UNEP

CBD

CONVENTION ON BIOLOGICAL DIVERSITY

Distr.
GENERAL

UNEP/CBD/SBSTTA/8/INF/6
13 February 2003

ENGLISH ONLY

SUBSIDIARY BODY ON SCIENTIFIC, TECHNICAL
AND TECHNOLOGICAL ADVICE
Eighth meeting
Montreal, 10-14 March 2003
Item 5.2 of the provisional agenda*

MARINE AND COASTAL BIODIVERSITY: REVIEW, FURTHER ELABORATION AND REFINEMENT OF THE PROGRAMME OF WORK

Report of the Ad Hoc Technical Expert Group on Mariculture

Note by the Executive Secretary

EXECUTIVE SUMMARY

The Ad Hoc Technical Expert Group on Mariculture was established by the Conference of the Parties in adopting the programme of work on marine and coastal biological diversity at its fourth meeting (decision IV/5, annex). The Expert Group was established to assist the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) in its work on the topic of mariculture. The terms of reference instructed the Expert Group to:

(a) Evaluate the current state of scientific and technological knowledge on the effects of mariculture on marine and coastal biodiversity;

(b) Provide guidance on criteria, methods, techniques and best practices that avoid the adverse effects of mariculture, and also subsequent stock enhancement, on marine and coastal biological diversity and enhance the positive effects of mariculture on marine and coastal productivity.

In evaluating the current state of knowledge on the effects of mariculture on marine and coastal biodiversity, the group identified the main mariculture species and methods, and the biodiversity effects of those methods (section II). The group agreed that all forms of mariculture affect biodiversity at the genetic, species and ecosystem level, but that under certain circumstances mariculture could also enhance biodiversity locally (section IV). The main effects include habitat degradation, disruption of trophic

* UNEP/CBD/SBSTTA/8/1.

/…

systems, depletion of natural seedstock, transmission of diseases, and reduction of genetic variability. The biodiversity-effects of pollutants, such as chemicals and drugs, are not very well studied, though are generally assumed to be negative.

There are many available methods and techniques for avoiding the adverse effects of mariculture on biodiversity, and they are summarized in section III of this document. They include, most importantly, proper site selection, as well as optimal management including proper feeding. Other mitigation measures include culturing different species together (polyculture), and the use of enclosed, and especially re-circulating, systems. Many of the other impacts can be avoided with better management practices and other technological improvements. A number of aquaculture-specific international and regional principles, standards and certification processes exist, and are described in section V of this document.

CONTENTS

I. BACKGROUND

1. The Ad Hoc Technical Expert Group on Mariculture was established by the Conference of the Parties in adopting the programme of work on marine and coastal biological diversity at its fourth meeting (decision IV/5, annex). The Expert Group was established to assist SBSTTA in its work on the topic of mariculture. The terms of reference for the Group were approved by the Conference of the Parties at its fifth meeting, in decision V/3. The work of the Group is intended to help implement programme element 4 (Mariculture) of the programme of work on marine and coastal biological diversity. The operational objective of this programme element is as follows:

> "To assess the consequences of mariculture for marine and coastal biological diversity and promote techniques which minimize adverse impact."

2. In its terms of reference the Group was requested to:

(a) Evaluate the current state of scientific and technological knowledge on the effects of mariculture on marine and coastal biodiversity;

(b) Provide guidance on criteria, methods and techniques that avoid the adverse effects of mariculture, and also subsequent stock enhancement, on marine and coastal biological diversity and enhance the positive effects of mariculture on marine and coastal productivity.

3. In decision V/3, paragraph 15, of the Conference of the Parties, the Group was also asked to identify best practices in mariculture.

4. The Expert Group met from 1 to 5 July 2002, at FAO headquarters in Rome. The complete list of members of the Group is contained in annex I to this document. The Expert Group elected Ms. Stella Williams (Nigeria) and Mr. Phillippe Goulletquer (France) as its Co-Chairs, and Ms. Doris Soto (Chile) and Mr. Mohamed Shariff (Malaysia) as Rapporteurs. The staff of the FAO Fishery Resources Division provided logistical and technical support for the meeting.

5. The Expert Group addressed the issues contained in its terms of reference as requested by the Conference of the Parties and the present report thus provides SBSTTA with an evaluation of the current state of scientific and technological knowledge on the effects of mariculture on marine and coastal biodiversity; and guidance on criteria, methods, techniques and best practices that avoid the adverse effects of mariculture on marine and coastal biological diversity, and enhance the positive effects of mariculture on marine and coastal productivity.

6. Section II of the present note presents an evaluation of the current state of scientific and technological knowledge on the effects of mariculture on marine and coastal biological diversity. This section corresponds to part (a) of the terms of reference, and reviews the main mariculture species, methods and their impacts. Section III presents criteria, methods, best practices and technology for avoiding the adverse effects of mariculture on marine and coastal biodiversity, while section IV discusses enhancing its positive effects. These sections correspond to part (b) of the terms of reference. Additionally, a summary of existing international and regional guidance on mariculture is provided in section V of the report.

II. EVALUATION OF THE CURRENT STATE OF KNOWLEDGE ON EFFECTS OF MARICULTURE ON MARINE AND COASTAL BIODIVERSITY

A. Volume and main species

7. Mariculture is the farming and husbandry of marine plants and animals in brackish water or marine environments. While mariculture output is still dwarfed by the tonnage of farmed freshwater organisms, it is growing globally, and its practices have important implications for marine and coastal biodiversity on the level of genes, species and ecosystems.

8. However, mariculture provides good quality food and is comparatively more efficient than many other food production forms. Humans consume less than 1% of terrestrial primary organic matter production, which totals about 132 billion tons, and less than 0.02% of the 82 billion tons of the primary production of the oceans (assuming that the fish caught are secondary consumers). Because of better feed conversion ratios, fish can replace terrestrial animals generally at about half the level of feed inputs. In other words, a hundred kilos of feed can produce thirty kilos of fish or fifteen kilos of pork. 1/ In this sense, mariculture is a more efficient user of primary productivity than is the farming of livestock.

9. Mariculture worldwide is growing. FAO statistics shows an increase from roughly 9 million tonnes in 1990 to more than 23 million tonnes in 1999. However, this increase is the result of the higher production of only few species. Thus, the Group made the assumption that the severity of biodiversity effects will roughly mirror production tonnage, and concentrated on the genera and species responsible for most global mariculture production, using the most recent summary data available (FAO Fishstat Plus 2000). Table 1 presents a list of the top mariculture species in 2000.

10. The list does not include marine species, such as milkfish and mullet, when they are cultured in brackish inland waters, nor does it include freshwater species, such as tilapia, grass carp and European eel, when they are grown in brackish or marine waters. It does not consider FAO's "not elsewhere included" (NEI) or designation, which groups species not listed individually. However, there are some species, which have shown potential for future growth and may be sensitive to aquaculture efforts (Anguilla) (Acipenser spp., Anguilla spp., Diplodus spp., Epinephelus spp., Lates spp., Lutjanus spp., Oreochromis spp., Scophthalmus. spp., Thunnus spp., Ulva spp. among others). Some of these species are of great local importance, and will undoubtedly rise in the tonnage rankings. It also means that the Group had to ignore the potentially very important local effects of small-scale culture, for example seahorse and giant clam culture. Additionally, the culture of microalgae, copepods, rotifers, and brine shrimp were also considered to be outside the scope of this document.

11. Species are listed in order of tonnage produced. Brackish-water aquaculture production is dominated by shrimp but also includes finfish such as milkfish, and molluscs. Marine aquaculture is dominated by seaweed, notably Japanese kelp, and molluscs, mainly the Pacific cupped oyster, but also includes high-value finfish such as salmon. 2/

1/ Åsgård, T., E. Austreng, I. Holmefjord, and M. Hillestad. 1999. Resource efficiency in the production of various species. *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

2/ FAO. 2000. Yearbook of fisheries statistics: summary tables. FAO, Rome. http://www.fao.org/fi/statist/summtab/default.asp

Table 1. Top mariculture species in 2000

Species	Annual Production (tonnes)	Culture Environment	Top Two Countries
Japanese kelp (*Laminaria japonica*)	4,580,056	m	China, Japan
Pacific cupped oyster (*Crassostrea gigas*)	3,944,042	m, b	China, Japan
Japanese carpet shell (*Ruditapes philippinarum*)	1,693,012	m, b	China, Italy
Yesso scallop (*Patinopecten yessoensis*)	1,132,866	m	China, Japan
Laver / Nori (*Porphyra* spp.)	1,010,963	m	China, Japan
Atlantic salmon (*Salmo salar*)	883,448	M, b	Norway, Chile
Tambalang / Elkhorn / Spinosum (*Eucheuma cottonii*)	604,600	m	Philippines
Giant tiger prawn (*Penaeus monodon*)	571,497	b, m	Thailand, Indonesia
Blue mussel (*Mytilus edulis*)	458,558	m	Spain, Netherlands
Blood cockle (*Anadara granosa*)	319,382	m	China, Malaysia
Wakame (*Undaria pinnatifida*)	311,105	m	Rep. of Korea, Japan
Fleshy prawn (*Penaeus chinensis*)	219,152	b, m	China & Rep. of Korea
Red seaweeds (*Kappaphycus* spp. & *Eucheuma* spp.)	205,277	m	Indonesia
Rainbow trout (*Oncorhynchus mykiss*)	153,340	m, b	Chile, Norway
Whiteleg shrimp (*Penaeus vannamei*)	143,737	b, m	Ecuador, Mexico
Japanese amberjack / Yellowtail (*Seriola quinqueradiata*)	137,328	m	Japan, Rep. of Korea
Mediterranean mussel (*Mytilus galloprovincialis*)	117,271	m, b	Italy, France
Coho salmon (*Oncorhynchus kisutch*)	108,626	m	Chile, Japan
Green mussel (*Perna viridis*)	87,533	m	Thailand, Philippines
Gilthead seabream (*Sparus aurata*)	87,106	m, b	Greece, Turkey
Silver / Red seabream (*Pagrus major*)	82,811	m	Japan, Rep. of Korea
New Zealand / Green shelled mussel (*Pena canaliculus*)	76,000	m	New Zealand
European seabass (*Dicentrarchus labrax*)	52,817	m, b	Greece, Egypt
Gracilaria seaweeds (*Gracilaria* spp.)	52,674	m, b	Chile, Viet Nam
Northern quahog / Hard clam (*Mercenaria mercenaria*)	50,685	m, b	Taiwan Province & USA
Banana Prawn (*Fenneropenaeus indicus* & *F. merguiensis*)	45,717	b, m	Indonesia, Viet Nam
Caulerpa seaweeds (*Caulerpa* spp.)	28,055	m	Philippines
Flathead grey mullet (*Mugil cephalus*)	27,737	b, m	Egypt & Italy
Milkfish (*Chanos chanos*)	25,723	b, m	Taiwan Province, Philippines

Species	Annual Production (tonnes)	Culture Environment	Top Two Countries
Chilean mussel (*Mytilus chilensis*)	23,477	m	Chile
Peruvian calico scallop (*Argopecten purpuratus*)	21,295	m	Chile & Peru
Japanese flounder / Bastard Halibut (*Paralichthys olivaceus*)	21,202	m	Rep. of Korea, Japan

m= marine, b= brackishwater

B. Methods

12. This document focuses on the most important and well-documented species and methods, and does not attempt to embrace all species and methods. Despite the huge variety of marine organisms cultured, the methods used can be reduced to a few basic strategies. While there are numerous schemes for grouping kinds of aquaculture (e.g. autotropic vs heterotrophic), the mariculture methods presented here are grouped in a common-sense way that makes it easy to identify and visualize their biodiversity effects. Detailed information about each culture method is provided in the full report of Expert Group. The culture categories are:

(a) For *molluscs*:

(i) Vertical or rack culture;

(ii) Hanging culture;

(iii) Bottom culture;

(iv) Land-based tank culture;

(v) Sea-ranching;

(b) For *echinoderms*:

(i) Tank culture;

(ii) Cage culture;

(iii) Sea ranching;

(c) For *crustaceans*:

(i) Pond culture;

(ii) Raceway culture;

(iii) Cage culture;

(iv) Sea ranching;

(d) For *marine aquatic plants*:

(i) Suspended culture (longline, raft, net) ;

(ii) Bottom culture;

(iii) Tank culture;

(e) For *finfish*:

(i) Cage culture (inshore and offshore);

(ii) Pen culture;

(iii) Pond and raceway culture (flow-through and recirculation systems);

(iv) Sea ranching.

13. Polyculture, the growing of two or more species belonging to different trophic levels in the same system, has a long history in freshwater aquaculture, especially in China. Some marine examples include grouper and mudcrab in ponds; milkfish and siganids in marine net cage; sea scallops suspended from salmon net pens; shrimp and scallop; and ezo scallop, Japanese kelp and sea cucumber are cultured in combination with open-water maricultural structures like net cages for finfish.

14. The following section briefly describes the main mariculture methods. Broodstock, seed supply and growout are considered separately for each method, as these very different activities have fundamentally different effects on biodiversity.

1. Mollusc culture

15. Mollusc culture is done in tropical and temperate regions depending on species. Oysters, scallops and mussels are dominating the temperate mariculture while in tropical areas the same species are cultured at a low and local commercial scale.

Broodstock and seed supply

16. Bivalve mollusc larvae or “spat” are either collected from natural grounds using suitable materials to which the larvae adhere or “set”, or produced by artificial fertilization in hatcheries. The latter technique allows much greater control over the genetic makeup of the stock, as well as transport of the larvae to distant grow-out facilities (“remote setting”). The parental stock usually come from natural environments, is maintained for short periods, and spawning is induced in captivity. Thus it is likely that the offspring retain the genetic diversity of the parental stock. Nevertheless, due to the high fecundity of molluscs, only few animals are required to sustain seed production, a practice which might cause negative impacts on the genetic diversity of the reared population. Studies are underway to define the required number of broodstock in order maintain genetic diversity (Taniguchi, 2002).

17. In many areas, triploid production of spats are carried out in order to decrease the growth period. Triploid organisms do not pose a genetic problem as they are sterile Nevertheless, 100% triploidy is not guaranteed and monitoring for permanent sterility is highly recommended. In oysters, a reversion to fertile condition after triploidy induction has been observed (Blankinship, 1994). Therefore, triploidy should be considered as a risky process for a species introduction, requiring first a containing system. On the other hand, tetraploids are cause for more concern as they can breed with wild populations and produce infertile offspring. Research is required to elucidate the potential biodiversity impact of such practices.

Growout

18. Larvae that have attached or “set” to their substrate are grown in hanging culture (suspended from floating rafts or floating long lines on strings, trays, stacks or mesh bags), vertical or rack culture (sticks or posts are staked on the bottom and act directly as a growing medium or support racks, or

platforms), bottom culture (shells, stones, rocks, cement slabs etc. added to the bottom provide attachment sites), or in land-based systems (mostly for sea-ranching). In the case of abalone, land-based culture techniques are applied for the whole life cycle (MacKenzie and Burrell, 1997).

19. Hanging culture is the most common method of oyster, mussel and scallop culture. In France, oysters are cultured both on- and off the bottom, using trestles, to produce the regularly shaped shells preferred by raw half shell consumers. 3/ (Goulletquer and Heral, 1997) Commercial clam growers and quahog culture operations depend largely on bottom culture. 4/ Mussel farming makes extensive use of bamboo either as stakes or as floating rafts with the vertical or rack culture method most commonly used. 5/ Seed scallops are most commonly suspended in the water from rafts, frames or longlines, sandwiched in metal or plastic mesh frames, hung in fine mesh lantern nets (shallow water cages) or pearl nets (deep water cages) or hung individually from strings (ear hanging). 6/

20. Aquaculture has also been used to restore and replace overfished stocks of molluscs. In overfished stocks, a restoration management plan should be adopted to conserve natural genetic diversity as the expansion of mariculture increases the risk on wild populations (Stotz, 2000).

21. Given the specificities of each mollusc culture method, different impacts on biodiversity are to be expected. Most culture methods make use of natural primary productivity and therefore the carrying capacity of the system should be carefully considered. In addition, sedimentation from faeces contribute to nutrient flows. Maintenance of culture structures sometimes include the use of antifouling chemicals. Regardless of the applied technique, the water column and the sea floor are subject to alteration in their biological composition. In the case of land-based abalone culture, artificial food is used as supplement to natural feed. This requires treatment of effluents in order to reduce impacts on the natural ecosystem. (Allen et al., 2000).

2. Crustaceans

22. Shrimp mariculture is mostly practised in tropical regions and some attemps are made to produce shrimp in temperate areas in pond and recirculating systems.

Broodstock and seed supply

23. Until the last decade, the global shrimp and prawn farming industry relied on wild-caught larvae or larvae produced by wild-caught females carrying fertilized eggs ("berried females"). These activities have had great adverse impacts on natural stocks (FAO, 2001). The removal of gravid females reduces the availability of shrimp larvae, a major source of food for many aquatic organisms. Furthermore the bycatch of non-target species is an impact on the environment. With the expansion of shrimp farming and especially the need to ensure the supply of disease-free post-larvae (the stage at which artificial feeding and growout in tanks starts), the trend is toward maintenance of broodstock in hatcheries and the complete closing of the life cycle in captivity using induced spawning techniques. Such controlled reproduction of

---

3/ Bardach, J. E, J. H. Ryther, and W. O. McKarney. 1972. Farming and Husbandry of Freshwater and Marine Organisms. John Wiley & Sons, Inc.

4/ Ibid.

5/ Baluyut, E. A. 1989. Aquaculture systems and practices: a selected review. UNEP/FAO, Rome. ADCP/REP/89/43. http://www.fao.org/docrep/T8598E/t8598e00.htm#Contents

6/ Bardach, J. E, J. H. Ryther, and W. O. McKarney. 1972. Farming and Husbandry of Freshwater and Marine Organisms. John Wiley & Sons, Inc.

farmed crustaceans has greatly reduced dependence on natural supplies of seed. A major consideration of such techniques lies in the loss of the genetic diversity of the cultured species (in case of escapes).

24. Seed overproduction in some hatcheries and their subsequent release into the wild results in enhancement of natural populations (Davenport et al., 1999). Another problem is posed by the transfer of broodstock and hatchery-produced larvae to different growing regions of the globe. In all cases, effects on genetic diversity should be considered.

Growout

25. In early days of shrimp farming, for example in China, shrimp culture was done in "trap ponds" where juveniles were allowed to enter and grow to marketable size. 7/ Presently, shrimp are grown in earthern ponds, concrete raceways and tanks in extensive, semi-intensive, and intensive culture systems. Environmental impact depends on the level of stocking density applied: extensive culture requires large areas and intensive culture use high quantities of artificial food and high water exchanges. Extensive aquaculture promotes the natural production of the pond, semi-intensive aquaculture supplements natural production with artificial feed, while intensive aquaculture requires artificial feed as the addition to the natural organisms in the water as a source of nutrition. 8/

26. In many countries, shrimp ponds used to be rice fields, mangrove forests, fish ponds or salt pans (for example, milkfish ponds in the Philippines, mangroves in Ecuador and other countries). 9/ Rapid expansion of shrimp mariculture led to the destruction of vast areas of mangroves disrupting the balance of these special ecosystems. However, efforts are now underway to restore mangrove habitats. In some countries, shrimp aquaculture is now being practised in inland ponds using transported seawater. Even though this technique might be beneficial in terms of saving mangroves and restricting the spread of disease, it has negative effects on soils and terrestrial environments.

27. Pond culture systems result in vast flows of nutrients and solids to natural environments with marked impacts on ecosystems and their biodiversity. Another major impact associated with shrimp aquaculture is the spread of disease to natural populations. Chemical inputs to the environment come from different sources like medicated feed and application of pesticides and insecticides. Shrimp aquaculture production decreased tremendously in the past decade due to disease problems, poor management techniques, lack of coastal planning and inappropriate site selection. New techniques are being developed such as zero exchange systems that confine the cultured animals and require limited amounts of water, therefore reducing the interaction between cultured animals and the environment.

3. Marine aquatic plant culture

28. Macro- and micro-algae and seagrass culture is mostly practised in temperate, but also in tropical regions for human use (i.e. cosmetics) and consumption. In the industrial sector, many uses have been identified as through the development of Agar products.

7/ FAO. 1978. Aquaculture development in China. Report on an FAO/UNDP Aquaculture Study Tour to the People's Republic of China, led by T.V.R. Pillay, Aquaculture Development and Coordination Programme, FAO, Rome, Italy, 2 May-1 June 1978. http://www.fao.org/docrep/X5686E/X5686E00.htm

8/ Baluyut, E. A. 1989. Aquaculture systems and practices: a selected review. UNEP/FAO, Rome. ADCP/REP/89/43. http://www.fao.org/docrep/T8598E/t8598e00.htm#Contents

9/ The Trade and Environment Database, Case Studies, Thailand Shrimp Farming. http://www.american.edu/TED/THAISHMP.HTM

Broodstock and seed supply

29. Cultured aquatic plants generally have complicated life cycles with several intermediate stages. The major source of broodstock is wild collection of specimens. Most culture of aquatic plants is now dependent on hatchery production of the early life stages (monospores, zoospores, gametophytes, sporophytes) which are attached to growing media and transferred to marine sites. Other propagation method involve fragmentation and protoplast techniques. In East Asia, selective breeding based on phenotypic characteristics is widely practised.

Growout

30. Young plants are cultured in three different methods: suspended (longline and raft), bottom cultures at sea, and inland tank cultures.

31. In bottom culture, large rocks or artificial substrate such as various shapes of concrete are placed on the seabed and either seeded with zoospores (an early life stage) or have sporophytes (young plants) anchored to them using rope. Bottom culture, now often used in conjunction with raft culture, is the earliest known form of kelp culture but is still employed in China, as well as in Japan and Korea. 10/

32. In off-bottom culture, monospores (another early life stage) or young plants are either suspended from weighted rope lines or attached directly to lines or culture nets. These ropes and nets are attached to floating rafts, buoyed longlines, fixed longlines or fixed pole structures and frames. Porphyra, "n*ori*" (laver) concosellis containing oyster cultch are attached to culture nets in the laboratory, and the nets are suspended from wooden or bamboo frames anchored to the bottom in shallow coastal areas or inland seas. 11/ Laminaria spp. and Undaria spp., "*wakame*" is cultured in open water on longlines that can reach depths of up to 6 meters depending on water clarity. 12/ The fixed off-bottom monoline method is the most common method used in the culture of Eucheuma spp. Raft or long-line methods are also used. 13/ Gracilaria culture in Chile uses a technique resembling agriculture, where the algae are planted on sand bottoms.

4. Finfish

33. Finfish culture is practiced in both temperate and tropical waters. In the case of tropical waters, there is a need of biological studies for seed production. Species cultured include both catadromus and marine fish.

Broodstock and seed supply

34. Broodstocks are divided into two main categories: (i) domesticated and (ii) a mixture between wild and domesticated. In the case of domesticated broodstocks, great concern is expressed regarding the conservation of genetic diversity. Less impact on genetic diversity is expected if wild fish are used in combination with domesticated animals. Nevertheless, this last method will put undesired pressure on wild stocks by promoting the capture of wild organisms. More research is needed in order for the industry to

---

10/ Bardach, J. E, J. H. Ryther, and W. O. McKarney. 1972. Farming and Husbandry of Freshwater and Marine Organisms. John Wiley & Sons, Inc.

11/ Ibid.

12/ Ibid.

13/ FMC BioPolymer website. FAQ on the benefits of cottonii and spinosum seaweed farming. http://www.fmcbiopolymer.com/contents/seaweed_farming/index.cfm?scrn=faq&answer=4#4

adopt the best technique in terms of reducing biodiversity impacts. As an example, the introduction of 100 to 200 Nile tilapia fry supports a 90,000 ton aquaculture harvest, suggesting a low genetic diversity (Beardmore, Mair & Lewis, 1997).

35. Most of the important finfish species are grown from larvae or "fry" produced by controlled reproduction in hatcheries. Induced breeding technology has progressed through the application of crude pituitary homogenates to the development of highly active gonadotropin-releasing hormone analogues that can stimulate spawning in recalcitrant species or through the manipulation of holding conditions. 14/ 15/ Of all the major marine finfish species cultured, salmonids are the main group from which gametes can be stripped from wild fish and combined later in the hatchery, the technique most commonly used for seed production. For most tropical and warm-water (sea bass and sea bream) species, and for some salmonids held in captivity before breeding, spawning is initiated by hormone application.

36. Collection of fry from the natural environment affects recruitment into wild populations by reducing the parental stocks. In the case of the collection of Atlantic glass eel, this could lead to the collapse of the natural reproductive stocks (EIFAC/ICES 2001). In Mediterranean, Asian and Latin American countries, seed is still being collected from the wild. In Egypt, for example, fry of mullets, sea bream and sea bass still derive primarily from the wild (FAO, 1996).

37. In many areas triploid production of seed are carried out in order to decrease the growth period. A second potential advantage is the production of sterile offspring. Nevertheless, this requires ensuring that the fry are all female triploids as the disruption of gonadal development may not be fully achieved in males (Kapuscinski and Bristel, 2001). On the other hand, tetraploids are cause for more concern as they can breed with wild populations and produce infertile offspring (Guo and Allen, 1994, Rothbard et al., 2000; Yamaki and Katsutotshi, 2000). In general, animals produced with such techniques compete more efficiently for resources (food), disrupt mating behaviour and success and may affect the natural stocks. Research is required to elucidate the potential impacts of such practices.

38. Experiments are now under way to produce transgenic fish (genetically modified fish) in order to enhance performance under growout condition (FAO, 2000). Special care must be taken to prevent broodstocks from mixing with wild populations.

39. The common practice of transfer of broodstock and fry between different regions of the globe could have an effect on biodiversity through the introduction of allochtonous species, diseases and other related impacts.

40. Effluents from hatcheries are usually rich in nutrients and chemical compounds. Recirculating systems control water quality and reduce disease introduction. In flow-through systems, a general practice is to include a settling pond for the treatment of wast-water before it is returned into the environment. Chemicals tend to persist in the water column and are introduced into natural environments. Regular monitoring of inputs into aquatic systems must be carried out.

14/ Harvey, B., and J. Carolsfeld. 1993. Induced breeding in tropical fish culture. IDRC. Ottawa, Ont. 144pp.

15/ Zohar, Y., and C. C. Mylonas. 2001. Endocrine manipulations of spawning in cultured fish: from hormones to genes. Aquaculture 197:99-136.

Growout

41. For most of the major species of finfish, fertilized eggs are incubated until hatching (a very short process in tropical species and warm water species, but several months in salmonids) and then conditioned to artificial feed in tanks before transfer to growout facilities (pens, cages, large tanks).

42. Cage culture is divided into two main categories: inshore cages and offshore cages, and can be either floating, fixed or submerged. Inshore cages are located in protected and usually shallow areas with generally less water circulation than offshore cages. On the other hand, offshore cages are located in deep water and open areas with less protection from storms but with better water exchange. Cage-reared fish are fed supplemental or artificial diets depending on the stocking density and the level of technology applied 16/ In inshore cages, possible impacts include water quality degradation, transfer of disease, alteration of the benthic community biodiversity, input of antibiotics, antifouling and other chemicals as well as the risk of escapes. These impacts can be minimized by the proper management, site selection and continuous monitoring. In order to reduce potential impacts, clear monitoring parameters must be established. In offshore cages the highest risk results from escapees. However, total nutrient inputs in the latter could be similar or even greater than inshore systems. For both types of cages, nets and mooring systems provide additional substrate for colonization.

43. Nets and fish pens are located in shallow, sheltered waters, and their edges are anchored to the bottom/substrate. In the Philippines, milkfish pens generally have a nursery compartment within the grow-out pen/enclosure. Fish in the nursery compartment and are not generally given supplemental feeding except for occasional rations of bread crumbs, rice bran, broken ice cream cones, fish meal, and *ipil-ipil* leaf mill. 17/ Direct biodiversity impacts of fish pens involve the disappearance of benthic communities over large surfaces. Strong alteration of hydrodynamics have also been observed.

44. A typical fish pond system consists of the following basic components: pond compartments enclosed by dikes, canals for supply and drainage of water to and from the pond compartments, and gates or water control structures to regulate entry and exit of water into and from the pond compartments. 18/ Most mullet farms use shallow ponds and low stocking densities (less than 1 fish per square metre). Milkfish culture in the Philippines follows a progressive culture scheme, with separate nursery, transition, and rearing ponds. 19/ Fish grown in semi-intensive and intensive culture ponds are given supplementary and full artificial feeds, respectively. 20/ Large pond systems cause changes in natural ecosystems and have effects on ecosystem diversity. The quality of waste water from ponds depends on the stocking density, and constant monitoring of water quality will ensure the minimization of impacts on natural ecosystems.

45. Recirculating system use different levels of water inputs. These types of systems are sometimes automized and include complete water treatment as well as permanent control of temperature and physical and chemical parameters. Fish is stocked at high densities and artificial feed is used. Water is treated before it is discharged into the environment. These systems can avoid the negative impacts of other aquaculture systems. However, a proportion of dissolved nutrients are still entering the natural

16/ Baluyut, E. A. 1989. Aquaculture systems and practices: a selected review. UNEP/FAO, Rome. ADCP/REP/89/43. http://www.fao.org/docrep/T8598E/t8598e00.htm#Contents

17/ Ibid.

18/ Ibid.

19/ Ibid.

20/ Ibid.

environment. In the case of disease outbreaks, the water can be treated before discharge. Recirculating systems require high initial investments and can only be feasible for intensive culture.

46. Enhancement or ranching is most developed with marine finfish. This deals with the deliberate release of organisms from hatcheries. In enhancement, fry are released in order to restock wild populations while in ranching the fish are harvested from artificially enclosed areas. These techniques could have important impacts on the genetic diversity of wild stocks.

5. Echinoderms

47. Echinoderms include sea cucumbers and sea urchins, in particular locally important species from Asia, Australia , North and South America.

Broodstock and seed supply

48. Broodstock is collected yearly from wild stocks and spawning is achieved through use of physical stimulus in laboratory conditions. Urchin larvae is grown in tanks, and juveniles are released to the sea. Sea cucumber larvae is sometimes collected from natural stocks present on seaweeds.

Growout

49. In general, there are no specific techniques for growout. In some cases, intermediate storage of echinoderms takes place in suspended culture in cages, prior to release to natural fishing grounds.

C. Biodiversity effects of the main types of mariculture

50. All forms of mariculture, regardless of physical structure or economic motivation, affect biodiversity at genetic, species and ecosystem levels. At the ecosystem level, both goods and services functions can be affected, with widespread consequences and knock-on long-term effects. Therefore, the interconnected nature of aquatic communities require that impacts on aquatic ecosystems should be considered in a holistic manner, both in the short and long terms. This section presents a summary of the main biodiversity effects of mariculture.

51. Mariculture can modify, degrade or destroy habitat, disrupt trophic systems, deplete natural seedstock, transmit diseases and reduce genetic variability. For example, coastal mangroves have been converted into shrimp ponds, enclosed or semi-enclosed waters have been affected by nutrient loading (or stripping), and benthic habitats affected by bivalve bottom culture practices as well as by sedimentation

52. However, mariculture could also provide local biodiversity enhancement under certain circumstances, for example birds could be attracted to mariculture sites (Davenport *et al.*, in press) and artificial reefs acting as species aggregating devices may result in enhanced biodiversity. *In situ* coral replanting programmes have also proved to have a positive effect on reef biodiversity (Ekaratne, per com.). 21/

53. Depending on energy sources used to produce biomass, mariculture could be divided into

21/ Ekaratne, personal communication.

(a) Autochthonous organic-based or "natural" trophic systems, such as kelp culture, and raft culture of mussels or oysters. Such culture practices derive their energy from solar radiation or nutrient sources already available in natural ecosystems, and tend to have fewer negative effects on biodiversity. In some cases, their impact on biodiversity may even be positive;

(b) Allochthonous organic-based or "artificial" trophic systems, such as net and pond culture of fish and shrimps, derive energy mainly from feeds supplied by growers and are more likely to disrupt the natural ecosystems.

54. All the environmental effects are strongly dependent on the sensitivity of a particular ecosystem, or its type. Thus, some wetland habitats and ecosystems are particularly vulnerable, such as those that have been identified as threatened or sensitive, either due to their rarity or their vulnerability to change. Such ecosystems include mangroves, estuaries, seagrass beds, coral reefs as well as specific benthic communities. Specific impacts will depend on different carrying capacity requirements for various culture practices in any given ecosystem, which however are poorly known.

55. Culture systems in open waters discharge their nutrient rich wastes (faeces and uneaten feed) directly into the water and could cause increase in trophic status. Semi-enclosed ecosystems such as sheltered bays are particularly sensitive to such effects. This may lead to blooms of phytoplankton, including toxic species, and their consequent degradation can drastically reduce oxygen levels. Algal blooms can also cause severe shading to seafloor vegetation that serves as nursery habitat and refuge for finfishes and benthic invertebrates. 22/ In sheltered bays the effects of such waste sedimentation on the sea bottom tend to be confined within 50 or 100 meters of the site. However, in bays swept by strong currents the nutrients may spread widely and spark algal blooms within days, 23/ although Beveridge 24/ and Gowen and Bradbury 25/ report that strong tidal currents tend to dilute wastes before they can cause hypernutrification or eutrophication. Both effects are culture density-dependent. 26/ 27/ Scallops and oysters, for example, individually produce up to 50~60g and 120g faeces in dry weight respectively each year. 28/ Some of this waste will decompose and be carried away, but most will settle under the beds. During storms, the sediment can be drawn up into water columns and cause heavy mortality by blocking the gills of the bivalves. This overlay of sediment can also shift the composition of benthic communities towards pollution-tolerant species, 29/ 30/ a clear biodiversity effect. The waste problems associated with

---

22/ Bricelj, V. M., and D. J. Lonsdale. 1997. Aureococcus anophagefferens: causes and ecological consequences of brown tides in U.S. mid-Atlantic coastal waters. Limnology and Oceanography 42:1023-1038. *Cited in* Smith.

23/ Silvert, W. Spatial Scales of Mariculture Impacts. Habitat Ecology Division From a paper presented at a workshop in Bergen, to be published in *Fisken og Havet*. Available at: http://www.mar.dfo-mpo.gc.ca/science/mesd/he/staff/silvert/scales.html.

24/ Beveridge, M. C. M. 1996. Cage aquaculture, 2nd Ed. Fishing News Books, Oxford.

25/ Gowen, R. J., and N. B. Bradbury. 1987. The ecological impact of salmon farming in coastal waters: a review. Oceanorg. Mar. Biol. Rev. 25:563-575.

26/ Ibid.

27/ Wu, R. S. S., K. S. Lam, D. W. MacKay, T. C. Lau, and V. Yam. 1993. Impact of marine fish farming on water quality and bottom sediment: a case study in the sub-tropical environment. Marine Environmental Research 38:115-45.

28/ Tang, Q., and J. Fang. Impacts of intensive mariculture on coastal ecosystem and environment in China and suggested sustainable management measures. Yellow Sea Fisheries Research Institute, Qingdao, 266071. http://www.aquachallenge.org/abstracts/tang.html

29/ Kapuscinski, A. R., T. Nega, and E. M. Hallerman. 1999. Adaptive biosafety assessment and management regimes for aquatic genetically modified organisms in the environment. Pages 225-251 *In* R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

intensive culture of high-value marine finfish have led to the beginnings of reform in industry practices (e.g. salmonids in British Columbia and most high-value finfish species in Japan). 31/ 32/ However, further development of such reform is needed.

56. Considering the fate of by-products of culture practices, particulate matter including organic forms of nitrogen and phosphorous and sulphates typically move downward into the benthos, while carbon dioxide, dissolved organic carbon, and various nutrients (e.g., ammonia and phosphate) frequently move into the water column. Benthic communities (e.g., microbes and suspension feeders) modulate their transport pathways, as does the structure of pelagic communities. The structure and function of these communities are in turn modified by these processes.

57. The potential dangers to biodiversity in areas that receive discharges of pollutants such as chemicals, drugs and other additives used in mariculture have not been adequately studied. Such discharges result from excessive use of these pollutants. Lack of access to information on appropriate use has led some aquaculturists to misapply some chemicals (e.g., antibiotics). Salesmen or pharmaceutical companies may also encourage misapplication. Commonly used chemicals include antibiotics, pesticides, disinfectants, antifoulants and hormones (ICES Working Group, 1995). Table 2 shows the types of pollutants arising from aquaculture practices, and their common effects on biodiversity.

Table 2: The nature of pollutants arising from aquaculture practices, their sources and their impacts on biodiversity

Pollutant	**Source / Uses**	**Impact**
Antibiotics	Hatcheries, culture ponds	Accumulation in sediments and living organisms, genetic diversity of benthic microflora
Pesticides	Cages, algal beds	Invertebrate mortality
Disinfectants	Hatcheries, culture ponds	Hypoxia, mortality
Antifoulants	Cages	Invertebrate mortality
Hormones	Hatcheries	Unknown

58. The organophosphate class of chemicals like dichlorvos and trichlorphon used outside the United States of America to control sea lice (parasite copepods that feed on salmonid mucus) includes nerve gases and many insecticides. Effects on the marine environment are not well studied, though are usually

30/ Mattsson, J., and O. Linden. 1983. Benthic macrofauna succession under mussels, *Mytilusedulis* L. (Bivalvia), cultured on hanging longlines. Sarsia 68:97-102. *Cited in* Goldburg.

31/ British Columbia Environmental Assessment Office. The Salmon Aquaculture Review Final Report. ISBN 0-7726-3317-7 (set). http://www.eao.gov.bc.ca/project/aquacult/salmon/report/final/vol1/toc.htm

32/ Mires, D. 1999. Preparation and implementation of fisheries policy in relation to aquatic genetic resources. Pages 63-72 *In* R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

assumed to be negative. However, supporters of the use of the carbamate insecticide Sevin to kill burrowing shrimp (which undermine intertidal zone sediments used for oyster beds) believe that by stabilizing sediments the insecticide promotes greater biological diversity.

59. Chemicals are also used as antifouling agents and as disinfectants. Antifoulants such as TBT are banned in developed countries for aquaculture purposes, but are still used in some other countries, where they continue to impact on biodiversity. Sandnes reports 33/ that as salmon production in Norway has increased the relative usage of antifoulants has declined, with the exception of copper, which rose from 119 tonnes in 1991 to 174 tonnes in 1995.

60. Hormones are used to induce or prevent reproductive maturation, for sex reversal and to promote growth. Bath and feed-incorporated applications of hormones are obviously more of a concern than controlled injection into individual broodstock animals because they become readily released into surrounding waters where they can persist in the environment or in aquaculture products. Hormone use is not well documented and is sometimes carried out without adequate understanding of the quantities needed.

61. Parasites in cultured stock pose problems not only for aquaculturists but also for other organisms in the environment. In British Columbia, for example, one theory for the rise of *Parvicapsula* infection in migrating Pacific salmon is acquisition from a fish farm. The parasite is suspected to be linked to profound changes in migratory behaviour of salmon that leads to massive pre-spawning mortality and may be responsible for decimation of diversity at the population level. 34/

62. While there is a welcome trend in capture and culture fisheries management to consider harvested species as part of an ecosystem rather than "stand-alone" targets, the effects of mariculture on aquatic ecosystems have been little studied. Given the scale of culture of some of the major species, the effects on the different hierarchical levels of biodiversity can be far-reaching.

63. The high value marine carnivorous species that are farmed require feeds incorporating animal sources of proteins. The most obvious effect of farming these carnivorous species such as salmon, trout, and sea bream is that more protein is fed to the fish than is later harvested for human consumption. Most of this feed comes from marine sources in the form of fish meal and fish oils, and the percentage of fish meal incorporated into fish feed has been increasing from 10% in 1988, to 17% in 1994 to 33% in 1997. 35/ However, a large proportion of fish meal is diverted to pig and poultry feeds. The fish meal industry, partly driven by global deficits in fish oils, 36/ is actively seeking plant protein replacements. Fish protein and lipids presently came from the huge fisheries for small pelagic fish like anchoveta and Chilean jack mackerel and Atlantic herring. These fisheries comprise four of the five top global fisheries. Although plant proteins are being developed for inclusion as protein sources in fish feeds, complete replacement of fish oils in fish meals may not be possible since they have a beneficial effect on in resistance against fish diseases.

64. Harvesting small fish for conversion to fish meal leaves less in the food web for other commercially valuable predatory fish, such as cod, and for other marine predators, such as seabirds and

---

33/ Sandnes, K., and A. Ervik. 1999. Industrial marine fish farming. Pages 97-107 *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

34/ C.Wood, personal communication 2002.

35/ Davenport *et al*, in press.

36/ Sandnes, K., and A. Ervik. 1999. Industrial marine fish farming. Pages 97-107 *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

seals. Pauly *et al*. (1998) have identified a significant trend in aquaculture of "farming up the food chain" that they consider in combination with the global problem of "fishing down the food chain". However, this statement continues to attract debate (Tidwell et al 2001 reference on Naylor et al., 2001). Increasing intensification of aquaculture, especially in Asia, and its concentration on higher-value carnivorous species, is inexorably raising dependence on capture fisheries through increased feed production. The competitive nature imposed on marine fisheries by capture and culture fisheries merit further investigation.

65. Bivalve culture takes nutrients away from the marine food web, but only affects biodiversity adversely if the carbon and nitrogen removed from the water column becomes excessive to leave less for other herbivores and phytoplankton, thereby affecting the growth and reproduction of zooplankton and other herbivorous marine animals. 37/ Bivalves do take suspended seston (particulate matter suspended in water) and change it into denser particles that fall to the bottom. 38/ Permanent extensive bivalve culture may bring about changes in the coastal food web 39/ 40/ altering the europhication process.

66. The loss or alteration of habitat becomes a biodiversity effect when it changes living conditions for other species. Seed collection from habitats such as lagoon bottom habitats using destructive gear results in habitat destruction or/and alteration. Mariculture takes up space, often very large amounts of it, not only in bays and oceans but also on nearby foreshores. The sheer occupying of acres of water can affect migratory routes and feeding patterns of a wide variety of non-target species. Salmon farms, for example, are believed by some to interrupt the free movement of wild migrating salmon and feeding killer whales. 41/ Underwater exploders and other acoustic devices intended to deter predators may also increase the stress on non-target animals.

67. Converting tidal wetlands for shrimp ponds and building roads, dikes, and canals threatens benthic habitat diversity in the tropics, particularly in Latin America and Asia. 42/ Tidal marshes and mangroves that serve as nursery grounds for wild shrimp and fish populations are lost, and less mangrove and marsh grass detritus enters coastal food webs. 43/ The draining of ponds for harvest releases diseases, antibiotics, and nutrients into estuarine and coastal waters. Despite the possibly large-scale implications, the effects in the coastal zone remain poorly studied. 44/ Conversion of new habitats for brackish-water prawn farming

---

37/ Tang, Q., and J. Fang. Impacts of intensive mariculture on coastal ecosystem and environment in China and suggested sustainable management measures. Yellow Sea Fisheries Research Institute, Qingdao, 266071. http://www.aquachallenge.org/abstracts/tang.html

38/ Grant, J. 1999. Ecological constraints on the sustainability of bivalve aquaculture. *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

39/ Horsted, S. J., T. G. Nielsen, B. Riemann, J. Pock-Steen, and P. K. Bjornsen. 1988. Regulation of zooplankton by suspension-feeding bivalves and fish in estuarine enclosures. Mar. Ecol. Prog. Ser. 48:217-224.

40/ Tenore, K. R., L. F. Boyer, R. M. Cal, J. Corral, C. Garcia-Fernandez, N. Gonzalez, E. Gonzalea-Gurriaran, R. B. Hanson, J. Iglesias, M. Krom, E. Lopez-Jamar, J. McClain, M. M. Pamatmat, A. Prez, D. C. Rhodas, G. deSantiago, J. Tietjen, J. Westrich, and H. L. Windom. 1982. Coastal upwelling in the Rias Bajas, NW Spain: contrasting the benthic regimes of the Rias de Arosa and de Muros. J. Mar. Res. 40:701-772.

41/ Morton, A. B., and H. K. Symonds, 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. ICES Journal of Marine Science 59:71-80.

42/ Smith, C. 2000. Global Change and Biodiversity Linkages across the Sediment-Water Interface. Bioscience. Full article available at: www.bioscience.org

43/ Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsby, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. Effect of aquaculture on world fish supplies. Nature 405:1017-1024. *Cited in* Smith.

44/ Smith, C. 2000. Global Change and Biodiversity Linkages across the Sediment-Water Interface. Bioscience. Full article available at: www.bioscience.org by the transport of salt waters to inland ponds, as well as conversion of productive rice growing areas to prawn ponds, changes their associated biodiversity.

68. The best-known example of habitat alteration arising from mariculture is the effect of shrimp farming on mangrove ecosystems, which have very high species diversity both in the water and on land and contribute about one-third of yearly landings of wild fish in South East Asia. Abandoned shrimp ponds serve as a threat to contiguous coastal habitats and their biodiversity.

69. The local or more widespread effects on non-target species such as the by-catch of seed collection from the wild have not been well studied. In culture systems where there are no methods for artificial control of reproduction, or where such methods exist but are beyond the means of local farmers, manual collection of fry for growout can remove significant amounts of biomass and biodiversity. For example, collection of one tiger shrimp larvae involves the removal of 1400 other macrozooplankton individuals (Davenport *et al*, in press). Naylor *et al.* 45/ review the effects of fry collection on natural seedstock, noting that 85% of the larvae collected for milkfish farming in the Philippines, for example, are from species other than milkfish, and are discarded – a significant bycatch. Although hatchery reproduction techniques are available for some species, in poorer areas where hormonal or environmental manipulation of broodstock is impossible, wild fry are still resorted to.

70. In net-pen culture, crowded and stressful conditions frequently lead to outbreaks of infection. Sometimes the infections result from organisms naturally present in wild fish; in other cases, the disease organism is an exotic one. Salmon net-pen farming provides an example of the spread of exotic pathogens. 46/ In 1985, a virulent strain of the bacterium *Aeromonas salmonicida*, which causes the disease furunculosis, was believed to have been brought from Scotland to Norway, 47/ spreading to salmon farms and thence to wild salmon and killing large numbers of fish. 48/ Bivalve and shrimp farming can also cause disease transmission. Wild broodstock of Pacific white shrimp (*Penaeus vannamei*) infected with white spot disease (WSSV) have been moved to previously disease-free regions 49/ while Taura Syndrome, caused by the TSV virus, may have been spread through the shrimp cultures of Latin America by the transfer of diseased postlarvae and broodstock. 50/ The impact of this introduced virus on its recipient environment is still unknown. 51/ 52/ The Japanese oyster drill (*Ocenebra japonica*) and a predatory

45/ Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsby, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. Effect of aquaculture on world fish supplies. Nature 405:1017-1024. *Cited in* Smith.

46/ Kent, M. L. 1994. The impact of diseases of pen-reared salmonids on coastal marine environments. Pages 85-95 *In* A. Ervik, P. Kupka, P. Hansen, and V. Wennevik (eds.). Proceedings of the Canada-Norway workshop on environmental impacts of aquaculture. Bergen, Norway: Norwegian Institute of Marine Research. *Cited in* Ellis and Associates (1996). *Cited in* Goldburg.

47/ Munro, A. L. S. 1988. Advantages and disadvantages of transplantations. Pages 75-83 *In* E. Grimaldi, and H. Rosenthal (eds.). Efficiency in aquaculture production: disease control. Proceedings of the 3rd Annual International Conference on Aquafarming "AQUACOLTURA '86," Verona, Italy. Edizioni del Sole 24 Ore, Milan, 227 pp. *Cited in* Goldburg.

48/ Heggberget, T. G., B. O. Johnsen, K. Hindar, B. Jonsson, L. P Hansen, N. A. Hvidsten, and A. J. Jensen. 1993. Interactions between wild and cultured Atlantic salmon: a review of the Norwegian experience. Fisheries Research 18:123-146. *Cited in* Goldburg.

49/ Wang, Y. L. 1999. Utilization of Genetic resources in Aquaculture: A farmer's view for sustainable development. R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

50/ Lightner, D. V. 1999. The Penaeid shrimp viruses TSV, IHHNV, WSSV, and YHV: current status in the Americas, available diagnostic methods, and management strategies. Journal of Applied Aquaculture 9(2):27-52.

51/ Boyd and Clay, 1999. *cited in* Wang 1999.

flatworm (*Pseudosylochus ostreophagus*) were brought to American waters along with the Pacific oyster, now the mainstay of bivalve farming in North America. However, these parasites have contributed to the decline of native West Coast oyster stocks. 53/ The case of MSX in the USA, Bonamia in Europe provide further examples of poorly managed aquaculture practices. However, a considerable amount of guidelines and legislation relating to disease regulation and control have been developed, such as those of the ICES, NACA, FAO, EIFAC.

71. The genetic effects of mariculture are varied and highly significant for biodiversity. Unlike many of the other effects discussed so far, understanding genetic effects demands a high level of understanding of the genetic structure of both the farmed and wild populations, something we do not have for any species. The field of fish molecular genetics is just starting to expand rapidly as new analytical techniques become available. For now, predicting the genetic effects of mariculture will remain difficult, and many prognostications may turn out to be wrong. The genetic effects of cultured marine animals are either inadvertent (through escapes of cultured animals) or deliberate (enhancement or sea ranching).

72. Studies of hatchery populations suggest that such loss of genetic diversity is common (54/ 55/ for fish and 56/ 57/ for invertebrates). Such reduced interpopulation variation is not necessarily bad for cultured populations, but can have a long-term impact on species survival if the farmed stocks intermingle with wild neighbours. 58/ 59/ This situation occurs when the species being farmed is a local one, and might be called "inadvertent enhancement". It is best studied in salmon aquaculture. It is known that the use of a smaller number of individuals for breeding programmes would result in inbreeding, crossing of two or more locally adapted populations leads to outbreeding depression because a high level of local adaptation occurs in each population. Though this outbreeding depression usually does not affect fitness in the first generation of progeny, subsequent progeny generations are affected by a reduction in fitness, as has been demonstrated with Pacific salmon in one recent study (Davenport *et al*, in press). The escape of fertile hybrids of closely related species that is being presently being carried out in sturgeon breeding programmes could bring about genetic changes, the effects of which are yet unknown. Another undesirable effect on biodiversity at the genetic level could be the loss of co-adapted gene complexes through repeated inbreeding.

73. The production of sterile fish is often advanced as a mitigating technology. However, although sterile fish cannot establish wild populations or interbreed with wild fish, they can still compete with wild

---

52/ Flegel, T. 1998. Shrimp disease epizootics: significance of international pathogen transfer. Pages 51-52 *In* Regional programme for the development of technical guidelines on quarantine and health certification, and establishment of information systems, for the responsibility movement of live aquatic animals in Asia. TCP/RAS/6714. Field Doc. No. 1. FAO/NACA/OIE, Bangkok.

53/ Clugston, J. P. 1990. Exotic animals and plants in aquaculture. Reviews in Aquatic Sciences 2(3,4):481-489. *Cited in* Goldburg.

54/ Verspoor, E. 1988. Reduced genetic variability in first generation hatchery populations of Atlantic salmon (*Salmo salar*). Canadian Journal of Fish and Aquatic Science 45:686-690. *Cited in* Smith 1999.

55/ Koljonen, M. L. 1989. Electrophoretically detectable genetic variation in natural and hatchery stocks of Atlantic salmon in Finland. Hereditas 110:23-35. *Cited in* Smith 1999.

56/ Durand, P., K. T. Wada, and F. Blanc. 1993. Genetic variations in wild and hatchery stocks of the black pearl oyster *Pinctada margaritifera* from Japan. Aquaculture 110:27-40. *Cited in* Smith 1999.

57/ Benzie, J. A. H., and S. T. Williams. 1996. Limitations in the genetic variation of hatchery produced batches of giant clam *Tridacna gigas*. Aquaculture 139:225-241. *Cited in* Smith 1999.

58/ Ibid.

59/ Gharrett, A. J., and W. W. Smoker. 1993. A perspective in the adaptive importance of genetic infrastructure in salmon populations to ocean ranching in Alaska. Fis. Res. 18:45-58. *Cited in* Smith 1999.

fish for food, spread disease, and disturb wild nesting sites. Escaped or released fertile tetraploids may attempt to breed with wild fish and disrupt overall spawning success. Gene transfer (not yet used in commercial mariculture) may have ecological effects if the introduced DNA causes major change in the ecological role of the transgenic fish (by, for example, increasing its size or its ability to use new food sources). Transgenic fish given a gene to speed growth, for example, could out-compete wild fish for food or spawning sites, while fish engineered for cold-tolerance might intrude on the ranges of more northerly species. Unanticipated pleiotropic (multiple) effects may also appear.

74. Most animals farmed on land are highly domesticated, and without human protection they would likely fail to survive in the wild. Organisms used in aquaculture on the other hand are still relatively wild, and may easily survive and reproduce outside their natural ranges. 60/ Because much of the world's aquaculture relies on species outside their native range, escapes are a constant biodiversity concern. In the short term, escapes of hatchery species may swamp wild populations through sheer weight of numbers. Skaala 61/ stated that the number of Atlantic salmon (*Salmo salar*) escaping from fish farms in Norway exceeded the number of wild fish harvested in Norway. 62/ A comparison of wild and farmed Atlantic salmon showed that farmed fish had higher growth rates and were more aggressive than wild fish, thus posing a threat to native populations that were already depleted by environmental factors. 63/

75. Many alien marine species resulting from escaped cultured stocks have become firmly established far from their native ranges and are culturally accepted as "just more biodiversity". However, when self-sustaining populations of escapes become established, they could interact with native communities in a number of ways, including predation, competition and even elimination of native species. Japanese oyster and Manila clam, for example, are treasured by recreational fishermen on the Pacific coast of North America as well as in Europe. The risk is probably greater with escape of species occupying similar niches to local ones, because they are more likely to interact with native populations and affect their survival. The ability of natural populations to recover from introgression of farmed genes has been very little studied.

III. AVOIDING THE ADVERSE EFFECTS OF MARICULTURE ON MARINE AND COASTAL BIODIVERSITY

76. While mariculture has a variety of adverse effects on biodiversity, many of these effects can be mitigated or eliminated. In some cases, it is even possible to produce some positive biodiversity-related effects. It is important to mention that mariculture based on allochthonous feed (most finfish and crustaceans) could have larger and more significant adverse effects than mariculture based on authochtonous feed (filter feeders, macroalgae, deposit feeders). The areas offering the most promise for avoiding adverse biodiversity effects of mariculture include **reducing waste by better management, changes in nutrition** (reformulation of feeds, reduction in use of animal protein, improving utilization) and technological improvements such as **"enclosed systems".** In such enclosed tanks or ponds, it is possible

---

60/ Courtenay, W . R., Jr., and J. D. Williams. 1992. Dispersal of exotic species from aquaculture sources, with emphasis on freshwater fishes. Pages 49-81 *In* A. Rosenfield, and R. Mann (eds.). Dispersal of living organisms into aquatic ecosystems. College Park, MD: Maryland Sea Grant College, University of Maryland. *Cited in* Goldburg.

61/ Skaala, O. 1995. Possible genetic and ecological effects of escaped salmonids in aquaculture. Pages 77-86 *In* Environmental impacts of aquatic biotechnology. OECD, Paris. *Cited in* Penman 1999.

62/ Penman, D. J. 1999. Biotechnology and aquatic resources: genes and genetically modified organisms. Pages 23-33 *In* R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

63/ Einum, S. and I. A. Fleming. 1997. Genetic divergence and intyeractions in the wild among native, farmed and hybrid Atlantuc salmon. Journal of Fish Biology 50:634-651. *Cited in* Smith 1999.

to treat the effluent in order to avoid outflow of chemicals, antibiotics, diseases, as well as excess nutrients. Table 1 in annex II below describes problems, impacts, main mitigation tools, and the results of mitigation.

77. Better management practices for non-enclosed systems, include:

(a) Most importantly, proper site selection. The location of cages, pens rafts (etc) should ensure proper water circulation to satisfy both the needs of mariculture and the flushing of nutrients and wastes;

(b) Secondly, optimal management including proper feeding to decrease conversion ratios. Proper feeding requires proper training and a good knowledge of behaviour of organisms to be fed. Often workers feeding finfish or crustaceans have poor knowledge of what they do, and the basis of feeding practices. This is true in particular in developing countries. It should be noted that cheap labour often works against biodiversity simply because the lack of proper management knowledge and **training investment**.

78. Other mitigation measurements include **culturing different species together (polyculture)** to make better use of available resources (such as salmon and bivalve culturing or salmon and macroalgae) and coupling mariculture with other activities such as artisanal fisheries and sport fishing (Soto and Jara 1999, Soto and Jara in press). However, all such forms of mitigation are effective only if chemicals and antibiotics are avoided in intensive production.

79. **Enclosed,** and especially **re–circulating systems** require, for many forms of aquaculture, high technological development and capital investment, making the use of such technology impossible for many species and countries. However future development of mariculture should focus in this direction in order to minimize impacts of every kind. This is particularly true for the production of fin fish and crustaceans.

80. Other impacts such as dependence on wild seed; reducing the use of chemical additives and treatments that promote ecosystem changes; and reducing disease transmission between cultured and wild stocks can be avoided with better management practices and other technological improvements which will be discussed here in more detail. For all of the foregoing strategies, development of appropriate policies and legislation is an overarching necessity. Responsible mariculture (codes of conducts, licence permits), policies and regulation **should reinforce mitigation measurements.**

81. Mariculture could also be considered as having positive effects when, under certain circumstances, it provides seed for sea-ranching and recovery of wild stocks, endangered species, or even improves productivity and biodiversity.

A. Best-site selection and better management to reduce nutrient input effects

82. Proper site selection is usually the best tool for management and mitigation of nutrient inputs to the environment. In some cases such nutrient inputs could have positive effects on local productivity and biodiversity. The key issue is not to allow nutrients to be lost to bacterial degradation but to enter natural food webs or artificial food webs in the case of polycultures.

83. Mathematical modelling can help estimate the relative impacts of a mariculture operation. For such modelling however, basic information, such as estimates of other nutrient inputs to bodies of water, is

often hard to find. 64/ Cooperation with other sectors is needed. Types of mathematical models include mass balance models and hydrological models for siting, as well as the use of geographic information systems (GIS) tools. In addition, the application of integrated marine and coastal area management (IMCAM) can help optimize spatial distribution and help mitigate the effects of mariculture. Examples include models developed for the coast of Norway (Ervik et al 1997) and for most lakes with salmon farming in Chile (Soto, 2002).

84. The use of enclosed or recirculating systems is an option when no others are available and when monitoring programs show a negative environmental effect or an overloaded carrying capacity in relation to nutrients. Replacing net pens with bags suspended in seawater has been endorsed as an option, which also helps avoid the escape of exotic species; however, the initial capital outlay is higher. 65/ Nevertheless, closed systems offer much better control of feeding and better flesh quality due to increased exercise, and are slowly becoming established (www.futuresea.com). Since netpens externalize costs to the environment, future policy and regulations that impose environmental penalties on such systems may help the development of aquaculture systems that produce less waste. 66/

85. Waste can also be reduced by improved filtration and fallowing. Technological means of collecting suspended solids include biofilters that transform excreted nitrogen into nitrite, nitrate, and finally nitrogen gas. 67/ In Australia, a study of submerged flow biofilter systems built in modular form showed complete denitrification of fish farm waters could be achieved, with approximately 40 percent of the phosphorus removed as well. 68/ Shutting down mariculture sites for months or years can allow accumulated nutrients to break down or disperse. 69/

86. Large shellfish culture beds may lead to increased excess sedimentation accumulation. This is mainly due to the biodeposit production by shellfish, which are silting underneath rearing structures. Since bivalves feed on natural material carried out by the water column, there is no net addition of organic matter into the environment, although particle density changes. This organic matter accumulation may result in potential eutrophication with biodiversity losses on the bottom. By way of example, this accumulation maximizes the development of the seafloor benthic biota, such as bacteria and deposit feeding species. To address this issue, improved site selection represents an efficient mitigation process, considering the local carrying capacity and the bottom capacity to process organic matter. Hydrodynamics of the site should be appropriate in order to limit local siltation. Similarly, the rearing structures should facilitate hydrodynamics. By using these mitigation techniques, a reduced effect on local benthic biodiversity is expected, as well as recovery of pelagic communities and improvements in ecosystem processes (Heral, 1990; Lenihan, 1999; Rice et al., 2000).

64/ Pillay, T. V. R. 1992. Aquaculture and the environment. Cambridge, MA: Fishing News Books, 191 pp. *Cited in* Goldburg.

65/ British Columbia Environmental Assessment Office. The Salmon Aquaculture Review Final Report. ISBN 0-7726-3317-7 (set). http://www.eao.gov.bc.ca/project/aquacult/salmon/report/final/vol1/toc.htm

66/ Goldburg, R., and T. Triplett. 1997. Murky waters: environmental effects of aquaculture in the US. The Environmental Defense Fund. 197 pp. Available at: http://www.environmentaldefense.org/pdf.cfm?ContentID=490&FileName=AQUA.PDF

67/ Ackefors, H. 1999. Environmental impacts of different farming technologies. Pages 145-169 *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

68/ Abeysinghe, D. H., A. Shanableh, and B. Rigden. 1996. Biofilters for water reuse in aquaculture. Water Science and Technology 34(11):253–260. IWA Publishing . Abstract and link to full article available at: http://www.iwaponline.com/wst/03411/wst034110253.htm

69/ Pillay, T. V. R. 1992. Aquaculture and the environment. Cambridge, MA: Fishing News Books, 191 pp. *Cited in* Goldburg.

87. Extensive, large scale shellfish mariculture may lead to a high stocking biomass and filter feeding capacity, impacting other herbivores, and the primary production of the water column. Such overstocking process results in decreased planktonic biomass, and a qualitative and a quantitative shift in pelagic communities, and therefore food webs. Improving site selection and establishing thresholds for stocking biomass based upon a sufficient primary productivity to sustain filter feeding represents an efficient mitigation process. Similarly, selecting species or/and strains can reduce pressure on phytoplankton biomass production (Burnell et al., 2001; Goulletquer and Héral, 1997; Heral, 1990)

B. Reducing waste by better management

88. The degree of impact from effluent wastes is dependent on husbandry parameters, including species, culture method and feed type, as well as on the nature of the receiving environment in terms of physics, chemistry and biology. 70/ Waste from marine fish farms can contain high concentrations of organic and inorganic nutrients. It is clear that in the case of culture methods which involve the use of fishmeal-based feeds, there will be a transfer of nutrients into the receiving waters (as well as original nutrient ratios) that may have the potential to lead to increases in nutrient concentrations and ultimately to eutrophication. Euthrophication is defined as "an increase in rate of supply organic matter to an ecosystem" (Nixon, 1995). Whether euthrophication will occur as a consequence nutrient addition will depend on the state of the receiving environment which may vary spatially, over short time-scales or seasonally, depending on which factors limit primary production. 71/

Improving efficiency of feeding process

89. Minimizing the input of nutrients can be achieved by improving the efficiency of food conversion. This can be done through improving feed formulations, resulting in better palatability and uptake and by reduction in food wastage. Minimizing effects could also be achieved by using some efficient strains of fish, shellfish etc.

90. Reduction in the input of waste feed can be achieved through a variety of methods including: use of acoustic detectors in marine cages to reduce loss of feed pellets, use of sensors that detect when fish reduce feeding activity, linked to input controllers as well as through the use of systems for collection and recovery of waste feed.

91. When automated and controlled feeding systems are not available, raising the awareness of farm workers to the effects, both environmental and economic, of feed wastage and training in efficient hand feeding can contribute to a reduction in feed usage.

92. In the case of Atlantic salmon production, feed conversion ratios (FCRs) have been improving continuously in the past decades as feeds have increasingly become tailored to the dietary needs of cultured species and as feed wastage has been reduced due to economic, and to some extent, environmental pressures. Ennel (1995) reported that the mean FCR in the Nordic area in 1976 was 2.08 but had fallen to 1.25 inn 1994 and was further reduced to 1.25 in 1995. Similar reductions in FCRs have been reported from other salmon producing countries.

70/ Wu, 1995.

71/ Black, 2001.

Reduction of nitrogen and phosphorus in diets

93. Nitrogen is generally assumed to be the nutrient limiting phytoplankton growth in marine waters. Minimizing the direct input of nitrogenous wastes to the environment from finfish farms can thus minimize potential eutrophication effects. Hall et al, (1992) found that 67 – 80% of the nitrogen added to cage system is lost to the environment. The majority (50 – 60% of the total nitrogen) is lost in dissolved form, either directly from the fish or by benthic flux from solid waste beneath the cages. The level of nitrogen in feeds has decreased as feed formulation becomes closely aligned with the dietary requirements of the fish. In particular, modern diets tend to contain more lipid and less protein which has contributed to a general reduction of food conversion ratios and a reduction in inputs of nitrogenous waste.

94. In the last twenty years the feed conversion ratio for Norwegian salmon feeds has been cut by about half, resulting in 80% fewer solids being discharged from salmon farms. 72/ From 1974 to 1994, Ackefors and Enell 73/ 74/ report a drop in the feed coefficient (amount of feed/amount of fish) for fish raised in cages and pens in Nordic countries from 2.3 to less than 1.3. Simultaneously, the nitrogen content in the feed has fallen to 6.8% (from 7.8%) and the phosphorous content to less than 1% from 1.7%. These percentages translate into decreases in discharges of phosphorous and nitrogen from net cage farming of finfish, expressed in kilograms per tonne produced, from 31 kg to less than 9.5 kg for phosphorous and from 129 to 53 kg for nitrogen. 75/

95. Shrimp farming should consider the use of natural feed items in the pond, such as zooplankton and benthic organisms to supplement the formulated diets. This practice will reduce the allochthonous loading into the ponds (Shishechian et al. 1999). Pond management practices such as aeration, feeding rate and stocking rate should aim to enhance natural food in the ponds.

96. Formulated feed low in phosphorus and nitrogen should be used in shrimp culture to reduce the occurrence of eutrophication in pond water as well as in associated water bodies. However, the movement towards this end is very slow, perhaps because of the lack of environmental awareness among producers of shrimp feed.

Improved shrimp pond management

97. Shrimp farmers normally release enriched pond waters during water exchange and flushed organic matter from the pond bottom at the end of each harvest to the estuary causing serious eutrophication problems. A decrease the frequency of water exchange should alleviate problems of eutrophication in the estuary. In disease-prone or polluted areas, culture practices show a shift towards closed culture system where water from external sources is not required during the culture period (Kongkeo, 1995).

72/ Lopez Alvarado, J. 1997. Aquafeeds and the environment. Pages 275-289 *In* A. Tacon and B. Basurco (eds.). Feeding tomorrow's fish. Proceedings of the CIHEAM Network on Technology of Aquaculture in the Mediterranean, June 24-26, 1996. Cahiers, Options Mediterranees. Jointly organized by CIHEAM, IEO, and FAO. *Cited in* Goldburg.

73/ Ackefors, H., and M. Enell. 1990. Discharge of nutrients for Swedish fish farming to adjacent areas. AM-BIO 19(1):28-35. *Cited in* Ackefors 1999.

74/ Ackefors, H., and M. Enell. 1994. The release of nutrients and organic matter from aquaculture systems in Nordic countries. Journal of Applied Ichthyology 10(4):225-241. *Cited in* Ackefors 1999.

75/ Enell, M. 1995. Environmental impact of nutrients from Nordic fish farming. Water Science and Technology 31(10):61–71. Swedish Environmental Research Institute (IVL), P.O. Box 21060 S-100 31 Stockholm Sweden. IWA Publishing. Abstract available at http://www.iwaponline.com/wst/03110/wst031100061.htm

98. Use of probiotics, preferably local ones, should improve the water quality of the ponds resulting in a better food conversion ratio, higher shrimp production and cleaner effluents. 76/

99. Removal of sludge from shrimp pond bottom after every harvest and extraction of nutrients from the sediments should not only prevent eutrophication in the estuary, but also the recovery of nutrients for mass culture algae in shrimp hatchery. 77/ In addition, pond management should ensure that all pond effluents should be treated in a reservoir containing macro-algae, bivalves and fish to decrease the turbidity and reduce nitrogen and phosphorus before being released into the sea or recycled to the ponds. In other cases there could be efficient coupling of filter feeders and shrimp.

100. Despite the many adverse environmental impacts arising from shrimp farming, with proper technology and farming management, the industry can be made sustainable. Greater training and awareness should be given to all entrepreneurs, stakeholders and even the labourers involved in pond management.

C. Use of enclosed and re-circulating systems (both for finfish and shrimp culture)

101. Closed systems can contain domesticated species and keep them from mixing with wild populations, keeping most particulate nutrients from going to the environment and also reducing to a great extent the outputs of dissolved nutrients. 78/ Although such water-recycling facilities are expensive, they present greater opportunities for long-range planning at diminished risk for the culture itself and avoid excess nutrient export to natural coastal systems. Improvements in the design and engineering efficiencies of modern recycled-water plants allow for higher stocking densities, less disease, fewer breakdowns and lower operating costs as well as the reduction of eutrophication potential to coastal waters.

102. Most enclosed systems can incorporate mechanisms to reduce nutrient inputs to coastal zones. The simplest systems are settling tanks for particulate organic matter which can be cleaned periodically. Such systems are widely used for freshwater salmon smolt production where biofilters, aerated settling tanks, are commonly used. However most of these systems are not particularly efficient in removing dissolved nitrogen, which may cause eutrophication. More sophisticated re-circulating systems can recycle up to 80% of the water in the tanks.

D. Integrated mariculture (polyculture)

103. Polyculture has a long history in freshwater aquaculture (especially in China) and could be applied more in the marine environment. In marine polyculture, bivalves, seaweed, and marine finfish are produced together. By using such complementary species, the waste of one can be converted to protein by the others. In finfish production, for example, feed that is not consumed filters down to suspension-feeding bivalves, or mixes with fecal waste and is taken up by primary producers such as seaweed (harvested directly), or by phytoplankton, which is then consumed by bivalves.

104. Effluents rich in organic matter from shrimp culture can also be utilized by bivalves. Many species can filter out small particles and also utilize microalgae from the effluent. These can be commercially valuable species for harvest or non-valuable species for use as fish-meal. This form of culture shows much promise in increasing sustainability in many types of aquaculture since it maintains a

---

76/ Devarajah et al, 2002.

77/ Yusoff *et al* 2001.

78/ Ackefors 1999.

balance of nutrients in the environment 79/ and increases the efficiency of protein production. 80/ In Northern China, for example, kelp is cultured in the outer portions of Sungo Bay, using nitrogen excreted by the 2 billion scallops produced there yearly. The potential competition of kelp with phytoplankton that might reduce the food supply available to scallops has not, however, been investigated. 81/ In Chile, salmon are farmed in polyculture with the red alga *Gracilaria chilensis*, which removes dissolved nitrogen and phosphorus and can be sold. 82/

105. It should be noted, that mitigation of the effects of mariculture nutrient input on marine ecosystems requires knowledge of local and regional carrying capacity to receive nutrients as well as knowledge of food webs and ecosystem processes. Such studies are usually lacking from most environmental impact assessment and licensing of permits. There is also the need of articulate and couple mariculture with artisanal fisheries and sport fishing as a way of helping nutrients to cycle and produce additional positive effects or neutralize potential negative effects.

E. Production of larvae in aquaculture facilities rather than from the wild

106. In culture systems, where there are no methods for artificial control of reproduction, or where they are beyond the means of local farmers, manual collection of fry for growout can remove significant amounts of biomass. This should be correlated to the impact of fishing juveniles before any reproductive contribution. Although under-documented, intense collection of juveniles can lead to disruption of natural recruitment of local populations, therefore affecting species sustainability. Moreover, a shift in plankton biodiversity, food webs, and habitat destruction are expected. It should be emphasized that these impacts are highly dependant on the species reproductive strategy and ecosystem sensitivity. Harvesting wild seeds, followed by transfers might also lead to a loss of biodiversity through effects on genetic resources heterogeneity of native species. Although it may impact social activities, an efficient mitigation process is to produce larvae in aquaculture facilities so as to sustain aquaculture production. Implementation of such a plan can lead to recovery of affected biodiversity.

107. New technologies such as cryo-preservation could be considered as a mitigation process to limit pressure on wild populations and optimize brood stock management and seed supply at the hatchery level. Additionally, there is an critical need of genetic databases to assess genetic resources and forecast any change produced by cultured species.

F. Mitigating the effects of antibiotics

108. The overuse of antibiotics has caused a widespread concern about the emergence and selection of resistant bacteria. It is a generally accepted fact that antibiotic resistance is associated with the frequency of use in the environment. 83/

79/ See, for example, Wilkinson, S. B., W. Z. Zheng, J. R. Allen, N. J. Fielding, V. C. Wanstall, G. Russell, and S. J. Hawkins. 1996. Water quality improvements in Liverpool docks: the role of filter feeders in algal and nutrient dynamics. Marine Ecology 17:197-211. *Cited in* Grant 1999.

80/ Bodvin, T., M. Indergaard, E. Norgaard, A. Jansen, and A. Skaar. 1996. Clean technology in aquaculture – a production without waste products? Hydrobiologia 327:83-86. *Cited in* Grant 1999.

81/ Grant, J. 1999. Ecological constraints on the sustainability of bivalve aquaculture. *In* N. Svennevig, H. Reinertsen, and M. New (eds.). Sustainable aquaculture: food for the future? A. A. Balkema, Rotterdam. 348 pp.

82/ Troell, M., *et al.* 1997. Integrating marine cultivation of *Gracilaria chilensis* (Gracilariales, Rhodophyta) and salmon cages for reducing environmental impact and increased economic output. Aquaculture 156:45-61.

83/ Hamilton-Miller 1990 and others.

109. Training should be provided in the use and the harmful effects of antibiotics to ensure their proper administration. In many cases, the outbreak of disease is due to poor health management practices resulting in stress, and thus making the cultured animals more susceptible to diseases. Proactive monitoring and use of proper diagnostic tools are often best practices to avoid a disease outbreak.

110. Regulations to reduce the use of antibiotics must be drawn up and enforced. More attention should be paid to reduction of stress factors by improving health management practices. There has been a general move in some countries in the industry away from heavy use of man-made chemicals and toward lower stocking densities and the use of probiotics (to improve water quality).

111. This situation, combined with public resistance to antibiotic use in some countries, has led to intensive research on vaccines for infectious diseases of farmed marine animals. Vaccination can treat some infectious diseases highly effectively 84/, for example coldwater vibriosis, once a serious problem for salmon farms in Norway. 85/ Sandnes and Ervik (1999) indicated a dramatic reduction in the use of antibiotics after the discovery of the vaccine against furunculosis. The use of antibiotics was reduced from 585 gr./ton of produced salmon in 1987 to 8 gr./ton in 1995.

112. Vaccines can be administered orally or by injection or through immersion or spraying. 86/ Major diseases for which vaccines have been developed include furunculosis, coldwater vibriosis, vibriosis, yersiniosis, and edwardsiellosis. 87/ In Norway, mariculture of salmon increased after the reduction in the use of antibiotics in 2000.

113. Further research should be encouraged in this area, and should include the close involvement of farming companies. Often there will be the need for economic assistance with such technological development, especially for developing countries.

G. Mitigating the effects of pesticides, piscicides and parasiticides

114. Pesticides and piscicides are used to remove pest species from the surrounding environment. Residues are often highly toxic and may persist for weeks in the water and sediment often killing non-target organisms. Lower stocking densities, large enough distances among farms, prophylactic methods and general management procedures (which includes proper training) should greatly help prevent the use of chemicals to control external parasites. Alternatively, totally self-contained systems should be used. Further detail on the use of chemicals and antiobiotics, as well as on mitigation measures, can be found in GESAMP report No. 65 (GESAMP, 1997).

84/ Hastein, T. 1995. Disease problems, use of drugs, resistance problems and preventive measures in fish farming worldwide. Pages 183-194 *In* H. Reinertsen, and H. Haaland (eds.). Sustainable fish farming, Proceedings of the First International Symposium on Sustainable Fish Farming, August 28-31, 1994. Oslo, Norway. Rotterdam: A. A. Balkema. *Cited in* Goldburg.

85/ Norwegian Fish Farmers' Association. 1990. The Norwegian fish farming industry in harmony with the environment. Trondheim/ Tromso, Norway: Norwegian Fish Farmers' Association. *Cited in* OTA (1995). (*Cited in* Goldburg.)

86/ Avault, J. W. 1997. Prevention of diseases: some fundamentals reviewed. Aquaculture Magazine (March/April. 1997):78-83. *Cited in* Goldburg.

87/ Hastein, T. 1995. Disease problems, use of drugs, resistance problems and preventive measures in fish farming worldwide. Pages 183-194 *In* H. Reinertsen, and H. Haaland (eds.). Sustainable fish farming, Proceedings of the First International Symposium on Sustainable Fish Farming, August 28-31, 1994. Oslo, Norway. Rotterdam: A. A. Balkema. *Cited in* Goldburg.

H. Reducing the use of hormones

115. Alternatives for the use of hormones include

(a) Proper genetic-selection programmes, which could provide better offspring and enhance certain traits otherwise achieved by using hormones;

(b) Use of photoperiod management in industrial production of salmon. This is probably one of the most promising mitigation tools for the use of hormones in the field of salmon production. Similar techniques could be developed for other species;

(c) Cryo-preservation could be considered as a mitigation process to optimize broodstock management and seed supply at the hatchery level.

I. Preventing disease transmission

116. Prevention should be encouraged as a mitigation process for disease transmission since no cures exist to several diseases in cultured species. Improved monitoring programmes for known and emerging diseases should be encouraged, as well as the use of biomolecular tools for diagnostics.

117. Mitigation should include contingency measurements such as quarantine stations and complete self-containment of infected organisms to be treated or to be transported for elimination. Effluent of contained systems should be treated with ultraviolet or ozone procedures.

118. To avoid diseases, protocols for quarantine and movement of animals should be in place to minimize transmission of diseases. International codes of practice, agreements and technical guidelines used to minimize the risk of diseases associated with movement of aquatic animals should be adopted. Examples of such are the OIE International Aquatic Animal Health Code and Diagnostic Manual for Aquatic Animals Diseases and Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for Exploration of the Seas (ICES). In addition, there is a need for regionally-orientated guidelines such as the most recent (2000) FAO/Network of Aquaculture Centres in Asia-Pacific (NACA) Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy. Collaboration between regional and International agencies such as NACA, OIE, ICES and FAO should be further strengthened, and should include close collaboration on the issues related to transboundary movement of aquatic animals.

119. The use of indigenous species for culture should be encouraged. In addition, strengthening of aquatic animal health capacity, along with improved laboratory facilities, control protocols and therapeutic strategies should be put in place to minimize losses due to disease transmission.

120. In addition to the above, establishment and implementation of a harmonized regional certification system, establishment of regional reference laboratories for standardization and validation of diagnosis, and establishment of regional training programmes in aquatic animal health issues including trans-boundary movement, risk assessment and contingency plans, are vital for preventing disease transmission.

J. *Preventing escapes*

Exotic species

121. Although geographic constraints may be difficult to address, especially in developing countries, mariculture of endemic species should be encouraged. Risk analysis and/or environmental risk assessment can be carried out before any introduction so as to assess likely impacts, and quarantine procedures followed (ICES, 1995). Improved management practices can limit the spread of escapes, including site selection outside their reproductive range to avoid reproduction. Use of sterile individuals can also be recommended when the risk to interact with native population is limited. Other contingency measurements should be mandatory in case of accidental escapes. As an example, a large-scale escape took place in Chile during 1995-96, and local fishermen took care of a large proportion of the escaped salmon (Soto et al 2001), demonstrating that recovery of escapees is possible.

Native species

122. Farmed native species may cause a decrease in intra-specific genetic variability when released to the environment. Similarly, transferring seed within the geographical range of the species may affect genetic variability. Therefore, a proper broodstock-management plan is critical. An alternative mitigation approach is to limit the spread of the selected strains by supporting the production of sterile individuals.

IV. ENHANCING THE POSITIVE EFFECTS OF MARICULTURE ON MARINE AND COASTAL BIOLOGICAL DIVERSITY AND PRODUCTIVITY

123. Mariculture could help preserve biodiversity when, as a successful economic activity, it can provide a release to the predation pressure over commonly harvested aquatic species. Thus, it can provide a local relief, although globally and indirectly, aquaculture has been blamed for over-harvesting of aquatic resources to obtain fishmeal. 88/ However, mariculture is a more efficient fishmeal user than other forms of food production (Tidwell and Allan 2001).

124. Nutrient loads from mariculture can generate eutrophication and also cause biodiversity losses. However nutrient loads in oligotrophic to mesotrophic coastal zones could enhance productivity and increase biodiversity, although it can be argued that these are changes from natural conditions. One way to diminish the ecological footprint of salmon farming (Folke *et al.* 1997) is to prevent nutrients from been lost to bacterial degradation. This can be achieved by finding alternative pathways (to direct bacterial degradation) that will need native species and ecosystem processes. Coupling these processes to the mariculture activity is still a challenge. Some ecological hypotheses have proposed that increased nutrient inputs could provide extended food webs (Person 1994) and possibly increased biodiversity, at least within a certain range.

125. Best-site selection (including optimal flushing and dispersal of nutrients) could actually promote an increase of local and total productivity, specially in oligotrophic and mesotrophic systems, particularly when additional substrate heterogeneity, such as building of artificial reefs to soft bottom areas, is provided for. 89/ Angel *et al* (2002) showed a relevant improvement of environmental conditions around fin fish farms by using artificial reefs. Other possibilities include coupling with some forms of shellfish culture or natural shellfish beds. All these possibilities should be explored.

88/ Soto and Jara 1999.

89/ Jara and Cespedes 1994.

126. Additionally it should be mentioned that some forms of mariculture, such as shellfish and macro-algae production, could contribute to biodiversity enhancement by providing habitat structure and food. Such effect could enhance food web structure, fluxes, and interaction between mariculture and wild fish and invertebrates.

127. Although not directly connected to mariculture, overfishing and other activities affect biodiversity and produce depletion of wild stocks. Mariculture, under controlled reproductive activity, could be considered as a mitigation process for biodiversity recovery. However, this should be addressed through a genetically sound broodstock management plan in order to avoid reducing genetic variability.

V. MARICULTURE GUIDELINES RELATED TO BIODIVERSITY

A. Principles and standards

128. Although no set of internationally agreed criteria has yet been developed specifically for the environmental regulation of aquaculture operations, many national and regional regulations and laws, largely based on scientifically accepted environmental criteria, have been adopted. However, the ICES recently prepared draft guidelines for the preparation of environmental impact assessment documents related to shellfish mariculture 90/ and the European Union funded the MARAQUA project, which also presented scientific principles underlying the monitoring of the environmental impacts of aquaculture. A variety of principles and standards are voluntarily being applied to the industry in an attempt to decrease its environmental impact and improve its public image. In addition, in its decision VI/7 A, the Conference of the Parties to the Convention on Biological Diversity adopted guidelines for incorporating biodiversity-related issues into environmental impact assessments.

129. Article 9 of the FAO Code of Conduct for Responsible Fisheries provides a set of voluntary principles and standards that, if applied, ensure that potential social and environmental problems associated with aquaculture development are duly addressed and that aquaculture develops in a sustainable manner. However, providing an enabling environment for sustainable development in mariculture is not only the responsibility of governments and aquaculture producers, but also the responsibility of scientists, media, financial institutions and special interest groups. Additional principles and standards include the ICES Code of Conduct, and NACA Code.

B. Certification

130. Aquaculture operations can be certified as: (i) producing cultured species to guidelines or codes of practice, (ii) producing cultured species to reputable and recognized standards, or (iii) through operational audits and assessments as producing species to defined criteria. The following section discusses these three methods of certification:

(a) Aquaculture operations are officially certified as producing cultured species to guidelines or codes of practice, sometimes followed by Eco-labeling of the product. For example, Global Aquaculture Alliance (GAA) is an international, non-profit trade association, which promotes environmentally responsible aquaculture through an eco-labeling programme called the "Responsible Aquaculture Program", which includes codes of conduct for responsible aquaculture and certification production standards. There are other schemes putting more emphasis on third-party certification. As an example, the GAA Codes of Practice for Responsible Shrimp Farming include sections on mangroves; site evaluation; design and construction; feeds and feed use, shrimp health management; therapeutic agents

90/ See http://www.ices.dk/reports/MCC/2002/WGEIM02.pdf.

and other chemicals; general pond operations; effluents and solid wastes; and community and employee relations;

(b) Aquaculture operations may be certified as producing cultured species to reputable and recognized organic standards. For example, the International Federation of Organic Agriculture Movements Basic Standards (IFOAM) provide organic production standards for agriculture and aquaculture that are used by certifying bodies and standard-setting organizations worldwide as a framework for development of certification criteria. IFOAM includes criteria for rearing of fish and servicing of cages; water quality; feeding; health; fish re-stocking, breeding and origin; propagation of fish stocks and breeding; and transport, killing and processing. Some organizations that are using IFOAM standards are The Naturland Standards for the Production of Salmon and Other Cold Water Fish (primarily in use in Germany and Ireland for trout and salmon farming), KRAV Kontroll AB Organic Standards 1999 (certifies salmon, trout, Arctic char and Brown trout farming in Sweden), National Association for Sustainable Agriculture Australia (used in Australia, PNG, Sri Lanka and Indonesia), BioGro New Zealand Production Standards and AgroEco (based in Holland, organic shrimp farming in Ecuador);

(c) Aquaculture operations may be certified, through operational audits and assessments, as producing cultured species to defined criteria. Certification is followed by eco-labelling of the product and often requires the implementation of a documented Environmental Management System (EMS). The International Organization for Standardization (ISO) has developed sets of generic management system standards, which provide general standards and criteria for the development of an EMS. The ISO 14001 Environmental Management System has been used by various organizations as a basis for environmental certification. On such organization is the European Eco-Management and Audit Scheme (EMAS). 91/ EMAS is a management tool for companies and other organizations to evaluate, report and improve their environmental performance. Participation is voluntary and extends to public or private organizations operating in the European Union and the European Economic Area. An increasing number of candidate countries are also implementing the scheme in preparation for their accession to the EU. Some companies, local authorities and other organizations outside the European Economic Area are already putting EMAS into practice informally and benefiting from continuous improved environmental performance.

139. Appropriate monitoring programmes are essential for achieving and maintaining an environmentally friendly mariculture industry. GESAMP (1996) has produced a a working definition for monitoring in relation to aquaculture as " the regular collection, normally under regulatory mandate, of biological, chemical or physical data from predefined locations such that ecological changes attributable to aquaculture wastes can be quantified and evaluated. GESAMP (1996) also emphasise that in order to have efficient regulatory tools, monitoring programmes must be integrated with simulation models that can be predict the impact of a given operation and respond with remedial action if the threshold levels for environmentally acceptable impact are breached. However, there is no definition of what such environmentally acceptable impact means, and what indeed are safe limits for impacts.

131. Monitoring and regulating the production process and the extent of the operation is also a prerequisite to integrating mariculture into coastal zone planning. It is only when adequate data are available that environmental, including biodiversity, and mariculture needs can be securely formulated. It therefore follows that integration will be successful when all participants (users of the coastal resource) are able to identify their environmental needs and impacts while demonstrating a high level of credibility in their assessments. To increase public confidence, it is recommended that the results of ongoing monitoring programmes are accessible to the public.

91/ European Eco-Management and Audit Scheme. http://europa.eu.int/comm/environment/emas/index_en.htm

132. Setting threshold levels for environmental impacts or environmental quality standards (EQS) requires a close cooperation between authorities who can determine what impact is acceptable, and scientists who understand what this means in measurable parameters. In many countries, the task is determined by environmental quality objectives (EQO) from which EQS values are derived. An EQO/EQS system is appropriate since it will contribute to transparent regulatory systems that are based on political decisions and public acceptance. This approach opens the possibility of defining zones with different allowable impacts and accordingly, different EQS values. 92/

133. Monitoring programmes must concentrate on the main impacts of mariculture. I has been suggested that following criteria should be used to select the impacts on which to place the main emphasis:

(a) The sum of the impacts must have relevance for both the environment and the mariculture operation;

(b) The impact must be convenient for monitoring, for example, routine analytical methods must be available and the signals must be distinguishable for background levels;

(c) Scientific information must be available to set adequate EQS;

(d) The monitoring must be cost efficient, as many mariculture operations are small enterprises.

C. Aquaculture laws and regulations

134. Due to growing global concerns over the environmental impact of aquaculture and its effects on biodiversity, many countries have enacted laws that specifically regulate the aquaculture industry. Unfortunately, many countries still depend on more general environmental protection laws or local environmental plans that are sometimes hard to enforce in relation to aquaculture operations or are vulnerable to political or legal manipulation. Many countries require environmental impact assessments (EIAs) to be carried out for proposed aquaculture projects, leaving established operations unregulated.

135. Some examples of aquaculture-related laws and regulations include:

(a) To date most EU Member States have determined that only finfish aquaculture projects should be subject to EIA and few shellfish projects, regardless of scale, have been subject to EIA. The MARAQUA project recommended, however, the adoption of the EIA process for all aquaculture operations;

(b) There are significant cost implications in carrying out a full EIA for new developments, particularly for smaller operators that dominate the industry in many countries. Such a situation may be resolved somewhat by implementing a “scaled down” version of an EIA for proposed developments. As an alternative to a full EIA Fernandes et al (2001) recommended that in some instances environmental studies of a more limited nature could be carried out and the results provided to the regulatory authorities in the form of an “Environmental Report” when making an application for a fishfarming permit.

(c) ICES (2002) concluded that there is a need for the refinement of criteria to determine if an EIS is required for shellfish operation and recommended that further work should be carried out to determine appropriate threshold criteria to determine which type of shellfish projects should be subject to: i) an EIA, ii) and environmental report or iii) no environmental assessment;

92/ Henderson and Davies, 2000.

(d) In Malaysia, an EIA is required for "land based aquaculture projects accompanied by clearing of mangrove swamp forests covering an area of 50 hectares or more," pursuant to the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987 of the Environmental Quality Act 1974. However, the EIA law in relation to aquaculture projects is weak. There is a voluntary "Code of Practice for Aquaculture" (6th Sept 1999); 93/

(e) New South Wales regulates aquaculture pursuant to Part 6 of the Fisheries Management Act, the Fisheries Management Aquaculture Regulations 1995 and by the Environmental Planning and Assessment Act. These laws designate aquaculture as a "designated development," which requires an EIA, 94/

(f) In 1996 the Supreme Court of India ordered the closure and rehabilitation of several non-traditional large-scale aquaculture industries that have caused harm to India's coastal areas. Traditional approaches and improved traditional methods of aquaculture was allowed to continue. The Supreme Court based its order on the reasoning that aquaculture is an industry and is hence prohibited under the Coastal Regulation Zone (CRZ) notification (which prohibits new industries or expansion within the CRZ area); 95/

(g) In Chile, an EIA could be required for any project proposed in coastal areas pursuant to the Environmental Framework Law (No. 19.300); 96/

(h) Sri Lanka's National Environmental Act (NEA) requires an EIA for any fisheries project larger than 4 hectares and prohibits any person from discharging, depositing or emitting waste into the environment that will cause pollution without a license issued by the authority or in accordance with standards prescribed under the act. This involves the issuing of license by the Central Environmental Authority (CEA). In addition, the Fisheries & Aquaculture Resources Act No. 2 of 1996, includes rules for the management, regulation, conservation and development of fisheries and aquatic resources in Sri Lanka. 97/

136. In recent years, the increasing global concern for the destruction of mangrove habitat by aquaculture operations, most commonly shrimp farming in brackish-water ponds, has led to more stringent regulations. In 2000, only Belize and Ecuador had laws in place that specifically prohibit the destruction of mangroves resulting from aquaculture projects, while other countries, such as Costa Rica, Malaysia, India, Thailand and China, depend on EIAs or moratoriums on development projects in mangroves, and general environmental regulations.

137. Other legislation is in place that should be considered when assessing proposals for mariculture projects. In the European Union, the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC) are important in this regard.

93/ The Environmental Law Alliance Worldwide (E-LAW). 2000. Survey of laws on aquaculture. Available on the Industrial Shrimp Action Network website at http://www.shrimpaction.com/ESurvey.html

94/ Ibid.

95/ Bonora, M. 1999. Shrimp Aquaculture in India. The Shrimp Sentinel Online, National Reports. http://www.earthsummitwatch.org/shrimp/index.html

96/ The Environmental Law Alliance Worldwide (E-LAW). 2000. Survey of laws on aquaculture. Available on the Industrial Shrimp Action Network website at http://www.shrimpaction.com/ESurvey.html

97/ The Environmental Law Alliance Worldwide (E-LAW). 2000. Survey of laws on aquaculture. Available on the Industrial Shrimp Action Network website at http://www.shrimpaction.com/ESurvey.html

D. Specific criteria on the effects of mariculture on biodiversity

138. Although the Group was unable to discover any established sets or reviews of mariculture criteria, some examples of specific criteria that have been adopted as indicators of environmentally sound or sustainable aquaculture can be cited.

139. For example, the Government of Japan has enacted regulations to ensure sustainable aquaculture, with regard to improvement and preservation of aquaculture grounds and the spread of disease. In the case of surface aquaculture, it was determined that oxygen levels in cages should be more than 4.0 ml/L of sea water, the quantity of sulfide in the mud under cages should be less than the oxygen available to reset with sulfide, and benthos, such as lugworms, should be present in the mud under the cages. 98/

140. Norway has established quality criteria for fish oil used in fish feed by commercial fish farmers. The feed must contain 5% free fatty acids, have a total oxidation value of 30 and contain only 0.5% water and impurities. 99/ This is significant because increasing the fat content in feeds helps reduce wastage by supplying a ready energy source and reducing the nitrogenous waste producing breakdown of protein for energy.

98/ The International Organization for Standardization. http://www.iso.ch/iso/en/ISOOnline.frontpage

99/ Albrektsen, S., Ø. Høstmark, and K. Hamre. 2001. Fish silage - effects on fish oil quality and on growth performance and quality of Atlantic salmon (Salmo salar L.). Cultivation of Salmon II Conference, 7-10 May, 2001. Bergen, Norway, Abstract available as pdf file at: http://www5.imr.no:8080/salmon/innhold.htm

Annex I

COMPOSITION OF THE AD HOC TECHNICAL EXPERT GROUP ON MARICULTURE

Technical experts:

Mr. A.K. Armah, Ghana
Ms. Daisy C. Arroyo Mora, Costa Rica
Mr. Stefano Cataudella, Italy
Mr. S.U.K Ekaratne, Sri Lanka
Ms. Vlasta Franicevic, Croatia
Mr. Phillippe Goulletquer, France
Mr. Manal Nader, Lebanon
Mr. Fabian Pina Amargos, Cuba
Ms. Shyama Rathacharen, Mauritius
Mr. Arturas Razinkovas, Lithuania
Mr. Tetsuo Seki, Japan
Mr. Mohamed Shariff, Malaysia
Ms. Doris Soto, Chile
Mr. Uwe Waller, Germany
Ms. Stella Williams, Nigeria
Mr. Serguei Zagranitchnyi, Russia

Observers:

Mr. Devin Bartley, FAO
Mr. Uwe Barg, FAO
Mr. Alessandro Lovatelli, FAO
Mr. Terry McMahon, OSPAR Commission
Ms. Fatimah Md.Yusoff, Universiti Putra Malaysia

Annex II

DESCRIPTION OF IMPACTS, EFFECTS, MITIGATION TOOLS AND RESULTS

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
1) Excess nutrient addition by fin fish and shrimp mariculture (or other carnivore organisms) to water column and sediments	Potential eutrophication with biodiversity losses	a) Best site selection (including optimal flushing and dispersal of nutrients	a.1. Offer of alternative fisheries resources.	a.1.Decreased of local nutrient inputs, lesser effects even positive effects on local biodiversity and ecosystem processes by releasing harvesting pressure over wild stocks at local scale
			a.2.Integrated aquaculture. Culturing different species together (eg. Salmon w/ mussels, or salmon w/ macroalgae)	Increased habitat structure, more efficient use of nutrients, increased nutrient fluxes, lesser effects or positive effects on biodiversity
			a.3. Coupling w/artificial reefs, sport fishing, local fisheries	Increased habitat structure, more efficient use of nutrients, increased nutrient fluxes, lesser effects or positive effects on biodiversity

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
		Better management, decrease conversion ratios (improved specialized training and education) b.1-fin-fish b.2. shrimp		Decreased nutrient inputs to environment, lesser effects or even positive effects on biodiversity and ecosystem processes
		Changes in nutrition, low P, N diets		Decreased nutrient inputs to environment, lesser effects on biodiversity and ecosystem processes
		Reducing stocking density		
		Use of enclosed, or re-circulating systems (both for finfish and shrimp culture)		Decreased nutrient inputs to environment, lesser effects on biodiversity and ecosystem processes
2) nutrients in outflow from enclosed systems, tank or pond mariculture (finfish/shrimp)		Removal of sludge from fish/shrimp pond waters and treatment of effluents, use of biofilters and external settling tanks		Decreased nutrient inputs to environment, lesser effects on biodiversity and ecosystem processes

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
			Integrated shrimp pond culture in self contained re –circulating systems. Coupling with seaweed, and fish production (policultures)	Decreased of nutrient discharges, lesser effects on local biodiversity and ecosystem processes
			Alternating shrimp and fish culture	Decreased of nutrient discharges, lesser effects on local biodiversity and ecosystem processes
3) Excess sediment accumulation by shellfish mariculture	Potential eutrophication with biodiversity losses on the bottom	Best site selection (according to carrying capacity to receive and process organic mater on sediments, eg. Local currents)		Decreased of local organic matter inputs to sediments, lesser effects on benthic biodiversity and ecosystem processes Additionally there are positive effect on water quality
4) Decreased planktonic biomass by shellfish overstocking	Shifting in planktonic populations, productivity and food webs	Best site selection Reducing rearing density (improving training and education)		Recovering biodiversity and original food webs and processes

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
5) Habitat destruction by shrimp farming in coastal areas and mangroves	a) Decrease in habitat heterogeneity (nursery grounds) and biodiversity in general	Site selection outside mangrove zone		Maintaining biodiversity
		Mangrove recovery and restoration		Recovering biodiversity
6) Mangrove disruption for oyster seed and adult collection	a) Decrease in habitat heterogeneity (nursery grounds) and biodiversity in general	Aquaculture of oysters		Recovering mangrove and associated biodiversity
7) Use of wild seeds (shrimp, some bivalves, some fish)	Depletion of larvae in the wild, depletion of plankton biodiversity, habitat destruction.	Producing larvae in aquaculture facilities (reproduction control)		Recovering, maintaining biodiversity
8) Use of antibiotics in open systems	a) Increased bacterial resistance, with decreased natural bacte rial biodiversity (losing some natural processes), decrease biodiversity due to increase disease exposure	Prevention of diseases = Improved health management practices (Training and education improvement)		Recovery maintenance of biodiversity and ecosyste mic processes

Problem	Impact	Main mitigation tool, enhancement of beneficial effect	Associated mitigation tool	Results of mitigation
		Pro active monitoring and use of proper diagnostic tools		Avoidance of biodiversity damage
		Improved administration methods for medication, eg. totally enclosed system for treatment		Avoidance of biodiversity damage
		Introduction of pro biotics		(neutral effects on biodiversity?)
		Development of vaccines (research and training)		Avoidance of biodiversity damage
9) Use of pesticides, piscicides, fungicides, other chemicals in open systems	a) Decrease of biodiversity	Better management practices (training and education)		Avoidance or diminishing biodiversity damage
		Totally self contained systems for treatment		Avoiding damage on biodiversity
10) Use of antifouling paints in fin-fish pens	a) Imposex on molluscs, and other unforeseen effects on biodiversity	Better management practices (training and education)		Avoidance or diminishing biodiversity damage

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
		Best site selection, high flushing rates		Avoiding damage on biodiversity
		Increase frequency of net changes		Avoiding damage on biodiversity
		Alternative paints/ netting/ or other safe antifouling approach		Avoiding damage on biodiversity
11) Use of hormones (growth etc.)	a) Unforeseen effects on biodiversity	Better genetic selection, improvement of management practices		Avoiding damage on biodiversity
12) Diseases transmission	a) Losses of biodiversity due to diseases	Better management practices (training and education)		Avoiding damage on biodiversity
		Pro active monitoring and use of proper diagnostic tools		Avoiding damage on biodiversity
		Enclosed systems or recirculating systems	UV or other treatment of outflow	Avoiding damage on biodiversity

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
13) Escapes (exotic species)	a) Biodiversity losses through competition, predation, habitat destruction, disease transmission	Better management practices (training and education)		Avoiding or diminishing damage on biodiversity
		Discouraging exotic species mariculture	Encouraging native species mariculture	Avoiding or diminishing damage on biodiversity
		Risk assessment previous introduction		Avoiding or diminishing damage on biodiversity
		Encouraging collection of escapees by fisherman or others (eradication programs)		Avoiding or diminishing damage on biodiversity
		Encourage sterility		Avoiding or diminishing damage on biodiversity
		Site selection outside environmental conditions for reproductive success		Avoiding or diminishing damage on biodiversity
14) Escapes (local species)	a) Decrease genetic biodiversity	Proper genetic brood stock management		Avoiding or diminishing genetic variability and biodiversity losses

Problem	**Impact**	**Main mitigation tool, enhancement of beneficial effect**	**Associated mitigation tool**	**Results of mitigation**
		Encourage sterility (?)		
15) GMO mariculture	Biodiversity losses through competition, predation, habitat destruction, disease transmission	Previous comprehensive scientific evaluation	Contained or re-circulating system	Avoiding or diminishing genetic and biodiversity losses
16) Over fishing and depletion of wild stocks.	Biodiversity losses	Mariculture for sea ranching		Recovery of biodiversity (but be careful with genetic variability reduction)
		Shellfish mariculture providing habitat structure and food		Positive enhancement of local biodiversity, by enhancing food web fluxes and interaction between mariculture and wild fish and invertebrates
		Algae culture could provide more refuge and habitat structure		Increased biodiversity

Annex III

RECOMMENDATIONS OF THE AD HOC TECHNICAL EXPERT GROUP ON MARICULTURE*

The Expert Group thanks FAO for its technical support and for the provision of meeting facilities and welcomes the efforts of the FAO in implementing the Code of Conduct on Responsible Fisheries.

1. General recommendations

The Expert Group:

(a) Recommends that Convention on Biological Diversity should adopt the Article 9 of the 'Aquaculture Development' of CCRF (FAO, 1995) and other provisions of the CCRF for dealing with mariculture because it has the necessary ingredients to develop legislation and policy framework at national, regional and international levels;

(b) Notes that the FAO glossary of terms is skewed towards marine capture fisheries, and recommends that this glossary be expanded in regards to its terminology related to aquaculture;

(c) Recommends that the Convention on Biological Diversity, FAO and other relevant organizations harmonize the use of terms in regards to mariculture by further developing and adopting the FAO glossary;

(d) Recommends that the Convention on Biological Diversity collaborate with the FAO, and other relevant organizations to develop programmes to assess the consequences of mariculture for biodiversity;

(e) Recommends the promotion of technical exchange and training programmes, and transfer of tools and technology;

(f) Recommends the facilitation of the provision of funding for country-level, regional, and international activities relating to the priority needs identified by the Expert Group;

(g) Recommends that the Convention on Biological Diversity undertake a comprehensive review of all relevant documents on good practices in management relevant to mariculture;

(h) Recommends that the Convention on Biological Diversity in collaboration with relevant bodies review and evaluate means where mariculture can be used to help restore or maintain biodiversity;

(i) Recommends promotion of good management and good legal and institutional arrangements for sustainable mariculture.

---

* These draft recommendations form the basis of the suggested recommendations to SBSTTA contained in the note by the Executive Secretary on dry and sub-humid lands biodiversity prepared for the eighth meeting of the Subsidiary Body (UNEP/CBD/SBSTTA/8/10).

2. Mitigating adverse effects of mariculture on marine and coastal biodiversity

The Expert Group recognizes the complexity of mariculture activities, the highly variable circumstances of different geographical areas, mariculture practices and cultured species, social, cultural and economic conditions. Although this diversity will influence mitigation options, the Group recommends the use of following methods and techniques for the mitigation of adverse biodiversity-related effects of mariculture:

(a) Environmental impact assessments (EIAs) or similar assessment and monitoring procedures should be made mandatory for mariculture developments with due consideration of scale and nature of the operation, as well as the carrying capacities of the ecosystem on the ecosystem level. Immediate, intermediate and long-term likely impacts on all levels of biodiversity must be addressed;

(b) Criteria should be developed for when EIAs would be required;

(c) Criteria should also be developed for application of EIAs on all levels of biodiversity (genes, species, ecosystems);

(d) Support the implementation of appropriate environmental impact assessment and monitoring programmes for mariculture;

(e) Global assessment should also be reinforced;

(f) Regional and international collaboration should be supported to address transboundary biodiversity impacts of mariculture, such as spread of disease and alien species;

(g) Development of appropriate genetic resource management plans at the hatchery level and in the breeding areas, addressed to biodiversity conservation;

(h) Development of effective site selection and effluent control methods for mariculture;

(i) Controlled low cost hatchery and genetically sound reproduction and making it available for widespread use to minimize/avoid seed collection from nature;

(j) In cases where seed is collected from nature, selective fishing gear should be used to avoid/minimize by-catch;

(k) Effective measures to prevent the inadvertent release of aquaculture species and fertile polyploids, through methods such as confinement;

(l) Use of local species in aquaculture;

(m) Avoiding the use of antibiotics through better husbandry techniques.

3. Future needs

The Expert Group recognizes that at the present time, there is insufficient information available about the effects of mariculture on biodiversity and its mitigation. Therefore, additional efforts should be developed along three topics: research, monitoring programs, policies and legislation.

(a) Research

1. General research needs:

(a) Development of research programs to support establishing efficient monitoring programmes

(b) Development of criteria for judging seriousness of biodiversity effects

(c) Improvement and transfer of integrated mariculture systems, including polyculture

(d) Monitoring programmes to detect biodiversity effects

(e) Research in the impact of escapees on biodiversity

2. Research related to impacts of mariculture on genetic diversity:

(a) Development of a genetic resource management plans for broodstock

(b) Understanding genetic effects of biotechnology developments in aquaculture

(c) Understanding genetic structure of both the farmed and wild populations, including:

(i) Effects of genetic pollution from farmed populations on wild populations

(ii) Maintenance of genetic viability of farmed populations

(iii) Studies of the genetics of wild populations as potential new candidates for mariculture

3. Research related to impacts of mariculture on species diversity:

(a) Support for basic global-scale taxonomic studies, perhaps in conjunction with the Global Taxonomy Initiative (GTI)

(b) Support for studies aimed at development of responsible aquaculture using native species

(c) Limiting by-catch of seed collection

4. Research related to impacts of mariculture and ecosystem diversity:

(a) Carrying capacity and carrying-capacity models for planning aquaculture, specially stocking rates

(b) Comprehensive studies should be carried out to quantitatively and qualitatively assess effects of mariculture on biodiversity for various aquatic ecosystems, selected by their sensitiveness degree.

(c) The competitive nature imposed on marine fisheries by capture and culture fisheries

(d) Improved understanding of the effects of inputs, such as chemicals, hormones, antibiotics and feeds on biodiversity

(e) Research on impact of diseases in cultured and wild species on biodiversity

5. Research related to impacts of mariculture, socio-economics, culture, policy and legislation:

(a) Comparative studies at legislation, economic and financial mechanisms of regulations for mariculture activity

(b) Development of quantitative and qualitative criteria to assess mariculture impacts on the environment according to culture practices

(b) Monitoring programmes

(a) Support mariculture-related disease monitoring programs at the global level

(b) Support the transfer of biotechnological diagnostic tools for wide use

(c) Update of taxonomic database including genetic diversity at the intra-specific level

Annex IV

CASE-STUDIES

A. Case-study—enhancement and sea-ranching

1. The idea makes perfect sense: use the tools of mariculture to create huge numbers of young animals that can be released into the wild at an early age, there to feed, grow and add to the fishery. If the fishery is gone they can even replace it, and the tools are so powerful that fry can be produced and released in staggering numbers. Why not?

2. Enhancement started before the turn of the century, with the rise of the salmon hatchery system in Western North America 100/, and as methods for controlled reproduction and larviculture were developed for more fish, and then for mollusks and crustaceans, those organisms began to be enhanced too. Stock enhancement and sea ranching are now done for a wide variety of species in over 70 (generally developed) countries. Enhanced species include Japanese flounder, Atlantic cod, penaeid prawns, European lobster, scallop, giant clam, abalone and sea cucumber. 101/ 102/ 103/ In Texas, red drum enhancement has been successful through a programme that includes large-scale stocking and management controls on commercial and sport catches, and habitat protection measures. 104/ Each year, North American hatcheries release more than 5 billion juvenile salmon 105/, and school programmes geared to classroom hatcheries have convinced several generations of children in the Pacific Northwest that salmon are produced in hatcheries. The Japanese programme for chum salmon is also well known, and maintains a consistent fishery targeted largely on roe (*ikura*) that has grown from 5 million tonnes in the 1960s to over 70 million in 1995. 106/ In fact, most stocks of Pacific salmon in Japan derive from hatcheries, and enhanced chum salmon are a key component of the Japanese coastal fishing industry.

Are there any wild fish left?

3. When large numbers of hatchery-bred fish are released to the wild there are significant genetic considerations, especially as the fish are fully expected to breed with "wild" stocks. Such questions did not even appear on the radar screens of fisheries managers until the past two decades; now, fisheries scientists grapple with them daily in an attempt to establish a role for enhancement that does not do outright damage to biodiversity. The recent *Wild Salmon Policy* of the Government of Canada, for example, has great difficulty even defining a "wild" salmon – after so many decades of wholesale enhancement the introgression of hatchery genes is assumed to require that a new category, "feral", be invented. Pacific salmon have endured a combination of insults (overfishing, habitat loss, pollution and

---

100/ Taylor, J. A. 1999. Making salmon: an environmental history of the Northwest fisheries crisis. University of Washington Press.

101/ Howell, B. R., E. Moksness, and T. Svasand (eds.). 1999. Stock Enhancement and Sea Ranching. Blackwell Science Ltd. Osney Mead, Oxford, UK.

102/ Cowx, I. G. (ed.). 1998. Stocking and introduction of fish. Papers form a symposium held March, 1996. Hull, UK. Okford: Fishing News Books. 456 pp.

103/ Bartley, D. M. Marine ranching summary. World Aquaculture Societies Working Group on Stock Enhancement and Sea Ranching Homepage. Available at: http://www.efan.no/was/WAS_ranch.html

104/ McEachron, L. W., and K. Daniels. 1995. Red drum in Texas: a success story in partnership and commitment. Fisheries 20:6-8. *Cited in* Smith 1999.

105/ Levin, P. S., and M. H. Schiewe. 2001. Preserving salmon biodiversity. American Scientist 89:220-227.

106/ Ohnishi, K. Trends in salmon enhancement program in Japan. The Japanese Association of Salmonid Science. http://www.affrc.go.jp:8001/salmonid/sum1/summary.2e.html change in ocean conditions) that have collectively severely reduced genetic diversity in the five main species. 107/

4. The practice of releasing hatchery fish is now under criticism for threatening native biodiversity (through competition with wild fish or introgression of hatchery genes), as well as for deflecting energy and resources away from management and habitat rehabilitation measures that might equally increase natural production. Enhancement has also been attacked for simply not working very well and costing too much. Many stocking programmes do not mark the released fish so that the effect on fishery landings simply cannot be measured. In fact, very little is known about the behaviour, survival, growth and even genetic impact of enhanced organisms. Scientists and managers have tended to divide into camps for or against enhancement, 108/ with little in the way of data to back up their claims. And environmentalists almost uniformly decry the practice. In North America today, managers try to avoid the term "hatchery" at all, preferring to concentrate on "supplementation", a technique that uses the same aquacultural tools but takes pains to use only broodstock representative of local populations where in the past a single population might be raised and broadcast well outside its native range. Technical protocols and methods for avoiding genetic problems with enhancement have been reviewed for some coldwater species 109/ 110/ General principles and recommendations have been published by FAO 111/ and codes of practice for transfer of stock have been drawn up by ICES 112/ to be applied to all enhancement programmes. 113/

5. The main uncertainties surrounding marine enhancement include:

(a) Do hatchery fish really contribute to fishery production?

(b) Can the same effect be gained through fishing reduction, habitat restoration or protected areas?

(c) Can the environment support the additional production?

(d) Do released fish displace wild stocks?

(e) What are the genetic, health and ecological effects of releases?

(f) Are the gains cost-effective and sustainable?

107/ Levin, P. S., and M. H. Schiewe. 2001. Preserving salmon biodiversity. American Scientist 89:220-227.

108/ See, for example, Wang, Y. L. 1999. Utilization of Genetic resources in Aquaculture: A farmer's view for sustainable development. R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

109/ Munro, A. L. S. 1988. Advantages and disadvantages of transplantations. Pages 75-83 *In* E. Grimaldi, and H. Rosenthal (eds.). Efficiency in aquaculture production: disease control. Proceedings of the 3rd Annual International Conference on Aquafarming "AQUACOLTURA '86," Verona, Italy. Edizioni del Sole 24 Ore, Milan, 227 pp. *Cited in* Goldburg.

110/ Benzie, J. A. H., and S. T. Williams. 1996. Limitations in the genetic variation of hatchery produced batches of giant clam *Tridacna gigas*. Aquaculture 139:225-241. *Cited in* Smith 1999.

111/ FAO. 1993. Expert consultation on utilization and conservation of aquatic genetic resources. FAO Fisheries Report No. 491. FIRI/R49. FAO, Rome, Italy.

112/ ICES. 1996. Report of the working group on introductions and transfer of marine organisms. ICES C.M. 1996/ENV:8. http://sgnis.org/publicat/papers/skora.pdf

113/ Smith, P. 1999. Genetic resources and fisheries: policy aspects. Pages 43-62 *In* R. S. V. Pullin, D. M. Bartley, and J. Kooiman (eds.). Towards policies for conservation and sustainable use of aquatic genetic resources. ICLARM Conf. Proc. 59. 277 pp.

Some unexpected results

6. The most obvious and controversial biodiversity question – do hatchery fish alter the genetic composition of wild stocks – is generally answered affirmatively. However, new data gathered with the molecular tools of microsatellite DNA analysis are not entirely consistent with this conclusion. In a just-released study of the genetic makeup of Atlantic salmon in Maine, some unexpected conclusions surfaced. Maine salmon have been enhanced since the 1970s, using eggs from local and more distant (Canadian) stocks. River-specific stocking (supplementation) did not start until 1991. In addition to this aggressive stocking programme, farming of Atlantic salmon began in the 1980s, using European-derived strains that invariably escaped to breed in the rivers.

7. What has been the genetic effect of this concerted addition of non-native salmon genotypes to Maine rivers? A scientific committee charged with examining all the available DNA evidence concluded that wild salmon in Maine are still genetically distinct from Canadian salmon, that there is considerable genetic divergence among populations in the eight rivers where wild salmon are found, and that the pattern of genetic variation seen in Maine rivers is similar to patterns seen elsewhere in salmon where no stocking has occurred. The committee concluded that Maine salmon populations were as genetically distinct from Canadian salmon populations and from each other as would be expected in natural populations anywhere else. 114/

8. Clearly, more such studies are called for before the pros and cons of enhancement are sorted out. Maine salmon may be an anomaly, the data may be insufficient, or enhancement may turn out to be more grey than the black in which it is currently painted. The genetic stakes, and the costs, certainly justify more research.

B. Case-study—shrimp-farming

9. Nearly one third of all shrimp landings are now farmed, despite the fact that shrimp farming is a relatively new industry. Half the landings are based on one species, *Penaeus monodon*, and South-East Asia and the Americas account for three-quarters of world production. 115/

10. Development of the industry has been volatile. Chinese production, once the leader, failed catastrophically in 1993 and has been rebuilding since then. Taiwan was one of the top producers in the late 1980s but is now a net importer. The practice of intensive shrimp farming is also politically charged: an Indian Supreme Court ruling closing down coastal intensive farming in the mid-1990s because of environmental and social effects was superseded by subsequent legislation.

114/ National Research Council. 2002. Genetic status of Atlantic salmon in Maine. Interim report from the Committee on Atlantic Salmon in Maine. National Academy Press. Washington, DC. ISBN 0-309-08311-7.

115/ Yap, W. G. Shrimp culture: a global review. ASEAN-SEAFDEC. The world of mangroves, mangrove-friendly shrimp culture. http://www.mangroveweb.net/html/ffarming.htm

11. Present shrimp production technology has been strongly criticized as unsustainable, with high prices encouraging overloading of the environment's ability to provide clean water and absorb wastes. Export-oriented shrimp culture was encouraged by many Governments, often supported by external aid, and environmental planning took a back seat. Hence ponds were poorly sited, often in mangrove areas and altering the ecological functions; freshwater aquifers were overused; coastal areas, lagoons and creeks were overloaded with wastes; seed and broodstock were reduced by collection; and disease outbreaks became epidemic to the point where it became extremely difficult to find pathogen-free seed or broodstock. 116/

12. All of the foregoing impacts have direct or indirect relevance for biodiversity. What progress has been made in reducing them?

Mangrove-friendly culture

13. From an ecosystem perspective, the role of mangroves is especially important. Mangroves reduce erosion and serve as spawning and nursery habitat for many species of fish and shrimp. 117/ Loss of mangroves became so serious, both biologically and economically, that world attention has focused on the issue within the past decade, and there are now strong signs of an emergent mangrove-friendly mariculture industry. This initiative, presently experimental and confined to ASEAN countries, involves the combination of silviculture (reforestation) with culture of fish, crabs or shrimp and is an attempt to develop and disseminate responsible culture technologies. 118/ Mangroves are also being promoted as environments for culture of mud crabs in pens, a technique that eliminates the conversion of coastal areas to ponds. In the Philippines, crab farming in tidal ponds is already an established industry and crab farming in mangrove areas shows enormous potential. However, the seed crablets come from the wild. It is important to develop and refine breeding, hatchery, and grow-out technologies in order to realize their potential to become a cash crop and export industry in tropical Asia without adverse environmental impact. 119/

Controlled reproduction reduces the need for wild fry

14. The difficulty of collecting fry, especially disease-free ones, led to the rapid development of methods for controlled reproduction, a significant research investment. Now, in countries with well-developed shrimp farming industries, reproduction is largely controlled in the laboratory, using eyestalk ablation techniques to induce spawning in captive broodstock. There is even a research effort to develop gene-banking technology for shrimp gametes and embryos, to ensure a steady supply of pathogen-free seed.

116/ Barg, U., R. Subasinghe, R. Willmann, K. Rana, and M. Martinez. 1999. Towards sustainable shrimp culture development: implementing the FAO Code of Conduct for Responsible Fisheries (CCRF). Pages 64-81, *In* B. W. Green, H. C. Clifford, M. McNamara, and G. M. Montaño (eds.). Central American Symposium on Aquaculture, 18-20 August, 1999. San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras (ANDAH), Latin American Chapter of the World Aquaculture Society (WAS), and Pond Dynamics/Aquaculture Collaborative Research Support Program (CRSP), Choluteca, Honduras. Available at: http://www.fao.org/fi/faocons/shrimp/honduras.asp#F1

117/ Josupeit, H. 2000. Environmental issues of warmwater prawns. Presented at Coldwater Prawn Forum, 22-23 June, 2000. Edinburgh, UK. FAO GLOBEFISH. http://www.globefish.org/index2.htm

118/ Aalvik, B. Production of Atlantic salmon and rainbow trout in Norway, preventive health care. Cultivation of Salmon II Conference. Bergen, Norway, May 7-10, 2001. Abstract available as pdf file at: http://www5.imr.no:8080/salmon/innhold.htm

119/ SEAFDEC - Aquaculture Department of the Philippines. http://www.seafdec.org.ph/home.html

Better than the alternative?

15. The shrimp culture industry, with its spectacular successes and dismal environmental failures, provides a model for the intervention of States in developing codes of conduct for responsible practices. FAO in particular has been working hard in recent years to implement the principles of the Code of Conduct for Responsible Fisheries, assisting, for example, in development of national codes of practice and technical guidelines. 120/ That this is worth doing from a biodiversity standpoint is not simply a matter of protecting mangrove ecosystems or reducing pressure on wild larvae. The wild shrimp fishery, a bottom fishery that uses gear dragged over the sea floor, is notoriously one of the most destructive fisheries in the world. By-catch, the capture of unwanted species, exceeds shrimp catch by the huge factor of six to one, meaning that 12 million tonnes of unwanted organisms are caught every year, two-thirds of which is thrown back dead. The benthic community is seriously damaged by trawling, and the overall effect on marine ecosystems may be profound. The depredations of the wild shrimp fishery are probably the last thing on the mind of farmers, but there is a strong argument to be made that a sustainable farming industry could reduce not only the pressures on the wild stocks but also the collateral biodiversity damage caused by trawling.

120/ Barg, U., R. Subasinghe, R. Willmann, K. Rana, and M. Martinez. 1999. Towards sustainable shrimp culture development: implementing the FAO Code of Conduct for Responsible Fisheries (CCRF). Pages 64-81, *In* B. W. Green, H. C. Clifford, M. McNamara, and G. M. Montaño (eds.). Central American Symposium on Aquaculture, 18-20 August, 1999. San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras (ANDAH), Latin American Chapter of the World Aquaculture Society (WAS), and Pond Dynamics/Aquaculture Collaborative Research Support Program (CRSP), Choluteca, Honduras. Available at: http://www.fao.org/fi/faocons/shrimp/honduras.asp#F1