49p.

GESAMP (IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution), 1989. Long-term consequences of low-level effects of marine contamination: An analytic approach. Rep.Stud.GESAMP,(40):14p.

Goldfield, M., 1976. Epidemiological indicators for transmission of viruses by water. In Viruses in water, edited by O. Berg *et al*. Washington, American Public Health Association, pp.70-85

Gomez, E.D. *et al*., 1989. State of the marine environment in the East Asian Seas Region. UNEP Reg.Seas Rep.Stud., (126):63p

Gowen, R.J. and N.B. Bradbury, 1987. The ecological impact of salmon farming in coastal waters: A review. Oceanogr. Mar.Biol.Ann.Rev., 25:563-75

Gowen, R.J., N.B. Bradbury and J.R. Brown, 1989. The use of simple models in assessing two of the interactions between fish farming and the marine environment. In Aquaculture - A biotechnology in progress, edited by N. De Pauw *et al.*, Bredene, Belgium, European Aquaculture Society, pp.1071-80

Gowen, R.J., P. Tett and K.J. Jones, 1983. The hydrography and phytoplankton ecology of Loch Ardbhair: a small sea loch on the west coast of Scotland. J.Exp.Mar.Biol.Ecol., 71:1-16.

Gowen, R.J., D.P. Weston and A. Ervik, 1990. Aquaculture and the benthic environment. Paper presented at the conference on feeding fish in our waters, nutritional strategies in management of aquatic waste. University of Guelph, Ontario, June 5-9 1990 (mimeo).

Gowen, R.J. *et al.*, 1990. The environmental impact of aquaculture activities. In, Aquaculture Europe '89 - Business Joins Science. Edited by N. De Pauw and R. Billard. Bredene, Belgium, European Aquaculture Society, Spec. Publ., (12)

Gunn, R.A. *et al.*, 1982. Norwalk virus gastroenteritis following raw oysters consumption. Am.J.Epidemiol., 115:348-551

Hagino, S., 1977. Physical properties of the pollutants. In Shallow sea aquaculture and self pollution, edited by Koseisha Koseikaku, Tokyo, Japanese Society of Scientific Fisheries, pp.31-41

Héral, M., 1988. Environmental impact of mariculture. Country reports: France. ICES Coop.Res.Rep., 37:176-85

Héral, M. *et al.,* 1989. Modélisation des écosystèmes conchylicoles: bassin de Marennes-Oléron. Rapport de fin de contrat. Paris, Fond de Développement de la Recherche et de la Technologie, MERS 86-50051, 186p.

Hoffman, G.L. and G. Schubert, 1984. Some parasites of exotic fishes. In Distribution, Ecology Management of exotic fishes. edited by W.R. Courtenay and J.R. Stauffer, Baltimore, John Hopkins University Press, pp. 233-61

Huang, Chung-Huang, 1990. Economic valuation of underground water and man-induced land subsidence in aquaculture. Appl.Econ., 22:31-43.

ICES, 1989. Report on the Working Group on Environmental impacts of mariculture, Oban, Scotland, 19-24 April 1989. Copenhagen, ICES C.M. 1989/F:11, 70 p.

ICES, 1989a. Report of the ICES Advisory Comittee on marine pollution, 1988. ICES Coop.Res.Rep., 160:123p.

ICES, 1989b. Report of the ICES Advisory Committee on marine pollution, 1989. ICES Coop.Res.Rep., 167:172p.

ICES, 1990. Report on the Working Group on Environmental impacts of mariculture, Aberdeen, Scotland, 27-31 März 1990. Copenhagen, ICES C.M. 1990/F:12, 69 p.

Imai, T., 1971. Aquaculture in shallow seas: Progress in shallow sea culture. Tokyo, Koseishi Kozeiku, (Translated by the US National Marine Fisheries Service and republished in 1977 by Amerind Publ. Co, PvT Ltd, New Delhi).

Isotalo, I. *et al*., 1985. The impact of the fish farming on the state of the Stroom area in Kustavi (in Finnish). Vesihallit Mon.Sarja, (352)

Jacobsen, P. and L. Berglind, 1988. Persistence of oxytetracycline in sediments from fish farms. Aquaculture, 70:365-70

Jones, K.J., *et al.*, 1982. A red tide of Gymnodinium aureolum in sea lochs of the Firth of Clyde and associated mortalities of pond reared salmon. J. Mar.Biol.Assoc.U.K., 62:771-82.

Joseph, P.R. *et al.*, 1965. Studies of cholera Et Tor in the Philippines. A retrospective investigation of an explosive outbreak in Bacolod City and Talisay. Bull.World Health Organ., 33:637-43

Kaspar, H.F. *et al*., 1985. Effect of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuro Sound, Marlborough Sounds, New Zealand. Mar.Biol., 85:127-36

Kohler, C.C. and J.G. Stanley, 1984. A suggested protocol for evaluating proposed exotic fish introductions in the United States. In Distribution, biology and management of exotic fishes. Edited by W.R. Courtenay, Jr and J.R. Stauffer, Jr. Baltimore, MD. The John Hopkins University Press, pp.387-406

Koff, R.S. and H.S. Sears, 1967. Internal temperature of steamed clams. New Engl.J.Med., 276:737-9

Liao, I.C., 1990. Aquaculture in Taiwan. In Aquaculture in Asia, edited by M.M. Joseph, Mangalore, Asian Fisheries Society, Indian Branch, pp.345-69

Linden, O., 1990. Development and poverty as factors in coastal environment management in developing countries. Paper presented at International Seminar on the Protection of Sensitive Sea Areas, Malmø, Sweden, 25-28 September 1990. London, International Maritime Organization

Lumb, C.M., 1989. Self pollution by Scottish salmon farms. Mar.Pollut.Bull., 20:375-9

Maclean, J.L., 1989. Economic aspects of *Pyrodinium* red tides in the western Pacific. ICLARM Conf. Proc., (21): 179-85

Mahoney, P., *et al*., 1974. Australian antigen: detection and transmission in shellfish. Science (Wash.), 183: 80-1

McCracken, *et al.*, 1976. An investigation of antibiotic and drug residues in fish. J.Appl. Bacteriol., 40:61-66

Melnick, J.L. and C.P. Gerba, 1980. The ecology of enteroviruses in natural waters. CRC Crit.Rev.Environ.Contam., 10:65-93

Metcalf, T.G. and W.C. Stiles, 1967. Viral pollution of shellfish in estuary waters. Am.J.Epidemiol., 88:379-91

Mosley, J.W., 1974. Epidemiological aspects of microbial standards for bathing beaches. In Discharge of sewage from sea outfalls, edited by A.L.H. Gamesson. Proceedings of an International Symposium, London. Pergamon Press, pp.80-93

Møster, G., 1986. Bruk av antibiotika i fishkeoppdrett Sogn og Fjordane Distriktshogskole, 5800 Sogndal, Norway

Munro, A.L.S., 1988. Advantages and disadvantages of transplantations. In Efficiency in aquaculture production: Disease control. Proc of the third international conference of aquafarming "Aquacultura 86", Verona, Italy, October 9-10 1986, edited by E. Grimaldi and H. Rosenthal. Milan, Italy, Edizione del Sole 24 Ore, pp. 75-83

Murphy, A.M. *et. al.,* 1979. An Australia-wide outbreak of gastroenteritis from osyters caused by Norwalk virus. Med.J.Aust., 2:329-33

Nishimura, A., 1982. Effects of organic matters produced in fish farms on the growth of red tide algae *Gymnodinium* type `65 and *Chatonella antiqua*. Bull.Plankt.Soc.Japan, 29(1):1-7

O'Mahany, M.C. *et al.*, 1983. Epidemic hepatitis A from cockles. Lancet, 1988 (Vol 1): 518-20

Paw, J.N. and T.-E. Chua, in press. An assessment of the ecological and economical impact of mangrove conversion in Southeast Asia. ICLARM Conf.Proc., (22)

Perrine, D. *et al.,* 1984. Eficacité du procédé d'ozonation des eaux recyclées de piscine dans la destruction des kystes d'amibes libres pathogènes ou non. In Ozone et Biologie. Paris, Association Internationale de l ozone

Pike, E.B. and J.W. Ridgway, 1985. The microbiological implications in European Community Directives related to the water cycle. J.Appl.Bacteriol., 59:105-26

Richard, Y., 1984. Aspects pratiques de la désinfection des eaux par l'ozone, p. 1-11. In Ozone et Biologie. Paris, Association Internationale de l'ozone

Ritz, D., M.E. Lewis and Ma Shen, 1989. Response to organic enrichment of infaunal macrobenthic communities under salmonid seacages. Mar.Biol., 103: 211-4

Rodhouse, P.G. *et al.*, 1985. Production of mussels, *Mytilus edulis*, in suspended culture and estimates of carbon and nitrogen flow: Killary Harbour Island. J.Biol.Assoc.U.K., 65:55-68

Rosenthal, H., 1976. Implications of transplantations to aquaculture and to ecosystems, FAO Technical Conference on Aquaculture. Rome, FAO, FIR:AQ/Conf. 76/E.67:19p.

Rosenthal, H., 1983. Coastal aquaculture and water quality in protected bay of Japan. Copenhagen, ICES, C.M.1983/E:22, 22p.

Rosenthal, H. *et al.,* 1988. Report of the ad hoc Study Group on Environmental Impact of Mariculture. International Council for the Exploration of the Sea. ICES Coop.Res. Rep., (154):83 p.

Salte, R. and K. Liestøl, 1983. Drug withdrawal from farmed fish: depletion of oxytetracycline, sulfadizine, and trimethoprim from muscular tissue of rainbow trout *(Salmo gairdneri)*. Acta Vet.Scand., 24:418-30

Samuelsen, O.B., 1989. Degradation of oxytetracycline in seawater at two different temperatures and light intensities and the persistence of oxytetracycline in the sediment from a fish farm. Aquaculture, 83:7-16

Sen Gupta, R. *et al.*, 1989. State of the marine environment in the South Asian Seas Region. UNEP Reg.Seas Rep.Stud.,(123):42p.

Shumway, S.A., 1990. A review on the effects of algae blooms on shellfish and aquaculture, J.World Aquacult.Soc., 21(2):65-104

Shuval, H.I., 1986. Thalassogenic diseases. UNEP Reg.Seas Rep.Stud., (79):40p.

Sorensen, J.C., S.T. McCreary and M.J. Hershman, 1984. Institutional arrangements for management of coastal resources. Prepared by Research Planning Institute , Inc., Columbia, South Carolina for National Park Service, US Dept. of the Interior, Washington, D.C., 165p.

Sornin, J.M., 1979. Enquête sur la sédimentation et l'exhaussement des fonts dans les zones conchylicoles des côtes de France. Rapport DEA, Université de Nantes, 41p.

Sullivan, J.J., 1988. Methods of analysis for DSP and PSP toxins in shellfish: a review. J.Shellfish Res., 7:587-95.

Tangen, G., 1977. Blooms of *Gyrodimium aureolum* (Dynophyceae) in north European waters, accompanied by mortality in marine organisms. Sarsia, 63(2):123-33

Tenore, K.R., J. Corral and N. Gonzalez, 1985. Effects of intensive mussel culture on food chain patterns and production in coastal Galicia, NW Spain. Proc. SIUEC (Symposium international on Utilization of Coastal Ecosystem, Rio Grande, RS, Brazil), Vol. 1: 321-28

Ting Thian Ming and J. Tung Sang Wong, 1989. Summary of red tide and paralytic shellfish poisonings in Sabah, Malaysia. ICLARM Conf.Proc.,(21):19-26

Tsutsumi, H. and T. Kikuchi, 1983. Benthic ecology of a small cove with seasonal oxygen depletion caused by organic pollution. Publ.Amakusa Mar.Biol.Lab., (7):17-40

Turner, G.E. (ed.), 1988. Codes of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms. EIFAC Occas.Pap., 23:44 p. and ICES Coop.Res.Rep., (195):44 p.

Tyler, J., 1985. Occurrence in water of viruses of public health significance. J.Appl.Bacteriol., 59:37-46

Van Houtte, A.R., N. Bonucci and W.R. Edeson, 1989. A preliminary review of selected legislation governing aquaculture. Rome, FAO, ADCP/REP/89/42:81p.

Welcomme, R., 1988. Proposed international regulations to reduce risks associated with transfers and introductions of aquatic organisms. In Efficiency in aquaculture production: Disease control. Proc of the third international conference of aquafarming "Aquacultura 86", Verona, Italy, October 9-10 1986, edited by E. Grimaldi and H. Rosenthal. Milan, Italy, Edizione del Sole 24 Ore, pp. 65-74

Welcomme, R. (comp.), 1988a. International introductions of inland aquatic species. FAO Fish.Tech.Pap., (294):318p.

Weston, D.P., 1990. Quantitative examination of macrobenthic commumity changes along an organic enrichment gradient. Mar.Ecol.Progr.Ser., 61:233-44

WHO, 1984. Aquatic (marine and freshwater) biotoxins. WHO Environ.Health Crit., 37:95p.

WHO Expert Committee, 1974. Fish and shellfish hygiene. Rome, Food and Agriculture Organisation of the United Nations and World Health Organisation, PM/E8465:62 p. and WHO Tech.Rep.Ser., (550):62p.

APPENDIX I

An example for the development of an integrated coastal zone management plan (from Chua, 1989)

APPENDIX II

Environmental impact assessment process

APPENDIX III

A code of practice for the use of inhibitory compounds in aquaculture

1. Medically important inhibitory compounds should be banned from use in aquaculture. However, some medically important compounds may need to be used in exceptional circumstances for certain specified diseases.

2. The availability of inhibitory compounds should be restricted to qualified individuals, such as veterinarians.

3. Access to inhibitory compounds should be denied to all laymen and inexperienced personnel.

4. The storage of inhibitory compounds should be in the manner recommended by manufacturers/suppliers.

5. The use of inhibitory compounds should be strictly in accordance with the written instructions from the manufacturer/supplier.

6. The use of pharmaceutical compounds should be by rotation. Thus, the repeated use of single compounds should be avoided.

7. The use of suitable withdrawal periods, after the use of pharmaceutical compounds, is necessary before animals are removed from the aquacultural facility.

8. The deliberate or accidental release of inhibitory compounds into the aquatic environment must be avoided.

9. Unused inhibitory compounds must be disposed of safely.

10. A surveillance programme must be adopted to ensure that the code of practice is carried out.

APPENDIX IV

Review and decision model for evaluating proposed introductions of aquatic organisms

The model (Figure 1) is composed of five levels of review and five corresponding "Decision Boxes". Components of the model are described below, with decisions being based on scale values obtained from an "opinionnaire" (Table 1).

Note - A simplified model has been enclosed as Figure 2.

(a) Proposal for introduction of aquatic organisms

An entity desiring to realize an introduction would prepare a proposal that includes the answers to the following questions:

(i) What organism do you propose to introduce (common and scientific name)?

(ii) What is its native range? What is the present range?

(iii) What is the purpose of the introduction?

(iv) Where and into what type of system would this organism be introduced and how many would be introduced?

(v) What precautions have been or will be taken to ensure that the organisms are not harbouring communicable pathogenic organisms and parasites?

(vi) If the organisms are to be maintained in a closed system, what measures would be taken to guard against accidental escape to open waters?

(vii) What is the current state of knowledge concerning the acclimatization potential of the organism? e.g.: (a) thermal requirements: tropical, temperate, Arctic; (b) habitat requirements: stream, river, lake, pond, etc.; (c) reproduction: describe the spawning habitat and reproductive strategy of the organisms.

A bibliography of pertinent literature should be appended to the proposal.

(b) Level of Review I

(i) Purpose of introduction - Does the proposing entity have valid reasons for introducing the aquatic organism? Could no native species serve the same function?

(ii) Abundance in native range - Knowledge of the population abundance of the organism in its native range is an important aspect of the evaluation. is it endangered, threatened or rare? Is it exploited from the wild or under culture?

(iii) Communicable pathogenic organisms and parasites - The evaluation would include assessing the safeguards for avoiding transmission of communicable pathogenic organisms or parasites to the proposed receiving system (s).

(iv) Site of introduction - It is important to discern from the outset whether the organism would be stocked in an open or closed system. Would it be stocked in or have potential access to a major drainage? If it is to be maintained in a closed system, the proposing entity must identify steps it would take to guard against accidental escape.

(c) Decision Box I

A proposal for an introduction would be rejected if:

(i) reasons for introduction were not deemed valid;

(ii) the introduction is for reasons other than conservation where the organism is endangered, threatened, or rare in its native range; or

(iii) the proposing entity has not established that adequate safeguards would be taken to avoid introduction of communicable pathogenic organisms and parasites. The proposal would be approved at this stage when the above criteria are met and provided that the introduction is perceived as being limited to a closed system. When this last condition is not fully met, the evaluation process would proceed to the next level of review.

(d) Level of Review II

This and subsequent levels of review are directed to experts selected by the Working Group. In Level II, the acclimation potential is assessed (Question 5 of the "opinionnaire", Table 1). Should pertinent information be insufficient, as evidenced by more than 50 percent of the experts marking "don't know" on the "opinionnaire", the Working Group might suggest that the propsing entity conduct research with a limited number of specimens under confined conditions for the purpose of obtaining the required data. The Working Group may suggest that all research be conducted within the organism's native range.

(e) Decision Box II

The proposal for the introduction would be approved when there is a strong chance that the organism would not establish a self-sustaining population (average value 3 for Question 5 in Table 1). Alternatively, further evaluation would be mandated for those organisms that would likely produce self-sustaining populations, or when evidence is insufficient for making a reasonable prediction.

(f) Level of Review III

This level of review is based on predicting the potential impact of the organism on the ecological integrity of the system(s) where it is proposed for introduction. In addition, the analysis of benefit and risk would include assessing the array of potential impacts on man. Review at this level requires detailed knowledge on the ecological relations of the organism in its native habitat, as well as considerable information on the community structure of the proposed receiving system(s).

(g) Decision Box III

The introduction would be rejected if the available information suggests (average "opinionnaire" values 2) that the organism would exert a major adverse impact on the receiving system(s) or on man. The proposal would be approved when indications are for the opposite outcomes. If the available information is not considered conclusive, the evaluation should proceed to level at Review IV.

(h) Level of Review IV

Level of Review IV requires development of a detailed literature review based on the format for a Food and Agriculture Organization (United Nations) Species Synopsis. However, additional sections concerning impacts of introduction (documented or potential) would also be required. Once the synopsis is prepared, this information will be sent again to the experts so they can attempt to arrive at a recommendation.

(i) Decision Box IV

On the basis of an analysis of the second round of "opinionnaire" data, the Working Group would either approve or reject the proposed introduction. Additional review (Level V) would be necessary whenever the current database is not considered sufficient, or if it is unclear whether the introduction is desirable.

(j) Level of Review V

This level of review requires that research be conducted to complete the species synopsis or to assess the potential impact of the introduction on the indigenous flora and fauna and habitats. It might be suggested that research be conducted under controlled conditions near the site where the introduciton is contemplated or the Working Group may suggest that all studies be caried out within the organism's native range.

(k) Decision Box V

Using all information collected at this stage, the Working Group should be able to make an informed recommendation regarding the proposed introduction. However, the Working Group may find it necessary to suggest additional research if important questions remain to be resolved. In such as a situation, the fifth and final evaluation stage would become a loop of the "Review" and "Decision" models until a recommendation could be made.

Table 1

Opinionnaire for appraisal of introductions of aquatic organisms. Each member of an evaluation board or panel of experts circles the number most nearly matching his/her opinion about the probability for the occurrence of the event. If information is unavailable or too uncertain: "don't know" is marked (Kohler and Stanley, 1984)

		Response					
		No	Unlikely	Possibly	Probably	Yes	Don't know
1.	Is the need valid and are no native species available that could serve the stated need?	1	2	3	4	5	X
2.	Is the organism safe from over-exploitation in its native range?	1	2	3	4	5	X
3.	Are safeguards adequate to guard against importation of disease/parasites?	1	2	3	4	5	X
4.	Would the introduction be limited to closed system?	1	2	3	4	5	X
5.	Would the organism be unable to establish a self-sustaining population in the range of habitats that would be available?	1	2	3	4	5	X
6.	Would the organism have mostly positive ecological impacts?	1	2	3	4	5	X
7.	Would most consequences of the introduction be beneficial to humans?	1	2	3	4	5	X
8.	Is data base adequate to develop a complete species synopsis?	1	2	3	4	5	X
9.	Does data base indicate desirability for introduction?	1	2	3	4	5	X

10.	Based on all available information, do the benefits of the exotic fish introduction outweigh the risks?	1	2	3	4	5	X