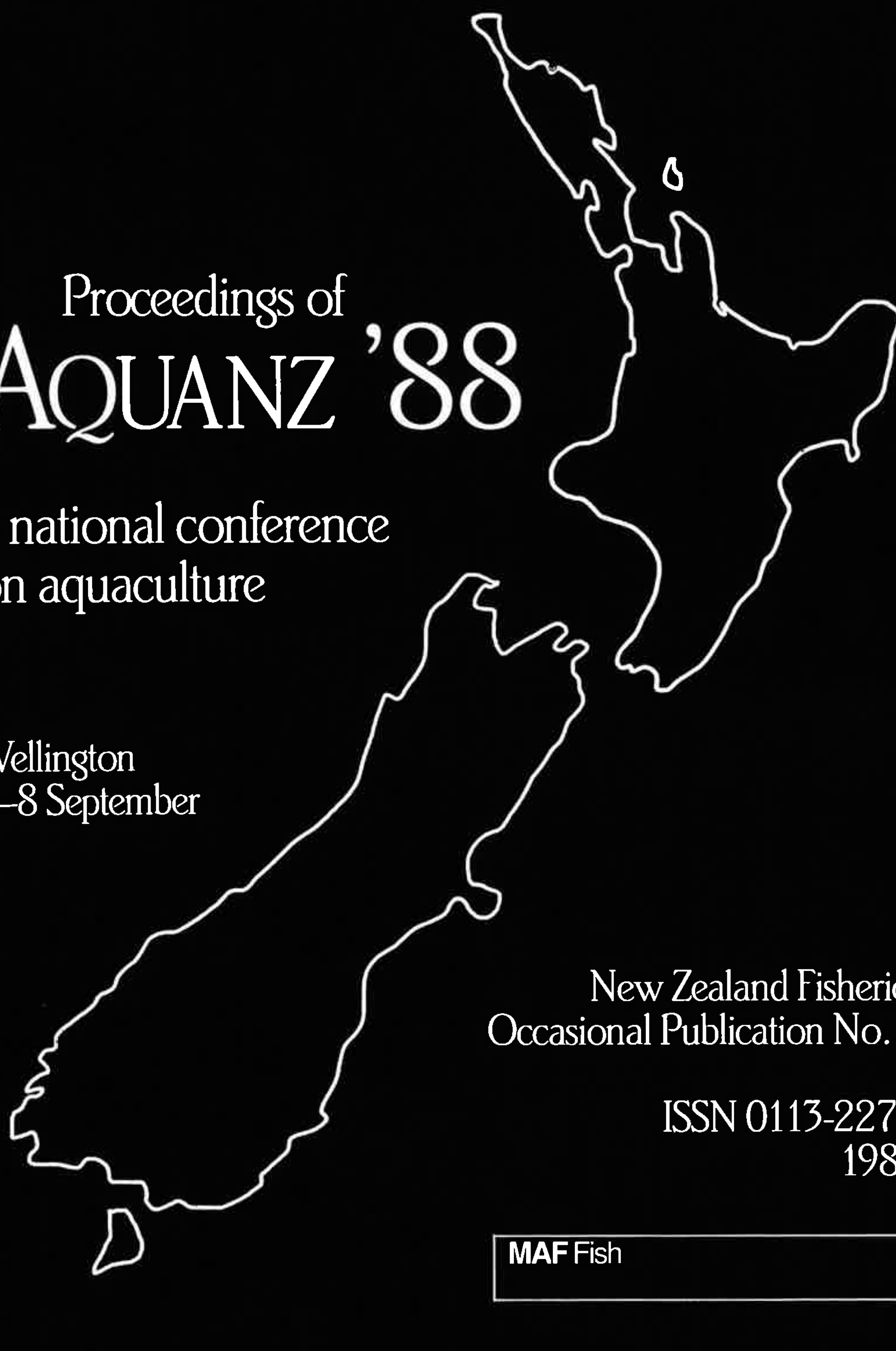
Proceedings of

AQUANZ '88

a national conference on aquaculture

Wellington
6–8 September



New Zealand Fisheries
Occasional Publication No. 4

ISSN 0113-227X
1989

MAF Fish

Proceedings of AQUANZ '88:
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Compiled and edited
by
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New Zealand Fisheries
Occasional Publication No. 4
1989

Published by MAFFish
Wellington
1989

ISBN 0-477-08084-7

MAF Fish

MAFFish is the fisheries business group of the New Zealand Ministry of Agriculture and Fisheries. It was established on 1 April 1987 and combines the functions of the old Fisheries Research Division and Fisheries Management Division and the fisheries functions of the old Economics Division.

The *New Zealand Fisheries Occasional Publication* series in part continues the *Fisheries Research Division Occasional Publication* series. It will contain bibliographies and conference proceedings. Other material of a kind previously published in the *Fisheries Research Division Occasional Publication* series is now published in the *New Zealand Fisheries Technical Report* series.

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Set in 10 on 11 Times

AQUANZ '88 was organised by
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Contents

An overview of marine aquaculture in New Zealand

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My talk will cover marine aquaculture and I want to concentrate on the achievements of the past. They are your achievements, they are our achievements, they are New Zealand achievements. They may be small by international standards, but many stem from New Zealand initiative, ingenuity, and an innovative approach to problems. They are not only the result of individual enterprise, but also of teamwork and sharing information. This is what this conference is about, and this is your opportunity to participate, to share, and to contribute.

I will be talking about the molluscan shellfish industry because that is where the greatest success has been achieved. I will briefly mention other topics and species as we are in a position to exploit new technologies and develop new industries because of the expertise and experience that exists in New Zealand.

Oysters

New Zealand marine aquaculture began with the native rock oyster as early as the 1930s, but serious farming of this species did not start until the 1960s. Soon the estuaries and harbours of Northland and Coromandel were sprouting farms of racks with their characteristic sticks of oysters.

But soon a problem appeared. An alien species, the Pacific oyster, appeared on the scene. What would happen to the native rock oyster? How fast would the new species spread? Did it have any value? Research scientist Dr Dinamani carried out extensive work and, although this did not stop the spread of the new oyster, we had a better understanding of its biology. It became recognised as a valuable product with faster growth and greater size. It had advantages and disadvantages, but it was here to stay and oyster farming expanded.

Further problems developed. Spat fall was irregular. More research was required and MAF recognised the need for an experimental shellfish hatchery. Mahanga Bay evolved. Two experienced scientists, Paul and Matty Chanley, were brought to New Zealand to assist in the research programmes. Work on developing techniques to rear oyster larvae and spat was initiated, for which there was industry support. The result has been the development of technology that could be used to set up a commercial hatchery in New Zealand. There were also rearing trials at the Puka Puka hatchery and the results of the research and development were published. Culchless on-growing was also tried and experimental tray cultures were set up.

The oyster industry still has some problems, but they can be overcome. Individual farmers have shown enterprise and introduced new techniques, and we do still have an industry worth several million dollars. There is no reason why it should not become a multimillion dollar industry.

Mussels

The green-lipped mussel, previously dredged and picked from around our coast, has proved to be an excellent candidate for mariculture. A Cinderella product in the early 1970s, today it has expanded into a significant export industry. Some will remember how it started with rafts moored in the Marlborough Sounds.

About 30 floats were imported from Japan in 1975 and the industry took off, modifying and adapting the long-line technology to suit New Zealand conditions. Mussel farming was in demand. It was a growth industry in every sense of the word, and our mussels were recognised in many overseas markets. With this rapid development of farms, research was essential. Apart from some preliminary rearing work done at the Mahanga Bay Hatchery, the emphasis was on what was happening in the Sounds. Where were the larvae that were to settle and grow into spat for seeding ropes? What did the larvae look like, as there were other mussels in the Sounds? Could we predict spat catching areas? Where should the farmer put his ropes? The MAF Spat Bulletin was established to provide this information.

And, as the farms increased in number, further questions. How many farms could the Sounds support? Where were the best locations to establish a farm? What sort of condition could you expect from an area, seasonally and from year to year? What did mussels actually eat? Did one farm affect another farm downstream?

In 1983, Bob Hickman, in conjunction with DSIR, began an intensive research programme that used the fisheries research vessel *Kaharoa*. At the same time, a student research contract was awarded to Roger Waite to carry out a feeding study.

Chlorophyll levels were recorded as a measure of food availability. Particulate matter, carbon, nutrients, salinity, temperature, and oxygen levels were also measured and now form a comprehensive data base. We have a much better understanding of food distribution. Already the information and data from the student work on feeding has been used by the industry. This work has given us a greater understanding of the relationship between available food and mussel condition within the various areas of the Sounds where farms have been established. A mussel farm was set up at Mahanga Bay to provide a second data base and information on breeding and condition.

However, other problems emerged. The industry wanted to know why spat were dying 3 weeks after settlement. Again, MAF responded, and Barbara Hayden initiated a research programme which included sampling the water column for larvae and finding out where were the greatest densities, where was the best settlement. What effects did physical factors have on larval distribution?

Experiments were set up to determine what happened after settlement. Processing and analysing the data has been tedious, but already the industry is using the results to obtain better and more consistent settlement. Barbara also looked at predation and experimentally excluded fish from spat to compare areas of low and high predation history.

The industry is still having problems. It is expanding, but is still dependent on natural supplies of spat and concern has been expressed for a number of years about the irregularity of supply. In October 1987 we hosted a workshop to discuss the issue. There are many questions to be answered, not only about the Marlborough Sounds, but also about sources of seed such as Kaitaia. Where is it derived from? Why is it irregular? Barbara Hayden's work may well answer some questions, but it is pleasing to note that the industry is also taking the initiative. Interest has been shown in funding a study of the Kaitaia spat.

It is also important that one company has taken the initiative and funded a hatchery based study. That company has recognised the skills of the aquaculture section of MAFFish and invested in Mahanga Bay to see if green-lipped mussels can be conditioned to breed over a long period and give assured supplies of spat. If the technology is developed, and proves to be economic, then the industry will be able to plan with confidence.

Scallops

Scallops support a dredge fishery that has had mixed fortunes in recent years. Heavy fishing and poor recruitment saw a rapid decline in catches in the early 1970s followed by some recovery. The species and fishery were studied extensively by Mike Bull in Nelson, but it became evident that perhaps the only way to overcome the vagaries of nature and increase production was by farming or by reseeding and enhancement.

In 1980 MAF set up a team of scientists to study the biology of the scallop. We needed to understand the critical phases of larvae, their distribution and settlement, and the growth of both early juveniles and later stages. Tagging studies were undertaken to measure growth and survival.

At the same time, information was gathered and trials were made on farming scallops in nets, after the development of similar techniques in Japan. Private groups also experimented with hanging culture, but, although biologically and technically feasible, it was not economic at the time.

In 1983 Japanese technology, finance, and staff were offered to see if enhancement could work here as it had in Japan. A joint programme was developed and, with the research base that had been built up here, thousands of spat were soon being collected and readied for relaying. Seeding was undertaken, and by 1986 the first experimental catches from seeded areas were dredged.

MAF continued the work on a larger scale, and at the beginning of August this year announced that "A feature of the coming scallop season will be the first commercial harvest of scallops grown under the fishery enhancement programme. From 14 August until 8 September scallops will be caught that were seeded in 1986." At the end of the period it is expected that 100 t of the landings will have originated from the seeded juveniles. The programme has been so successful that the Japanese have continued their support to carry out a similar programme in the Coromandel-Hauraki Gulf area.

Paua

For many years paua was an under-utilised resource valued only for its shell. There was a flurry of activity when export markets for the meat opened up and the canned product came into its own. The fishery soon came under pressure. Studies showed that recruitment was erratic. Could this be solved using the Japanese reseeding technique? But, first, could we develop similar techniques to the Japanese for breeding and rearing seed paua?

The answer is yes, for all three species have been reared at the Mahanga Bay Hatchery. Paua can be kept in breeding condition and can be bred on demand for up to 8 months of the year. (This work has been reported on frequently in *Catch* magazine.)

Following the early success there was a rapid development in the technology. Mahanga Bay geared up to produce large numbers of juvenile paua for experimental seeding. At the same time we studied the critical phases of larval development and settlement. Could we use the knowledge gained to increase survival? Larval rearing became a routine procedure, the technology improved, and the V-shaped tank, an efficient and cost-effective design for producing thousands of baby paua, evolved. At that time we received financial support from the paua processing industry which helped to speed up the investigations. This was the first instance of competing companies combining to support fisheries research for the benefit of all New Zealand.

MAF supported a student to look at the growing of the red seaweed *Gracilaria*, a suitable food for feeding to paua. Paua eat a lot, and any successful rearing operation must have an assured supply of food.

The success of the paua programme encouraged others to look at the farming of this valuable species; we were now in a position to advise prospective farmers. Several training courses have been run by the aquaculture section. We have investigated the on-growing of paua in barrels and are about to patent a new concept, and we will be working closely with individuals in industry to test the new system.

Farming of paua was a dream for some in 1981. In 1987 it became a reality when the first farm was established on the Wairarapa coast. Recently a second farm started operations on the Taranaki coast. These are achievements both for us and for the New Zealanders who have taken the initiative and more than a few risks to set up new industries.

However, we did not lose sight of the original objective of the programme, enhancement through reseeding. MAF recognised the need to speed up the work and so contracted Dr David Schiel to study the ecology and biology of juvenile paua before the outplanting experiments and trials. We also further developed the technology for enhancement. An innovative approach using larvae has proved to be successful, and so too has the juvenile outplanting. We can see only further achievements and successes in the development of paua enhancement, and are now awaiting commercial involvement to carry out larger scale trials.

Other species

Finally, I want to mention other species that have been worked on or considered.

The dredge oyster, a species reared at Mahanga Bay, has been considered for farming in the past and some data were published recently. Now a comprehensive programme to produce spat on demand, both for possible farming and enhancement trials, has been developed and awaits approval and finance. I should add that one enterprising and forward-thinking individual has already experimented with suspended culture of this oyster species and had encouraging results. At the same time, the occurrence of *Bonamia* in the dredge oyster fishery in Foveaux Strait has highlighted the need for care in exploring and developing new farming industries.

This brings me to disease studies. We have at the Fisheries Research Centre the expertise to monitor and study diseases that may occur in intensively farmed animals both in the hatchery and in the farm. This experience was very valuable when *Bonamia* struck, and it enabled us to understand the problem and give advice in a very short time.

Snapper farming was considered in 1980, but although the technology was known the economics of setting up a venture then were not good. Some work was tried at Mahanga Bay and an Auckland company experimented with the on-growing of juvenile snapper. The rearing technology has improved considerably in recent years, and we are poised to take advantage if the economics look better.

Algal and live food production techniques have been developed at the hatchery, and we have experimented with the supplementary diets essential to fish larval rearing. Likewise we have information on the larval stages and the on-growing of juvenile rock lobsters, and this topic will be addressed at this conference.

Conclusions

I have talked about the achievements in marine aquaculture. I have illustrated developments from both commercial and research viewpoints. More importantly I have given examples of the essential ingredients for success in marine aquaculture. We have used our indigenous species successfully, we have exploited the biological knowledge to increase production and develop new technologies, and we have worked together using initiative and ingenuity.

It is interesting to reflect on the last aquaculture conference in 1979 when the then minister, Duncan MacIntyre, asked the question "Does artificial seeding of the Nelson area with scallops have a place in the future of this resource?" We know the answer now. At the same conference I spoke about the possibilities for paua, and they have also come to fruition. It is in aquaculture that New Zealand can and will develop using its own resources.

Duncan MacIntyre also spoke about dairy wastes and how they could be used in aquaculture. You will be interested to hear that the dairy industry is currently investigating the use of waste products in artificial foods for feeding to paua, and we have been testing their formulations at the hatchery. I am confident that a product will be developed that will ensure paua farming has a future in New Zealand.

Commercial enterprise, research, and development will continue to go hand in hand. Since aquaculture worldwide is one of the fastest growing branches of the food industry, it is likely that similar growth will take place in New Zealand. Our climate and environment, both marine and freshwater, make New Zealand one of the best countries for aquaculture development. We have an extensive coastline, many protected bays and estuaries, clear unpolluted waters, and a temperate climate with water temperatures suitable for growing a great range of species. The emerging aquaculture industries can only enhance our reputation as a top primary producer. If we continue to build on the past achievements, we can only succeed.

Freshwater aquaculture in New Zealand: developing a perspective

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Introduction

I would like to place freshwater aquaculture in New Zealand in perspective, both with regard to the use of aquaculture technology here, and to the way our activities and environment fit into the international environment. By comparison with pastoral farming, aquaculture is both recent in occurrence and small in dimension. Nevertheless, it has much to offer with regard to changing human dietary patterns in many parts of the world, including New Zealand, and also to the opportunity to produce protein from very productive environments (Shorland 1978, Mitchell and Rowe 1979).

Let us take a broad perspective of aquaculture, and define it as: the captive reproduction and/or rearing and/or feeding of aquatic animals to fulfill some need or use by humans. So defined, aquaculture may include captive fish production for the following purposes:

1. The stocking of natural waters for exploitation by anglers.
2. The stocking of natural waters for exploitation by commercial fishers to obtain protein for sale as food.
3. The stocking of natural waters for exploitation by subsistence/artisanal fishers.
4. The stocking of natural waters to provide forage fish for other species of value in 1 to 3 above.
5. The stocking of natural waters with fish for biological control of pest plants or animals.
6. The stocking of fish farm ponds with fish to control pest plants or animals.
7. The rearing of bait fish for sale to anglers.
8. The production of fish for aquarists and pond keepers.

All these uses occur widely overseas. Because of New Zealand's relative affluence, angling is an important recreation and the release of fish for recapture by anglers has played an important role in local aquaculture (1 above). Ocean ranching of salmon falls within the category "release for recapture by commercial fishers", though only just (2 above). Because of the cheapness and ready availability of high quality proteins and our relatively high standard of living, the release of fish for subsistence and artisanal fishers in New Zealand has had no historic role at all (3 above); at present, it seems unlikely ever to do so. Nor has there been any aquaculture involving the rearing of forage fishes for other predatory species (4 above). The use of fish for biological control has a role that is still developing (5 above), but so far this has not included the use of biological controls in fish farms (6 above). Nor has New Zealand aquaculture involved production of fish for bait (7 above); most New Zealand anglers eschew bait fishing and those that don't usually catch easily available indigenous fishes for this purpose (bullies, *Gobiomorphus* spp.; inanga, *Galaxias maculatus*; or smelt, often *Stokellia anisodon*). There has always been a modest industry involving production of fish for aquarists and pond keepers (8 above). This is a field that has a very low profile, but probably involves a higher number of individuals than the revenues earned would imply.

The production of forage or bait fishes, or fish for release for biological control in fish farms, is unlikely to have a significant future in New Zealand, and the production of fish for aquarists and pond keepers is at the fringes of the purposes of this meeting, so I will not refer to any of these technologies again, but will concentrate on releases for anglers, releases for commercial recapture, production of fish for biological control, and captive rearing of fish for protein production.

The New Zealand environment

If we believe what people write (e.g., Davis and Teirney 1986), New Zealand has large quantities of good quality fresh water. Electricity generation agencies will certainly tell us that, as will recreational anglers and freshwater fisheries managers. I know that there are concerns from time to time about the quality and quantity of our fresh waters, but I believe that New Zealand is well endowed with freshwater resources.

New Zealand's climate varies from warm temperate in the north to cool temperate in the south, so that in a global sense our fresh waters are distinctly temperate in nature. In some districts effluent discharges from centres of population or industry, or nutrient enrichment deriving from intensive land-use practices, substantially raise nutrient levels in natural waters. On the whole, our waters are pure, with low natural levels of dissolved solids, and carry low levels of pollutants.

It is important to give some thought to what role this abundance of fresh water has for New Zealand in aquaculture as we near the 21st Century. This may be regarded as looking too far ahead, but given the time it takes to develop new policy and law and to obtain and adapt technology, that is the time frame we need to be looking at. In addition, as I will discuss a little later, it seems likely that for New Zealand to develop its full potential in aquaculture, it may be necessary to contemplate further introductions of species suited for aquaculture, and this process certainly takes time, as those who have endeavoured to bring new species into New Zealand will testify.

Aquaculture in New Zealand's past

Let's have a look at New Zealand's European history and review what has happened in the past in freshwater aquaculture. Accepting the broad definition of aquaculture that I gave earlier, it seems that New Zealand aquaculture began in the last third of the 19th Century.

Trout hatcheries. When acclimatisation societies and Government became involved in the introduction and establishment of trout and salmon in New Zealand in the 1870s and later, there was a need for hatcheries to rear the imported stock, multiply it, and spread fish into suitable habitats. I do not know how many such hatcheries there were, but I suspect more than twenty. In some instances their fish production was vast. In the 1920s to 1940s the Hawke's Bay Acclimatisation Society released up to 700 000 trout per year, and in 1957–58 was still releasing 500 000. The Otago Acclimatisation Society records that between 1869 and 1923 no less than 23 million trout were released in its district (McDowall in press). I have no reason to believe that these two examples are in any way distinctive, nor do I think that the activities required to produce these vast numbers of fish are improperly classified as a form of aquaculture. Thus, for more than 120 years there has been aquaculture production of salmonid fishes by acclimatisation societies for release into wild habitats to enhance fish populations available for recreational angling — this is production of fish for human use, call it trout farming if you like!

And while it is true that this was essentially an acclimatisation society function, it was not exclusively so. In particular, A.M. Johnson of Christchurch, though involved at times in acclimatisation society hatchery production, was also highly active at others in a private capacity as an importer of new fish species and as a producer of fish for sale to acclimatisation societies for their own enhancement activities. In addition, Government, through the Marine Department, later the Ministry of Agriculture and Fisheries, as well as the former Wildlife Service of the Department of Internal Affairs, have engaged in substantial activity in fish hatchery management and production.

Thus in a somewhat restricted sense, with these early beginnings, New Zealand has had a long and quite successful history in freshwater aquaculture, and on quite a large scale.

At a time when we are seeking to encourage diversification of New Zealand's economic and employment bases by various means, including the expansion of aquaculture, it is perhaps paradoxical that we are also seeing a substantial decline in the level of activity in the production of hatchery-reared trout for release into wild habitats (McDowall in press). It was recognised more than 40 years ago that New Zealand's wild stocks of trout do not need significant releases of stock (Hobbs 1948), and over the succeeding decades trout hatcheries have been closed down and abandoned. There are now very few operating and those that remain are sometimes difficult to justify on biological and economic criteria.

Trout farming. Trout farming has long been a controversial topic in New Zealand. During the late 1960s, Government held the view that trout farming would be good for the country. Recreational anglers had other ideas. Over several decades there has been conflict over the acceptability of trout farming. This conflict has been fuelled, in some measure, by claims that trout farming, as a form of aquaculture, will alienate waters from public use, lead to a decline in water quality as a result of effluent discharges, and result in the releases of diseases into our trout stocks. This conflict has long ago moved from the biological environment to the political one, and that's where it stays.

Legislation was introduced to allow trout farming in 1971, after a substantial commission of inquiry. Anglers made this matter an election issue in 1972, and the Labour Party promised that if elected they would repeal the legislation. They were elected and they did repeal the law. Since then, though the matter has not totally died, there has not been any concerted effort to get trout farming approved by Government. Anglers were successful in having a clause included in the Fisheries Act (1983) that explicitly outlaws trout farming. Though much has been claimed for the economic potential of trout farming in New Zealand, I am not sure about the economics of freshwater rearing of trout, given competition from sea-cage reared trout, high world production, and our distance from significant markets overseas.

Eel farming. At the end of the 1960s there developed an interest in eel farming. It was about this time that commercial eel fishing was developing rapidly as it became obvious that there were substantial overseas markets for eels. Eel farming was a natural follow-on from commercial eel fishing, and the developing overseas technology began to become available to New Zealanders. In the period 1971 to 1974 five eel farms were established, four in northern New Zealand, and one in Otago. At the outset they used outdoor ponds at ambient temperatures, but some used indoor facilities with heated waters derived from industrial effluents.

However, by late 1975 only one eel farm remained in operation (Jellyman and Coates 1976). Problems leading to failure included: diseases; difficulties in obtaining reliable supplies of seed stock from New Zealand rivers (eel farming worldwide depends on the capture of wild glass eels or elvers); the poorer quality of New Zealand eels, specifically their low fat levels; economic problems (especially the cost of artificial foods); and the collapse of overseas markets and a drop in prices, which were never very good as a result of the lack of fat in our eels.

Subsequent research has shown that it is possible to grow eels in New Zealand to a marketable size (150 g) in about 18 months, but not economically (Jones 1985). An interest in eel farming persists, but at the moment there are no commercial eel farms in New Zealand. One aspect of eel production that received brief consideration in the 1930s (McDowall in press), and which may have potential in relation to eel aquaculture (as well as wild eel harvesting), is the production of fine leathers from eel skin. This has never been incorporated in eel farming technology here, though there has been a little recent interest in the capture and/or farming of eels for leather.

Salmon. Salmon aquaculture is currently the most active area in freshwater aquaculture in New Zealand. Ocean ranching of quinnat salmon and the freshwater pond rearing of both quinnat and sockeye salmon are effective practices now being pursued. There seems no technological reason why both should not continue to succeed.

I understand that there may also be some interest in the ocean ranching of sockeye and perhaps Atlantic salmon. World experience with the transfer of anadromous stocks of salmonids suggests that success is very rare (McDowall in press) (New Zealand is the only country in the world with sustained, self-supporting stocks of the long-distance ocean-migrating salmonid species), and success with ocean ranching of sockeye or Atlantic salmon in New Zealand is likely to be very elusive.

Biological control. Use of fish in biological control in New Zealand began about 60 years ago when mosquitofish were introduced, ostensibly to reduce mosquito numbers in still waters close to human habitation. Fortunately, this troublesome fish was not released very widely, and for several decades was present, little known, in a few northern localities. Its introduction can only be seen as frivolous, and no attempt appears to have been made to determine its value or effect. During the past decade the mosquitofish has become much more widespread in northern areas.

Over the past 15–20 years there has been extensive research in New Zealand on the potential of two large Asiatic carps in biological control. Grass carp (*Ctenopharyngodon idella*) were brought here to determine whether they had a role in the removal and control of excessive growths of aquatic macrophytes in waterways (Mitchell 1980). Silver carp (*Hypophthalmichthys molitrix*) were introduced by the Hawke's Bay Acclimatisation Society to evaluate their use in dealing with phytoplankton blooms that were threatening trout populations in increasingly eutrophic lakes. Substantial reports have been issued on both research programmes (Rowe and Schipper 1985, Carruthers 1986); in summary, it appears that grass carp have a useful role in removing macrophytes in drains and small lakes, and that they cause less damage than chemical herbicides or draglines. New Zealand is moving towards the wider use of grass carp, though only sterile triploid fish will be used to obviate any fears that the species may reproduce and become troublesome.

Silver carp were found to be capable of controlling phytoplankton blooms in a small lake, but the data obtained did not show an improvement in the quality of the lake water as a fish habitat. The future value of this species in New Zealand is still uncertain, though there is some interest in releasing stocks into small eutrophic lakes where blue-green algal blooms are a problem.

That, briefly, is our history in fish aquaculture.

Future developments

Where do we go from here? What role do we see aquaculture in fresh water having in about a decade? What is the most fruitful use of our freshwater resources for fisheries? What aquaculture uses can we imagine for fish species already present in our waters? What are the limiting factors on fisheries production from our fresh waters by means of aquaculture? Should we consider importing additional fish species into New Zealand for aquaculture?

Our fresh waters already support highly valued, primarily recreational, fisheries that must not be downgraded to second class status. These fisheries already have substantial, if largely undocumented, economic values in terms of both direct costs and downstream economic impacts. There would be little difficulty in demonstrating a surprisingly high monetary/economic value from our recreational fisheries generally, as Shaw *et al.* (1985) have done for the Lake Taupo fishery.

In addition, I want to emphasise my view that to reduce all values of recreational fisheries to economic ones, to dollars and cents, profits and losses, to returns on investment, would be quite wrong, short sighted, and inappropriate. In saying this I am not wishing to imply that economic matters should be ignored, that investment in recreational fisheries should be without consideration of cost benefit, or that priority must be given to recreational fisheries without recognition of the opportunity costs that might need to be forgone to protect the recreational fisheries values. But I am saying that where there is potential conflict between in-river, semi-passive uses like recreational angling, and out-of-river, consumptive uses, then decisions cannot be made simply on economic criteria. If this were the way New Zealand society functioned, we would have milled all of our kauri trees decades ago and kokako would long have been extinct. The highest value for our rivers may well be as places to take tourists to catch (and often release) large trout in scenic surroundings.

In the freshwater environment there is little need for conflict between aquaculture and recreational fishing. I think that there is ample water available in New Zealand to launch a mass of aquaculture ventures without having any perceptible impact on the water resource, either in terms of quantities of water taken from the natural environment, or the quality of water returned after use in aquaculture. With catchment boards responsible for managing water abstraction and maintaining water quality, and the Department of Conservation vigilantly responsible for the protection of fish habitat, I suspect that we do not have a great deal to worry about on this score. Fears expressed by anglers about the consequences to trout populations from trout farming (spread of disease, decline in water quality, alienation of water from public use) have not developed with salmon farming. There is no reason why these things should happen with any properly managed aquaculture. Fish farms probably are in more danger from diseases in wild stocks than wild stocks are in danger from diseases in aquaculture facilities!

Existing fish species. Our first responsibility is to determine whether there are species suitable for aquaculture already present in New Zealand. I believe there is some potential which has already been recognised by some individuals or agencies.

Apart from eels, the only indigenous fish that have attracted any aquaculture interest are whitebait, and specifically the chief species in the whitebait fishery, inanga (*Galaxias maculatus*). Because of its very high market price, several individuals have investigated the prospect of whitebait farming; to date there have been no pilot projects, and no-one has sought a licence to start whitebait farming.

Much of the technology for whitebait farming exists. Possibly the most difficult (and crucial) area involves rearing the tiny larvae from hatching (< 10 mm long) through to the marketed whitebait stage. This is possible (Mitchell 1982), but doing so without severe mortalities remains a problem, as is the small absolute growth attained (about 0.5 g per fish over about 6 months). These make the economics of whitebait farming seem highly dubious, though there are no explicit technological questions that seem incapable of solution. The issue of the palatability of captive reared whitebait is another matter for investigation. The ocean ranching of whitebait has been suggested, but there is no evidence to support a return of whitebait to their hatching/release site, and some that appears to negate homing (McDowall 1984).

The indigenous koura, *Paranephrops* spp., are very fine eating and have long attracted interest both for harvesting wild stocks and aquaculture. If it were possible to economically rear koura in captivity, there would be no difficulty in obtaining markets at gourmet prices. However, the combination of slow growth rates and high mortalities forms a fatal flaw in koura aquaculture technology (Jones 1981).

Salmonids. There exists an untapped potential for farming various salmonids, primarily trout, the chief impediments being prohibition by law and opposition from anglers.

Carps. There are several introduced carps in New Zealand which are used in aquaculture overseas; grass carp and silver carp, European carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), rudd (*Scardinius erythrophthalmus*), tench (*Tinca tinca*), and orfe (*Leuciscus idus*). Because of New Zealanders' culinary interests, and the high salary and other costs of local industry, it seems unlikely to me that any of these, other than perhaps grass and silver carp, have much potential. In addition, European carp are designated a noxious fish owing to real concerns about the impact of this species should it become widespread in wild habitats.

Both grass and silver carp may have value in dual purpose aquaculture. There is no reason why they should not be used for removing troublesome plant growths at the same time as they are grown and harvested for human consumption. Management strategies for these dual roles are needed (Mitchell 1980), but I can see no essential problems. Perhaps it is time that we saw aquatic macrophytes and plankton blooms as assets to be creatively harvested; the best way of harvesting them might be to get fish like grass and silver carp to eat them. Moves in this direction are already underway in Northland, where the Northland Catchment Commission and the Maori trustees are examining releases of silver carp into Lake Omapere. We could, perhaps, export juvenile grass carp to other users as we can produce reliably disease-free stock.

Maori people have long had an interest in goldfish as food (known as morihana and named after a policeman by the name of Morrison who first brought the species to Lake Taupo (McDowall in press)), but whether this interest can be transferred from the capture of goldfish from wild habitats to either subsistence or economic aquaculture is not known.

Catfish. New Zealand has long had stocks of the American brown bullhead (*Ictalurus nebulosus*). Once restricted to the Waikato and Lake Mahinapua, it is now much more widespread and is now in Lake Taupo. It is used, sparingly, in aquaculture overseas. Some commercial eelers catch many catfish, but they have had difficulty finding worthwhile markets in New Zealand. Possibly, brown bullhead reared in captivity would be in better condition, have thicker fillets, and be more acceptable to buyers, but overseas experience suggests that they are unlikely to be commercially successful here.

Perch. The European perch (*Perca fluviatilis*) is a much under-rated angling species that has been in New Zealand waters for over 100 years. Few people realise the fine eating qualities of this fish which has possibilities for aquaculture. As in all new ventures, there will be some technological problems to solve, not the least of which will be coping with their aggressive and predatory habits and their apparent need for live food at the larval stage (Craig 1987). However, this species is worth more than a passing glance; the very similar yellow perch (*Perca flavescens*) is cultured in North America for stocking wild populations (Stickney 1986).

Crustaceans. Entrepreneurs have looked overseas for crustacean species to introduce, and the Australian marron (*Cherax tenuimanus*) has been brought to New Zealand. Stocks are still in quarantine at facilities north of Auckland. Concerns about pathogens present on the stock, and about their potential impact on the indigenous biota should they escape into the wild, mean that marron have an uncertain future in New Zealand (Hughes 1988). In addition, there are concerns about the economic viability of marron farming, both here and in Australia.

Also still very much in the early stages is culture of the tropical prawn *Macrobrachium rosenbergi*; a well developed project is rearing this prawn in water heated by effluents from the Wairakei geothermal power station on the Waikato River. This is a high cost and high technology venture aiming to produce an expensive, gourmet product for the New Zealand restaurant trade. It is too soon to comment on its viability. Whether or not *Macrobrachium* has a future in aquaculture in New Zealand, it seems to me that ventures of this type are unlikely to play a major part in any substantial expansion of domestic aquaculture production. This is not meant as an implied criticism of the existing project, nor is it intended to convey the impression that it is of little value or unlikely to succeed. Rather it is a recognition that such ventures are likely to be highly specialised and at the fringes of the mainstream of freshwater aquaculture in New Zealand if this is to undergo major expansion in productivity and revenue generation.

Summation — and the future

This brief account indicates that, other than several salmonids and two large carps (all introduced), there are few species in New Zealand, native or introduced, that are well suited to aquaculture and for which there is a well developed technology. If there is to be a future in freshwater aquaculture, aside from these salmonids and carps, introductions of further species seem necessary, and moves are already underway to investigate this process for some species. There are two sets of criteria that must be met for any introduction.

First and foremost, the target species must be one that is considered unlikely (very unlikely) to have harmful impacts on the New Zealand biota. New Zealand's history and environment are littered with mistaken introductions and there is no need to recount these here (though see King 1984, McDowall in press). Requirements placed on any proposed introductions are bound to be extremely stringent, and, in particular, any candidate species must not threaten either the indigenous freshwater fish biota or the acclimatised salmonid fisheries. I suspect that these criteria will be very difficult to meet. The Animals Act (1953) explicitly excludes certain biota, and also contains a general prohibition on "Any other animal that is likely to become a nuisance or to cause injury or damage" (Animals Act, Section 14k). The precise meaning of this exclusion is a matter for some discussion at present, and it is recognised by the Ministry of Agriculture and Fisheries that significant attention to regulatory control over the importation of biota is urgently needed.

As it seems inevitable that any introduced species will either escape or be released into the wild, it is crucial that even though the import is planned for captive rearing, its likely impact on the native biota is documented and widely understood. Given that some of the most important fish species in overseas aquaculture are predatory, there probably will be real difficulties in obtaining approval for their importation. Possibly this will be agreed to only if it is possible to produce sterile farm stock, the fertile brood stock being kept in carefully protected, quarantine facilities to which there is very limited access. This is not an unlikely possibility as for many species there exist technologies for production of sterile stock either by hybridisation or genetic manipulation.

Second, species considered for aquaculture must be suitable for that purpose — obvious perhaps,

Table 1: World list of fish used in aquaculture (A = No. of species in family; B = No. of species used in aquaculture; C = No. of species present in New Zealand)

Family and common name	Range	A	B	C
Polypteridae (bichirs)	tropical	11	1	0
Acipenseridae (sturgeons)*	warm to cold	23	12	0
Polyodontidae (paddlefishes)	warm to cool	2	1	0
Osteoglossidae (bonytongues)	tropical	6	4	0
Gymnarchidae (gymnarchids)	tropical	1	1	0
Clupeidae (shads and herrings)*	tropical to cold	180	8	0
Anguillidae (eels)	tropical to cold	15	5	2
Esocidae (pikes)	cool to cold	3	2	1
Salmonidae (trouts and salmons)*	cool to cold	68	24	7
Osmeridae (smelts)*	cool to cold	10	4	0
Plecoglossidae (ayu)	cool	1	1	0
Chanidae (milkfish)	tropical	1	1	0
Characidae (characins)	tropical	many	9	0
Anostomidae	tropical	?	5	0
Citharinidae	tropical	?	6	0
Cycprinidae (carps and minnows)	tropical to cold	1600	69	8
Catastomidae (suckers)	warm to cold	58	5	0
Cobitidae (loaches)	tropical to cool	35	2	0
Ictaluridae (American catfishes)	warm to cool	34	7	1
Bagridae (bagrid catfishes)	tropical	many	6	0
Siluridae (Eurasian catfishes)	tropical to cool	many	4	0
Schilbeidae (schilbeid catfishes)	tropical	65	6	0
Clariidae (air-breathing catfishes)	tropical	100	5	0
Heteropneustidae (airsac catfishes)	tropical	2	1	0
Plotosidae (eel-tailed catfishes)	warm	30	1	0
Pimelodidae (fat catfishes)	tropical to warm	285	3	0
Cyprinidontidae (killifishes)	tropical	300	5	0
Poecillidae (live bearers)	warm to cool	138	1	1
Atherinidae (silversides)	tropical to warm	156	4	0
Centropomidae (snooks)	tropical to warm	30	2	0
Percichthyidae (temperate basses)	warm to cool	40	7	0
Serranidae (sea basses)	warm to cool	370	1	0
Theraponidae (tiger perches)	warm	15	1	0
Centrarchidae (sunfishes)	warm to cool	30	13	0
Percidae (perches)	cool to cold	117	5	1
Sciaenidae (drums)	tropical to cool	160	3	0
Cichlidae (tilapias)	tropical to warm	700	49	0
Mugilidae (mullets)	tropical to cool	70	14	1
Eleotridae (sleepers)	tropical	150	1	0
Gobiidae (gobies)	tropical	1000	2	0
Anabantidae (climbing gouramies)	tropical	40	5	0
Helostomidae (kissing gouramies)	tropical	1	1	0
Channidae (snakeheads)	tropical	10	5	0

* Anadromous species involved partly in ocean ranching.

but highly relevant. There are three sets of criteria in choosing (Webber and Riordan 1976):

1. Consumer criteria: the fish flesh produced must be attractive to consumers and be marketed at an acceptable price.
2. Biological criteria: the characteristics of the species must be acceptable to New Zealand, environmentally, and be suited to aquaculture; it must be possible to spawn the fish, rear the young, and provide suitable foods, etc.
3. Site criteria: there needs to be a careful matching of species' requirements and the New Zealand aquatic environment.

It does not matter much which of these has highest priority, though there is no use bringing fish here that no-one wants or can afford to buy; nor is it any use making a case for introducing a species that is environmentally unacceptable to decision makers or the public at large. It is possible to modify and adapt the site criteria, at least to some extent.

Throughout the world, about 300 species have been used or investigated for aquaculture (Bardach *et al.* 1972, Jhingran and Gopalakrishnan 1974, Huet 1979, Stickney 1986). They range from tropical to polar in distribution, and may be carnivores, omnivores, or herbivores. Carnivorous species abound at all latitudes, omnivores tend to occur mostly at warmer latitudes, and herbivores are mainly tropical, few of them being grown at warm temperate latitudes and virtually none at cool temperate latitudes (Tables 1 and 2). As a result, few herbivorous/omnivorous fish species are likely to be suited to aquaculture in New Zealand. Furthermore, if we are to depend primarily on higher trophic level carnivores, we will be involved largely in high technology, expensive production of high quality, expensive products. At present supplies of high quality fish meals (the basis for manufactured fish diets) are limiting, and this could be a serious constraint on the expansion and economics of aquaculture in New Zealand.

Table 2: Relationship between geographical distribution and trophic characteristics of fish species used in aquaculture

	Tropical	Warm temperate	Cool temperate	Cold
Carnivores	61 (44%)	69 (61%)	85 (75%)	39 (88%)
Omnivores	59 (42%)	38 (35%)	27 (24%)	5 (12%)
Herbivores	19 (14%)	6 (4%)	1 (1%)	0 (0%)

New Zealand's conditions range from cool temperate in the south to almost warm temperate in the north. Some warm temperate species would find much of the North Island too cold for rapid growth and sexual maturation (e.g., there is real difficulty growing grass and silver carp to maturity at Rotorua, though this would be possible at lower elevations in the Bay of Plenty or north of the Waikato). There are only limited opportunities to extend the temperature range of habitats available to aquaculture by using naturally occurring geothermal waters or heated industrial effluents.

Overall, there seem to be few species that are both suitable and environmentally acceptable. The exclusion of highly predatory fishes means that some candidates will be given only very brief consideration; examples are the pikes (family Esocidae), basses and sunfishes (family Centrarchidae — the largemouth bass was suggested in the 1960s for augmenting angling species, and eventually turned down (McDowall 1968)), additional freshwater perches (family Percidae), temperate basses from Australia (family Percichthyidae), drums (family Sciaenidae), and some cichlids and tilapias (family Cichlidae). Tilapias are also likely to be excluded as they tend to proliferate in the wild and become a nuisance. Imports of additional salmonids are likely to strike barriers for two reasons: at present New Zealand has very few of the troublesome diseases found where salmonids are native, and there would be concerns about possibly harmful interactions between proposed new species and salmonids already acclimatised in New Zealand. The introduction of genetic material of Atlantic salmon, to enrich the impoverished gene pool of New Zealand's captive stocks (Hutchinson 1975), may be possible without jeopardising the disease-free status of our stocks by importing cryopreserved sperm.

A substantial proportion of the species remaining (after all these groups have been discounted) is, in my view, unsuited to New Zealand aquaculture. In this category I put the paddlefishes (family Polyodontidae), clupeid herrings (Clupeidae), osmerid smelts (Osmeridae), suckers (Catastomidae), loaches (Cobitidae), live bearers (Poeciliidae), and silversides (Atherinidae). It does not leave much — sturgeons (Acipenseridae), additional salmonids (though see above), the Japanese ayu (Plecoglossidae), various catfishes (Siluriformes), possibly some tilapias, and the mullets (Mugilidae). We already have a highly suitable mullet here, so introduction of further species should not be considered until the possibilities with our species are exhausted.

Sturgeons are an interesting possibility. There is a growing interest in sturgeon aquaculture in Europe and North America, and considerable progress has been made in developing the necessary technology (Doroshov 1985). The flesh quality of some species is highly regarded and the roe is the basis for caviar; both command high prices. Sturgeons are carnivores, but not piscivores, and feed on benthic animals in the river substrates. Their potential environmental impact needs careful examination, but superficially seems likely to be less damaging than that of some other candidates. Sturgeons are a slow-growing, long-lived species; this reduces their value for aquaculture, but also makes them less likely to be troublesome in the New Zealand environment.

The ayu (*Plecoglossus altivelis*) may be Japan's most valued freshwater fish (Kafuku and Ikenoue 1983). Because of this, a high demand, and declines in the Japanese fisheries, technology for farming it is being developed in Japan, and production had reached 8000 t by 1979. Initially, farming depended on the rearing of wild seed stock, but technology for the artificial maturation and production of ova from captive stock has been developed. The ayu is a herbivore, and so is likely to be less demanding in the foods needed for rearing; it is very unlikely to become established and/or troublesome here.

Many of the catfishes used in aquaculture are temperate in distribution, and some might be sufficiently benign in our environment to make importation safe. Some investigation of catfish aquaculture in North America, Europe, and Asia would be a good investment.

I share a concern that we tend to be looking at high quality aquaculture products in New Zealand that are expensive to produce, use costly foods, and are at the expensive end of the food spectrum. I believe that this will be difficult to change, for it is a product of our temperate climate, the slow growth rates of many of the cheaper aquaculture species, the general demand for known and usually expensive fish products here, and the high cost structure of New Zealand society. I see no easy solutions.

The best possibilities for freshwater aquaculture probably lie in high quality, expensive, often export products based on high technology, using cold water predatory fishes like trout and salmon. Let us make sure that we are exploiting the potential of those species as effectively as possible.

Nevertheless, opportunities may exist for lower quality, cheaper products for the local market, that can compete with the cheaper marine species, based on lower intensity, lower technology, using omnivorous or herbivorous fish species that consume readily available food sources of little or no other value; species already present here may be suited for this purpose.

Finally, we should be imaginative and energetic in identifying species for aquaculture that New Zealand's growing conditions would favour, and which do not pose a threat to our biota or environment, and I think that some such species do exist.

References

Bardach, J.E., Ryther, J.H., and McLarney, W.O. 1972: "Aquaculture — the Farming and Husbandry of Freshwater and Marine Organisms". Wiley, New York. 868 p.

Carruthers, A.D. 1986: Effect of silver carp on blue-green algal blooms in Lake Orakai. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 68.* 63 p.

Craig, J.F. 1987: "The Biology of Perch and Related Fish". Croom Helm, London. 333 p.

Davis, S.F. and Teirney, L.D. 1986: Fish and fisheries. *In* Henriques, P.A. (Ed.), "Aquatic Biology and Hydroelectric Power Development in New Zealand", pp. 237-263. Oxford, Auckland.

Doroshov, I.S. 1985: The biology and culture of sturgeons, Acipenseriformes. *In* Muir, J.E. and Roberts, R.J. (Eds.), "Recent Advances in Aquaculture, Vol. 2", pp. 251-282. Croom Helm, Beckenham.

Hobbs, D.F. 1948: Trout fisheries in New Zealand: their development and management. *N.Z. Marine Department, Fisheries Bulletin No. 9.* 175 p.

Huet, M. 1979: "Textbook of Fish Culture — Breeding and Cultivation of Fish". Fishing News Books, Farnham. 436 p.

Hughes, H.R. 1988: Importation of marron (*Cherax tenuimanus*) — investigation of the Ministry of Agriculture and Fisheries approval procedures. Report by the Parliamentary Commissioner for the Environment, Wellington. 23 p.

Hutchinson, R.T. 1975: Atlantic salmon. *Wildlife — a review 6*: 6-10.

Jellyman, D.J. and Coates, G.D. 1976: The farming of freshwater eels in New Zealand. *Indo-Pacific Fisheries Council 17th Session, Symposium on the development and utilisation of inland fishery resources, panel II (c).* 6 p.

Jhingran, V.G. and Gopalakrishnan, V. 1974: Catalogue of cultivated aquatic organisms. *FAO Fisheries Technical Paper 130*: 1-83.

Jones, J.B. 1981: The aquaculture potential of New Zealand freshwater crayfish. *N.Z. Agricultural Science 15(1)*: 21-23.

Jones, J.B. 1985: Eel farming in New Zealand. *Rivista di Italiana Piscicoltura e Ittiopatalogia 20(2)*: 65-67.

King, C.M. 1984: "Immigrant Killers — Introduced Predators and the Conservation of Birds in New Zealand". Oxford, Auckland. 224 p.

Kafuku, T. and Ikenoue, H. 1983: Modern methods of aquaculture in Japan. *Developments in Aquaculture and Fisheries Science No. 11.* Elsevier, Amsterdam. 216 p.

McDowall, R.M. 1968: The proposed introduction of the largemouth black bass, *Micropterus salmoides* (Lacepede) into New Zealand. *N.Z. Journal of Marine and Freshwater Research 2(2)*: 149-161.

McDowall, R.M. 1984: "The New Zealand Whitebait Book". Reed, Wellington. 210 p.

McDowall, R.M. 1988b: "Diadromy in Fishes — Migrations between Freshwater and Marine Environments". Croom Helm, London. 308 p.

McDowall, R.M. (in press): "New Zealand Freshwater Fishes — a Natural History and Guide". Octopus, Auckland.

Mitchell, C.P. 1980: Do grass carp have a future? *Freshwater Catch 9*: 10-12.

Mitchell, C.P. 1982: A different look at whitebait. *Freshwater Catch 16*: 16-17.

Mitchell, C.P. and Rowe, D.K. 1979: Freshwater fish faming — an alternative for the smallfarmer? *The Smallfarmer (August)*: 29-30.

Rowe, D.K. and Schipper, C.M. 1985: An assessment of the impact of grass carp (*Ctenopharyngodon idella*) in New Zealand waters. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 58.* 177 p.

Shaw, D.J., Fletcher, M., and Gibbs, E.J. 1985: "Taupo — a Treasury of Trout: the Economic Activity Generated by Anglers, their Profiles, Fishing Patterns and Catch in the Taupo Fishing District". N.Z. Wildlife Service. 40 p.

Shorland, F.B. 1978: How good is our diet today? A study of food in relation to life expectancy, with reflections on the ageing process. *N.Z. Journal of Science 21*: 3-40.

Stickney, R.R. 1986: "Culture of Nonsalmonid Freshwater Fishes". CRC Press, Baton Rouge. 201 p.

Webber, H.H. and Riordan, P.F. 1976: Criteria for candidate species for aquaculture. *Aquaculture 7(2)*: 107-123.

Discussion

Q. What effect would a change in climate and water conditions have on freshwater aquaculture?

A. An increase in ambient temperatures would shift cold species south and make it possible to rear additional species in the north. Sockeye salmon have a rather low maximum temperature tolerance so farming them in North Canterbury might become difficult.

Q. Can you see any reason why commercial trout farming cannot be operated hand-in-hand with recreational fishing?

A. Management of recreational fisheries would be more difficult if farming were allowed. Biologically there is no reason why trout farming shouldn't succeed. It's now a political decision.

Q. Why is there confusion as to whether or not the Chatham Islands can be used for trout farming?

A. When trout farming was banned in 1972 the legislation exempted the Chathams. The Fisheries Act 1983 is unequivocal in banning trout farming in New Zealand and that includes the Chatham Islands.

An overview of world and Australasian salmon and finfish production

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Introduction

World aquaculture production figures are collated by the Food and Agriculture Organization (FAO) of the United Nations. Unfortunately, the most up-to-date figures available are only for 1985 (Nash 1988).

At the World Aquaculture Society conference in Hawaii this year, Dr Nash spoke of the difficulties and problems with the collation of this data, and there has been some discussion as to whether the FAO figures represent an underestimation or overestimation of the actual production. Nevertheless, the figures at least give a good indication of the major contributors to aquaculture production.

Production in 1985 was over 10.5 million tonnes, of which 4.7 million tonnes (44.5%) was finfish. Table 1 shows the 1985 world finfish production by geographical areas. Asia is by far the leader, accounting for more than 75% of total world production. For most of the continents, finfish made up about 40–50% of the total, but Africa and U.S.S.R. both had extremely high percentages for finfish — 99.2% and 100% respectively. The figure for Africa is probably a true indication of the finfish contribution, although for the U.S.S.R. data had not been provided for crustaceans, molluscs, or algal production.

Leading producers

The greatest producer of finfish in 1985 was the Peoples Republic of China with 2.4 million tonnes (Table 2). Finfish made up most of the aquaculture production for Indonesia and Vietnam (87.7% and 93.6% respectively). Much of the production in these two countries was extensive polyculture. However, in Japan, where the culture was mostly semi-intensive to intensive, finfish were less than a quarter of total production.

Major species

Production data for 1985 were provided for 102 finfish species. Table 3 shows the nine most important finfish species and the countries with production over 1000 t.

World production was dominated by 25 species of carp which yielded over 2.5 million tonnes; the major species were the bighead, silver, common, and grass carps. Six species of tilapia and cichlids produced 250 000 t, nine species of salmonids produced over 150 000 t, and six species of catfish yielded over 130 000 t, the major species being the channel catfish in the United States. Rainbow trout was the major salmonid with 16 countries producing more than 1000 t. Other important species were Japanese eel and Atlantic, pink, and coho salmon.

Table 1: World finfish production in 1988 (from Nash 1988)

	Finfish production (t)	% of total production
Asia,	3 792 000	42.6
Europe	340 800	40.5
U.S.S.R.	296 000	100(?)
North America	197 000	50.4
Africa	60 600	99.2
South America	28 500	41.8
Oceania	1 200	5.5
Total	4 717 500	

Table 2: Leading producers of finfish in 1985 (from Nash 1988)

Country	Finfish production (t)	Total aquaculture production (t)	Finfish (% of total for country)
China	2 392 800	5 202 000	46.0
U.S.S.R.	296 000	296 000	100(?)
Japan	283 900	1 184 300	24.0
Indonesia	271 900	309 900	87.7
Philippines	243 700	494 800	49.3
U.S.	195 200	353 200	55.3
Vietnam	191 000	204 000	93.6
Rest of world	201 700	988 200	20.4

Asian production

Table 4 gives the 1985 finfish and total production figures for 16 Asian countries. Of the 8.5 million tonnes produced in Asia during 1985, finfish contributed over 3.5 million tonnes. The leading finfish producing countries, the Peoples Republic of China, Japan, Indonesia, the Philippines, and Taiwan together made up over 80% of the Asian total finfish production.

Table 3: Important finfish species and countries with production over 1000 t in 1985 (from Nash 1988)

Species	World production (t)	Countries
Bighead carp	850 800	China, Hong Kong, Malaysia, Hungary
Silver carp	838 600	China, Hungary
Common carp	365 100	Indonesia, China, Japan, Iraq, Israel, Austria, France, Italy, Czechoslovakia, German Democratic Republic, German Federal Republic, Hungary, Bulgaria, Turkey
Milkfish	329 000	Indonesia, Philippines
Grass carp	297 000	China, Malaysia
Tilapia (various)	194 500	Indonesia, China, Japan, Hong Kong, Thailand, Philippines
Japanese amberjack	152 300	Japan
Rainbow trout	150 400	U.S., Japan, Austria, France, Italy, Norway, Spain, Sweden, German Democratic Republic, United Kingdom, Turkey, Finland, German Federal Republic, Greece, Portugal
Channel catfish	122 900	U.S.

Salmonids

Salmonid production has grown enormously over the past decade. From a world production total of 38 000 t in 1985, the projection for 1990 is 195 000 t, although some experts predict even higher figures. Three quarters of this production will consist of Atlantic salmon, with the silver (coho) and chinook Pacific salmons being the next two most important species. The degree of this increase will be governed by the ability of the major salmon markets in Japan and the United States to absorb the extra salmon.

Leading salmon producing countries include Norway, the United Kingdom, Japan, Canada, Ireland, Chile, Australia, New Zealand, the United States, and the Faeroe Islands.

Over 80% of world salmonid production occurs in Norway. Here fish farming is ranked as one of the most important growth industries of the 1980s. According to the Export Council of Norway, output has expanded at an annual rate of 30–40% since 1980. In addition to salmonids, a variety of other species are cultured including halibut, turbot, lobsters, oysters, cod, plaice, and mussels.

Table 4: Aquaculture production in some Asian countries (1985) (Source: FAO estimates, courtesy of M.B. New and M.A. Robinson)

Country	Finfish (t)	Total (t)
Bangladesh	117 6194	8 125 197
Burma	5 044	8 5 044
India	–	8 18 800
Nepal	3 795	3 795
Pakistan	17 800	17 800
Sri Lanka	50	52
Malaysia	5 594	50 583
Philippines	243 728	494 485
Indonesia	271 879	309 910
Thailand	42 400	99 000
Singapore	334	1 191
China	2 392 841	5 202 210
Taiwan	130 189	231 382
Hong Kong	7 389	7 453
South Korea	3 745	770 594
Japan	283 870	1 175 789
Asian total	3 526 277	8 513 285
% of Asian total	41.4	100.0
% of world total	72.7	78.4
Total world	4 847 729	10 857 660

There has been substantial Norwegian investment and expertise in Canada, Chile, the United States, Australia, and New Zealand.

The Norwegian salmonid industry has increased from almost 7000 t in 1979 to an expected production of 80 000 t in 1988. This represents a fourfold increase in rainbow trout production, and a twelvefold increase in Atlantic salmon.

The recent toxic algal bloom was less diastrous than was first thought. Altogether only 600 t of fish were lost from the southern parts of Norway. Quick action by industry and government saw the initiation of a rescue co-ordination group which supervised the movement of some 1800 cages on 115 fish farms from the affected areas to the heads of fjords where the lower salinity water prevented the spread of the algae. This meant that the marketing of Norwegian salmon has been largely unaffected by the algal bloom (Anon. 1988a).

Catfish production in the United States

Since 1976, production of channel catfish has risen from 8600 t to over 100 000 t in 1987. About 80% of production is in the Mississippi Delta region; other leading areas are Arkansas and Alabama.

Other species of importance in the United States are Pacific salmon, rainbow trout, red fish, and hybrid striped bass.

Australian developments

Over the past few years there has been an explosion of interest in aquaculture in Australia. This has resulted in a number of companies being listed on the stock exchange; Sea Hatcheries Ltd. (barramundi), Marine Industries Ltd., Tasmanian Atlantic Salmon Ltd., and Tassal Ltd. (salmonids), and Southern Sea Farms Ltd. (marine fish).

According to statistics supplied to FAO by the Australian Fisheries Service, the value of production of finfish was A$13.7 million in 1986 and A$10.2 million in 1987. However, because of data collection problems, these figures must be considered conservative (Anon. 1988b).

The production and value of the major finfish species in Australia in 1986 and 1987 are given in Table 5; these figures are conservative owing to problems and deficiencies in data collection.

Sea cage culture of Atlantic salmon in Tasmania has seen much development with almost one dozen farms operating from more than 25 sites. Production for 1987–88 is expected to be about 650 t, plus about 1200 t of rainbow trout (Gjovik 1987). By 1989–90 these figures are expected to increase to 3000 and 1500 t respectively.

Commercial salmonid culture is also being undertaken in Western Australia and Victoria, and there are plans for an integrated on-land culture facility in Queensland. Production in these states could be as high as 3000 t by 1990.

The production of plate size (400–600 g) barramundi (*Lates calcarifer*) in Queensland is expanding rapidly. At present there are 10 permits for the culture of barramundi. According to the Queensland Department of Primary Industries, production should increase from 1 t (1986–87) to 50 t this season (1987–88). As fingerling supplies improve, production is set to soar, with 300–500 t projected for the major barramundi farming company, Sea Hatcheries Ltd., in 1988–89.

Sea Hatcheries has a A$1.5 million hatchery/nursery complex at Mourilyan Harbour (south of Cairns, Queensland) and a floating cage farm in the Hinchinbrooke Channel (200 km south of Cairns). Continuous upgrading of equipment and techniques has occurred at all levels of Sea Hatcheries's production over the past 12 months, including the development of consistently successful induced spawning of both wild and captive brood stock; greatly improved weaning diets; fish grading equipment and techniques; cage maintenance and changing systems; and fish processing, handling, distribution, and marketing procedures.

Sea Hatcheries also has joint ventures with a freshwater farming operation at Gordonvale (20 km south of Cairns), and a second marine farm with Comalco (Aust.) Ltd. and the Weipa South Aboriginal and Islander Community in far north Queensland.

Problems with the differentiation of farmed versus wild caught barramundi have to be addressed, but this is a management issue. An interesting development is the advent of integrated culture with penaeid prawns which is under trial. Sea Hatcheries are examining the breeding and culture of other marine fish such as golden snapper (*Lutianus johni*), mangrove jacks (*L. argentimaculatus*), and two species of estuarine cods (*Epinephelus tauvina* and *E. malabaricus*).

Southern Sea Farms Ltd. in Western Australia are ready to move into pilot scale production of mahi mahi or dolphinfish (*Coryphaena hippurus*). This fish has amazing aquaculture potential as it can be grown in commercial quantities to 2 kg in only 6 months. The fecundity of the mahi mahi is also incredible — a 10 kg female can produce over 500 000 eggs a week. Given only a 10% survival rate for the offspring, one female could give rise to 1000 t of fish each year.

Southern Sea Farms have built a comprehensive data base on the effects of stress, feeds, stocking densities, and handling procedures on the culture and growth of mahi mahi. This thorough investigation of all the factors affecting the culture of mahi mahi by Southern Sea Farms should be an example to the rest of the industry. Southern Sea Farms are also investigating the potential of several other high priced marine fish, including yellowtail kingfish (*Seriola lalandi*), samson fish (*S. hippos*), and dhufish (*Glaucosoma hebaicum*).

The stocking of lakes and farm dams with native fish for recreational fishing and/or food production is becoming popular in Australia. Species include barramundi, silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), catfish (*Tandanus tandanus*), and the Murray cod (*Maccullochella peeli*). Interest in the culture of some non-commercial species for restocking waterways is also high.

The goldfish and aquarium fish industry in Australia is a major contributor to the value of aquaculture production; estimates put this industry at A$80 million in 1976–77. Unfortunately, no recent figures are available, but just allowing for inflation and population growth could give an estimate near A$200 million by 1990.

An interesting area for future development in Australian finfish culture will be the selection of a

Table 5: Production and value of finfish species in Australia (1986–87)

Species	Production (t)		Price (A$ per kg)		Value (A$ 000)	
	1986	1987	1986	1987	1986	1987
Barramundi	2	1	8.00	8.00	16	8
Rainbow trout	5	426	4.70–9.00	5.07–10.68	3 148	3 429
Brown trout	21	2	6.00	6.80	18	14
Unspecified trout	–	800	–	5.75	–	4 600
Atlantic salmon	10	62	20.00	16.50–23.50	200	1 095
Goldfish	100	na*	100.00	na	10 050	na
Redfin	50	na	3.00	na	150	na
Eel	50	200	3.50	5.50	175	1 100

* Not available.

herbivorous fish for polyculture with freshwater crayfish such as marron (*Cherax tenuimanus*), yabby (*C. destructor*), red claw (*C. quadricarinatus*), and the giant freshwater prawn (*Macrobrachium* sp.). Such a fish would provide benefits not only in algae and aquatic plant control, but also in improved production rates and greater returns on investment. However, the marketing prospects of such fish species must be considered first.

Giant aquariums

Although giant aquariums and sea-life parks are not in the mainstream of aquaculture, facilities such as Kelly Tarlton's Underwater World in Auckland and others around the world represent an interesting diversion for aquaculture. These facilities are at the forefront of education and play a major role in increasing the awareness of the general public in marine science, aquaculture, and the need for clean, unpolluted waters.

The aquaculture industry can learn from these aquariums and marine parks about the keeping of many different species and such important skills as health maintenance, water quality control, and breeding.

The future

Dr Liao of the Tung Kung Fisheries Research Station in Taiwan gave an extremely interesting paper at the World Aquaculture Society conference in Hawaii (Liao 1988). He saw sea-ranching as the growth area of the future, especially given the success of some of the Japanese experiments.

Given that the major seafood markets of Japan, the United States, and Europe will continue to grow, and that the production from wild capture fisheries have reached their zeniths, there is no doubt that aquaculture has a great future. FAO estimates that by 1990 there will be a 200 million tonne shortfall in production to satisfy the demand for seafood. Fishfarming is certain to fill this shortfall. A major part of this increase will be from expanded production of salmonids, carps, milkfish, catfish, and some species of marine fish such as barramundi and mahi mahi. Areas where development work is needed include hybridisation and genetic manipulation, feed formulations and manufacture, and intensive culture and/or polyculture.

Acknowledgments

My sincere thanks to the MAFFish group of the New Zealand Ministry of Agriculture and Fisheries for inviting me to speak at this conference. I also thank the following people who kindly provided me with information and slides for my paper: Mike Heasman (Sea Hatcheries Ltd., Queensland); Lynda Cowan (Fisheries Aquaculture Research Associates, New South Wales); Steve Nell and Alan Wall (Southern Sea Farms Ltd., Western Australia); Rees Griffiths (University of New South Wales); Jan Gjovik (Tassal Ltd., Tasmania); Dan Cohen (Aquaculture Production Technology Ltd., Israel); R.F. Middelmann (Department of Primary Industries and Energy, Canberra, ACT); Angela Kaplan (Trade Commission of Norway); Hon. Neville Harper (Minister for Primary Industry, Queensland); and Simon Stanley and Colin Grant (Sea Fisheries, Tasmania).

References

Anon. 1988a: Norwegian algal bloom update. *Austasia Aquaculture Magazine 3(2)*: 21.

Anon. 1988b: Oysters our top producer in 1985. *Austasia Aquaculture Magazine 2(11)*: 5–8.

Gjovik, J. 1987: Marine farming of salmon and trout in Tasmania. *Austasia Aquaculture Magazine 2(7)*: 4–5.

Liao, I. 1988: East meets west: an eastern perspective. Keynote paper presented to the Annual Conference of the World Aquaculture Society, Honolulu, Hawaii. 17 p.

Nash, C.E. 1988: A global view of aquaculture production. Plenary paper presented to the Annual Conference of the World Aquaculture Society, Honolulu, Hawaii. 21 p.

Rhodes, R. 1988: Status of world aquaculture 1987. *In* Homer, K. (Ed.), "Aquaculture Magazine Buyer's Guide '88 and Industry Directory", pp. 4–18. Aquaculture Magazine, Asheville, North Carolina.

Discussion

Q. How important is it for an industry to have good statistics?

A. I think it's very important. Statistics should be used by and for the industry to determine trends and new developments. The industry should try and get behind the Fisheries Department and help it as much as possible.

Q. What is the genetic base of the salmon in Australia?

A. They come from a number of importations from Canada and have adapted to Australian conditions over 30–40 years. We (Australia) are fortunate in having disease-free stock and our industry is totally opposed to the importation of fresh salmon products from Canada which could threaten this.

Q. Could you tell us something about the balance between industry-funded research and government — or public-funded research in Australia?

A. I think that industry must realise it can't work entirely on its own. Sponsored research in universities is going to become very important in Australia. Government departments and fisheries departments have funding problems, and though it won't come easily, industry is going to have to come across with money.

Q. Can you tell us about the types of polyculture practised in Australia?

A. There isn't much polyculture at present, except for some crustaceans. It's not been done on an economic basis yet, but it should be looked at over the next few years.

Development of salmon farming in New Zealand: prospects for the future

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Introduction

Salmon farming is currently the fastest growing aquaculture industry in New Zealand. Production forecasts for the 1988–89 season show that salmon will be close to or exceed the present export value of mussels, the present most valuable aquaculture industry.

The recent rapid growth in investment and production of salmon in New Zealand is part of a worldwide expansion in salmon farming. In Norway over the past 10 years there has been a phenomenal increase in the production of farmed Atlantic salmon in sea cages. Salmon are now Norway's third most valuable industry, after oil and forestry. The Norwegian success is being emulated by a number of countries, most notably the United Kingdom (Scotland), Ireland, Canada, and Chile. This rapid growth has come about because of the successful technology that has been developed for farming Atlantic salmon, and which is now being adapted for other species.

So far the world production of salmon has been expanding in response to market demand. Some have expressed concern about increased supplies affecting market prices, but at present the public seems to have an insatiable demand for salmon and New Zealand farmers cannot produce enough to satisfy the demand for our own chinook salmon.

Development of salmon farming

Three species of salmon are present in New Zealand, all introduced from the Northern Hemisphere. These are two species of Pacific salmon, chinook (*Oncorhynchus tshawytscha*) and sockeye (*Oncorhynchus nerka*), and Atlantic salmon (*Salmo salar*). In North America and Japan, chinook is commonly marketed as king salmon.

Chinook and sockeye salmon were introduced from North America in 1901. The chinook established self-sustaining populations in rivers along the east coast of the South Island, and the stock has proved ideal for aquaculture. There is a good genetic base and the species is suitable for all three methods of salmon aquaculture being practised in New Zealand: ocean ranching, sea cage (net pen) culture, and freshwater pond rearing.

Sockeye salmon failed to establish a sea-run and became voluntarily lake limited, completing their entire life cycle in fresh water. There is some freshwater pond rearing of sockeye, but production is very small compared with chinook. Attempts at sea cage rearing have not been successful.

Like sockeye, Atlantic salmon failed to establish self-sustaining sea-run populations and became voluntarily lake limited. Experiments with cage culture have had limited success. The stock used for aquaculture trials was derived from a hatchery brood stock with a very poor genetic base. For any progress to be made with Atlantic salmon culture in New Zealand, new genetic material will be required. This could be achieved by using what remains of the wild stock or importing new genetic material from overseas in the form of eyed eggs or milt. There has been some interest in importing Atlantic salmon for cage culture. There are certainly some advantages in using this species in preference to chinook. Atlantic salmon are easier to handle at sorting and harvest, the technology for culturing the species is well established, and the market for it is well developed. However, New Zealand farmers are developing unique and successful technologies for farming chinook under New Zealand conditions. Against this must be balanced the disease risk from introducing new stock and the competition New Zealand Atlantic salmon farmers would face from already well established producers (such as Norway and Scotland) in the Northern Hemisphere and developing farms in Chile and Tasmania in the Southern Hemisphere.

Ocean ranching

Ocean ranching entails the rearing of juvenile salmon in fresh water and their subsequent release to the sea where they feed and grow to adult size. As maturing adults, they should then conveniently return to the place of release.

Commercial salmon farming in New Zealand started in 1976 with the introduction of ocean ranching which was expected to enhance the recreational fishery. Two types of operation have developed, upriver brood stock hatcheries and coastal release and recapture sites. Ocean ranching was accepted by anglers as they would be able to catch returning salmon as they moved up river. The hatcheries were at first located well up river, close to the spawning grounds, and the fish were suitable only for brood stock purposes. The flesh quality of most of these salmon is not of marketable quality. These upriver hatcheries have been successful in enhancing the fishery and producing stock for other farming operations.

To overcome the problem of getting marketable fish back to farm sites, coastal release and recapture sites have been developed to harvest returning salmon. Eggs or juveniles are transferred from upstream brood stock hatcheries and reared at freshwater sites adjacent to the sea or an estuary. The fish return directly to these sites in prime market condition, similar to salmon entering rivers from the ocean.

There are currently seven licensed upriver hatcheries and one Government hatchery. There are four coastal sites, although only one (the New Zealand Salmon Co. Ltd.) has had any substantial returns.

Sea cage culture

In sea cage culture juvenile salmon are transferred from fresh water to sea cages where they are fed and grown to market size. A dry pellet food is used and the red flesh colour is imparted by natural pigments added to the diet up to 7 months before harvest. Unlike the ocean rancher, a sea cage farmer has control over his stock and can harvest over an extended period. This method of culture is at the forefront of the world expansion in salmon farming. In New Zealand there are currently 11 sea cage operations in the Marlborough Sounds, Akaroa Harbour, and Stewart Island.

New Zealand salmon farmers are the world leaders in developing sea cage systems for growing chinook salmon. The cage culture of chinook salmon is expanding in British Columbia and Chile, but at present New Zealand is the largest producer of this species.

The first sea cage operation started in Stewart Island in 1982. Sea cage culture is now the dominant method of farming and accounts for over 90% of total salmon farm production.

Freshwater pond rearing

As with sea cage culture, fish are grown to market size in captivity, but in fresh water.

There are 11 freshwater pond rearing farms, most of them in Canterbury. Two of these are large operations, producing between them about 70 to 200 t. This method of culture has attracted much attention from conventional New Zealand farmers who have a suitable supply of fresh water and are interested in farm diversification. Several small scale operations have been developed, aiming to produce about 5 to 10 t per year. Pond-rearing farmers have produced mainly pan or plate sized fish of up to 600 g that have been used to supply the domestic, restaurant and hotel trade, although some fish have been exported.

Production

Salmon farming in New Zealand is mainly an export industry with its major markets in the U.S. and Japan. The marketing of salmon throughout the world is such that the sea caught product is available from about May to October. Between October and May, when sea caught fish are not available, farmed salmon finds a market in Japan and the U.S. In these markets, New Zealand has to compete with Norway and Chile, and with Canada as its production increases. To date, most of the salmon for export has been produced from sea cages. The fish are harvested between October and March, although innovative husbandry techniques now permit some farms to harvest fish on a year-round basis.

Total farm production for the 1987–88 season was about 1200 t, compared with about 700 t in 1986–87. Salmon exports for the 1987–88 season were 1000 t valued at $9 million f.o.b. Production forecasts for next season are 2000 t, with an export value of $24 million. The dollar per kilogram increase represents the sale of larger fish and the growing recognition by the market of the high quality of New Zealand farmed salmon.

Production beyond the 1988–89 season is difficult to predict, but could be about 4000 t by the early 1990s. The production from sea cages and pond rearing can be calculated, but it is not possible to predict the amount likely to be produced from ocean ranching.

Most of the salmon produced for sale in the world is caught at sea by commercial fishing vessels. The annual catch of Pacific salmon is stable at about 600 000 to 700 000 t, and of Atlantic salmon at 10 800 t. The contribution of farmed salmon to total salmon production is increasing rapidly. Production of farmed Atlantic salmon was about 75 000 t in 1987, some seven times greater than the commercial fishery. The market potential for Atlantic salmon has been estimated at 120 000 t by 1990 (Dale *et al.* 1986). Production will be concentrated in Norway, where

Table 1: World sea cage farmed salmon production (t) (Anon. 1988)

Country	1987	1990
Norway	47 000	100 000
Scotland	12 600	25 000
Faeroes	4 000	6 000
Iceland	1 000	3 000
Ireland	2 500	10 000
U.S.	2 500	4 000
British Columbia	1 500	16 000
Japan	6 000	9 000
Chile	1 600	5 500
New Zealand	1 200	4 000
Tasmania	--	7 000
Total	79 900	189 500

the projected production for 1990 is 100 000 t. Other major producers will be Scotland, the Faeroes, and Ireland (Table 1). However, recent problems associated with salmon farming in Norway and Scotland, such as cardiac arrest in large fish, disease problems, algal blooms off Norway, and a public backlash against the uncontrolled expansion of salmon farming in some of these countries, casts some doubt on the production forecasts.

The production of farmed Pacific salmon in the U.S. in 1983 was estimated to be 1600 t from sea cages and 9500 t from ocean ranching (New 1986). Production from Japan was nearly 3000 t in 1983 and is expected to increase to 9000 t by 1990. Chile is expected to be producing 8000–10 000 t annually by the early 1990s. Excluding ocean ranched fish, the farm production of Pacific salmon could be 15 000 t by the early 1990s, of which New Zealand might have a 27% share.

The total worldwide production of farmed salmon will be between 186 500 and 191 000 t by 1990, increasing to nearly 400 000 t by the end of the century. The market driven state of the industry is expected to continue until 1990, after which it is anticipated there will be a levelling in supplies and prices. With increasing supplies, price declines are inevitable (Anon. 1988).

Prospects for the future

With these world production forecasts in mind, what are the prospects for salmon farming in New Zealand?

Because of the projected world increase in salmon production, New Zealand cannot expect to be a major producer and must, therefore, find a market niche. To an extent, this has already been achieved with our exports of fresh chilled salmon to the U.S., and chilled and frozen salmon to Japan. However, there will be increasing competition. Chile already affects the price structure when its fish enters the market about January and prices drop. In addition, Northern Hemisphere producers can now harvest fish all year round. Our present advantage is in producing chinook salmon which is readily accepted on the market and can command better prices than Atlantic salmon. Chile's production is mainly coho salmon, which does not fetch the high price of chinook, although production is shifting towards more chinook and some Atlantics.

As a potential producer of chinook salmon, British Columbia also offers competition. In November 1987 there were 118 operating farms with a total capacity of 18 000 t. Chinook salmon made up 65% of the total stock (Caine *et al.*). Although the 1987 farm production was about 850 t, production is set to show a massive increase over the next few years.

The salmon industry in New Zealand is currently nearing the end of the first stage of development of any new aquaculture industry, that of developing production systems. There has recently been some rationalisation within the industry as some farms have closed. The initial investment expectations of salmon farming were too high, particularly for ocean ranching, and for sea cages there was a lack of appreciation of the need to develop a technology to suit New Zealand conditions.

Ocean ranching has always been the method to attract most public attention, and it does have the potential to produce large numbers of salmon. (This potential has not yet been realised and it is difficult to state if and when it will be.) Unfortunately, the recent phase of development of coastal release and recapture sites has coincided with a substantial by-catch of salmon at sea by commercial fishing vessels and poor natural survival of salmon over the past 2 years. The Minister of Fisheries has recently introduced a management plan for salmon to reduce the by-catch, but ocean ranching will always be subject to the problem of varying natural survival beyond the control of the farmer.

Sea cages are likely to remain the predominant method of culture, but the possibility for expansion using current techniques is limited because of a shortage of sites. The temperature requirements of salmon are such that sea cage production will be limited to the South Island. At first glance the Marlborough Sounds looks an ideal area for salmon farming with an already established mussel industry. However, much of the inner Sounds is unsuitable because of shallow water and water temperatures over 20 °C. Salmon farms require certain biophysical features, such as a water depth of at least 20 m and good current flow around and through the cages. In the final analysis, there will be few such sites available for traditional cage rearing using small cages.

The potential for improving and expanding production lies in the use of new technologies, and in particular the use of larger cages. The first sea cages in New Zealand had a capacity of

200–250 m³. Cage size has progressively increased. One company has been using an imported Bridgestone cage of 8000 m³ and another has constructed a cage with a capacity of 15 000 m³. A third company is constructing two cage complexes, each of four 4000 m³ cages, giving a rearing capacity of 16 000 m³.

This new cage technology will enable the industry to use more exposed sites, and the outer Marlborough Sounds have now become the focus for future development. This area offers deeper water, lower temperatures, and less conflict with other user groups. Overseas, large offshore cages are being used off the coasts of Iceland and Ireland, and in the Baltic. The sky seems to be the limit, a new cage farm has just started 10 nautical miles off the coast of northern Norway in the open North Sea in a water depth of 150 m. The cages have been designed to withstand 22 m waves.

Larger cages also make for more efficient production. Large, 500 t plus production farms using large cages are able to considerably lower the production cost per tonne. This improvement in production efficiency will be a key factor in enabling New Zealand farmers to compete with overseas producers. On this basis, New Zealand production costs can compare very favourably with those in Norway and Scotland, and even Chile.

Other means of improving production include the use of all female stock (in which there is considerable interest) and onshore sites supplied with sea water. There is one shore-based salt water farm operating in Marlborough, and there are several pumped sea water farms operating in Norway, Scotland, and British Columbia. This method of culture offers more control over environmental conditions and the ability to stock fish at much higher densities than is possible in sea cages.

Much concern has been expressed over the environmental impact of salmon farming. There is certainly some impact, but provided farms are sited correctly this impact can be minimised. Marine aquaculture, including salmon, is dependent on maintaining a clean environment. With salmon farming, the first to suffer from the consequences of poor site selection and contamination of the sea bed under the cages are the salmon themselves, and consequently the farmer. Salmon require good water quality and movement of water through and under the cages to maintain good growing conditions.

What impact there is from salmon farming in New Zealand must be put into perspective against the impact of other users. In the Marlborough Sounds, for example, land clearance and forestry have vastly altered the environment. Very little imported material is used in marine farming, and this activity is an example of a growing industry using the natural resources of the country in a non-exploitive and renewable manner. The present and potential economic benefits of marine farming to New Zealand are surely of vital importance in the present economic circumstances.

Alternative finfish species

Although current marine finfish aquaculture in New Zealand is concentrated on salmon, there has been interest expressed in the cage culture of other species, such as snapper. In New Zealand, the focus on alternatives to salmon will be species that have a high market value and can be successfully grown in our cooler, temperate waters. The most obvious alternative, if we ignore the current legal situation, is rainbow trout. The technology is well established, the markets favourable, and good stock is available in New Zealand.

Rainbow trout are farmed in sea cages in conjunction with salmon in Norway, Scotland, British Columbia, Chile, and Tasmania. Australian sea trout are currently fetching good prices on the Japanese market. Trout are more tolerant of reduced salinities and lower oxygen levels than chinook salmon and, therefore, may be suitable for sites that are unsuitable for salmon.

The prospect of trout farming will undoubtedly again raise considerable opposition, as it did in the early 1970s. However, to those who oppose trout farming, we would suggest that such an industry today would not be the type of industry that was considered 15 years ago. In the past, trout farming has been considered as a freshwater farming operation. However, the reality now is that if trout farming were allowed, most of the production would come from sea cages. As such, trout farming would be concentrated in the South Island where the most suitable sites would be found. Perhaps the most sensible way to introduce trout farming into New Zealand that would be most acceptable to the different interest groups would be to restrict the commercial production of trout to sea cages.

What are the main issues concerning salmon farming at present that the industry and Government agencies consider most important? They are the licensing of marine salmon farms and environmental impact.

Much concern has been expressed by farmers over the licensing system, but it is accepted that this is partly a consequence of being in the forefront of a new industry for which the ground rules had not been established. The establishment of salmon sea cage farming has been a learning process for both the industry and Government agencies responsible for licensing. Legislative and licensing procedures are now needed to allow farmers to expand into new areas using new technology and encourage investment. Now that the technology for the farming of chinook salmon in New Zealand has been proven commercially viable, are the management systems in place to permit the continued expansion of the salmon farming industry into the 1990s?

We consider the future of salmon farming and finfish culture in general to be very positive. The main focus for this future will be sea cage culture, the use of large cage technology in more open water sites, and improved production efficiency. We are confident that there is a long term place in the world market for high quality chinook salmon produced in a clean Southern Hemisphere environment.

References

Anon. 1988: Norwegian farm future still bright. *Fish Farming International 15(3)*: 18–19.

Dale, E., Owens, J., and Stenseth, A. 1986: 120 000-ton market for farmed salmon. *Fish Farming International 13(4)*: 10–11.

Caine, G., Wall, L., Truscott, J., and Deegan, R. 1983: 1987 salmon farm survey. Unpublished report, Ministry of Agriculture and Fisheries, Province of British Columbia. 27 p.

New, M.B. 1986: Can aquaculture restore the balance? *Australian Fishexpo 1986, Adelaide 30 July — 1 August 1986*: 16–32.

Discussion

Q. The expansion of salmon farming in New Zealand could be limited by a lack of suitable sites for either biological or "bureaucratic" reasons. Is there any likelihood of more sites becoming available?

A. We see future expansion in terms of sea cages in more exposed sites, particularly the outer Marlborough Sounds. Maritime planning in this area seems to have considered only mussel farming. We need to identify the right sites from a biophysical viewpoint, and then check on conflicting uses.

Q. Is there a case to be made for bringing in fish from Tasmania, assuming they have a better genetic base?

A. It's an assumption that Tasmanian fish are better. I believe their genetic base is quite limited, and better stocks are available in the Northern Hemisphere. The risks could be minimised by bringing in cryopreserved milt from a certified source rather than eyed eggs.

Q. Is there a suitable fish species in New Zealand for the biological control of sea lice, as in Norway?

A. There probably is one, but fortunately we don't have a sea lice problem in sea cages.

Finfish nutrition and feed: a constraint for the future

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Introduction

The farming of finfish, in particular salmon, in New Zealand is a relatively new venture. The concept of farming "ocean release" salmon, however, is not new and began in the early 1950s. The salmon industry is coming of age and is now an overseas money earner. The industry is going through puberty, and, like all adolescents, it has limitations placed upon it and has its share of problems, not least being the problems of nutrition and feeding. Before discussing nutritional problems and limitations, it is important to clearly define the nutritional objectives of the industry. What is ideal and what can be achieved currently? What do we have to do to reach the ideal, and what is it going to cost us to achieve it?

Nutritional objectives and principles

The nutritional objective of a commercial finfish farming operation must be to minimise feed cost per kilogram liveweight of good quality salable fish. (Feed accounts for up to 70% of the cost of farming salmon.)

Before this objective can be achieved, the feeding requirements of the species being farmed must be assessed. The common nutritional principles of feeding all fish can be applied to particular species, and species differences then accommodated. Growing and reproducing fish require protein and amino acids, lipids, fatty acids, vitamins, minerals, trace elements, pigments, and energy. These are obtained from various feed ingredients, where they must be present in a form available to the fish. Various raw materials are combined to produce a diet which meets the requirements of particular species. The diet is said to be "nutritionally balanced" when it provides adequate amounts of the essential nutrients in the correct proportions. Nutritionists spend much of their time determining the "ideal" balance of nutrients for various species, and putting together raw materials to meet it at minimum cost.

Feed palatability is a major consideration, and can limit the type of raw materials included in the diet. Feed particle size and presentation affect the acceptability of feed to fish. The manufacturing process can affect the nutritional quality and acceptability of the diet; in particular, nutrient availability may be improved or reduced, depending on the process.

The nutrient requirements of various fish species have been detailed elsewhere (e.g., Halver 1972, Cowey and Sargent 1979, National Research Council 1981). This paper will examine the nutrients which are important to all fish and which influence the feeding of fish in New Zealand.

Protein and amino acids

For fish to grow and replace worn out tissues, protein must be supplied in the diet. Proteins are composed of amino acids and each protein has its own unique amino acid profile. Some amino acids can be produced in the body from other nutrients (non-essential), others can not and must be supplied in the diet (essential). If one or more of these amino acids is not present, then protein production becomes limited by the most limiting amino acid. Any excess amino acids are broken down and subsequently lost to the fish.

Some raw materials provide the right amounts of amino acids better than others. Raw materials of different amino acid composition can be combined so that the composition of the final raw material is close to that required by the fish for protein manufacture. The closer the diet is to the ideal balance for the fish, the less the inefficiency.

The suitability of a protein source for inclusion in fish diets depends on three factors: firstly, the amino acid content of the protein in absolute terms; secondly, the availability of these amino acids and their balance; and thirdly, the amino acid balance needed by the fish for the purpose of maintenance, growth, and reproduction. With "high quality" proteins it is possible to achieve an efficiency of retention of digested protein as high as 70%.

Lipids

Fish use lipids for energy, for cellular structure, and for maintenance of membrane integrity. Membrane fluidity is regulated in part by the fatty acid composition of the phospholipids that control such processes as cellular transport and the activities of membrane-associated enzymes. Today's commercial diets for salmonids have a high fat content, reflecting the quantities of polyunsaturated lipid in the natural diets of cold water and marine fishes. The lipid requirements for fish are not adequately defined, but there is a preference for marine lipids because they are richer in fat soluble vitamins and highly unsaturated fatty acids than those of terrestrial animals.

The high degree of unsaturation of fish oils imposes stringent dietary requirements of marine fish for certain long chain polyunsaturated fatty acids (omega 3). Fish, especially marine species, have a high oil content, so lipid rather than carbohydrate is the favoured energy source. Adequate energy provided in the form of dietary lipids can minimise the use of more costly protein, and increase the efficiency of protein utilisation.

Fatty acids

Fish tissues usually contain predominantly polyunsaturated fatty acids of the omega 3 series rather than the omega 6 series found in terrestrial animals. Most fish species require omega 3 polyunsaturated fatty acids. This specific requirement reflects a major characteristic of their environment — low and constant temperatures. The degree of fatty acid unsaturation in fish tissue increases when the environmental temperature is lowered, thereby maintaining membrane fluidity to allow normal cellular functions. An increase in temperature leads to reduced unsaturation. Thus fish reared at warm temperatures are likely to have polyunsaturated fatty acid requirements different from fish raised at lower temperatures. Many fish raised at low temperatures (10–20 °C) have specific requirements for omega 3 polyunsaturates, as occurs in New Zealand. In contrast, channel catfish can be equally successfully raised at 30 °C, their optimal temperature, on diets containing either beef tallow or olive oil (omega 6) or menhaden oil (omega 3) as sole lipid supplements.

Wax esters

Wax esters are the normal dietary lipid of many commercial species, including young salmonids. Their natural diet is predominantly zooplankton, particularly calanoid copepods, which contain wax esters as their major lipid reserve (up to two-thirds of their dry body weight). Wax esters are not present to any appreciable extent in the freshwater environment and are not generally consumed by freshwater fishes.

High levels of dietary wax esters may overload the metabolic capacity of the intestine in some species. Young salmonids actively feeding on copepods produce numerous floating faecal pellets rich in wax ester. The efficiency of assimilation of wax esters by fish is not known.

Vitamins

Vitamins are organic compounds required in minute amounts for normal growth, reproduction, and general maintenance of fish metabolism. In commercial fish diets in New Zealand they are added via a premix; all vitamins are currently imported. Ascorbic acid, a vitamin essential to fish performance, is easily destroyed during feed manufacture.

Minerals and trace elements

Minerals and trace elements perform a wide variety of structural, biochemical, and physiological functions. In commercial diets in New Zealand, trace elements are usually added via a mineral premix. At least part of salmonid mineral requirements can be obtained directly from the water, others are more effectively obtained from feed sources.

Energy

Energy is required for maintenance, growth, and reproduction. Three classes of compounds provide dietary energy; protein, lipid, and carbohydrate. Both lipid and carbohydrate have a sparing effect on protein for energy, so for maximum protein deposition adequate levels of these compounds must be included in the diet. Carbohydrates are the least expensive form of dietary energy, but as fish resemble diabetic higher animals in their use of them, their level in the feed should be restricted. Adequate levels of lipid in the feed are essential for maximum performance.

The optimum energy level should be provided in diets because excess or deficiency can result in reduced growth rates. Energy needs for maintenance and voluntary activity must be satisfied before energy is available for growth, so dietary protein will be used for energy when the diet is deficient in energy in relation to protein. However, excessive energy intake can lead to a deposition of large amounts of body fat. This is undesirable in food fish because it reduces dressing percentages and shortens the shelf life of frozen fish, but may be desirable in hatchery fish reared for release or transfer to alternative on-growing sites. The design of practical feeds is usually a compromise between a protein level that produces good growth with little conversion to energy, and an energy level that gives high rates of protein synthesis, but does not result in undesirably high levels of carcass lipid.

Feed specifications

The specifications of some salmon diets currently produced in New Zealand and overseas are shown in Table 1. Clearly, New Zealand feed is comparable with that made overseas. The high ash and lower moisture in New Zealand feed is a reflection of the types and quality of raw materials used. The comparison does not indicate the quality of protein or fat in the feed; these aspects will be discussed later.

Table 1: Proximate analyses of salmon grower diets manufactured in New Zealand and overseas

	Pelleted diets				Extruded diets	
	N.Z.	U.S./Canada	Denmark	U.K.	U.S./Canada	Denmark
	1*	2	3	4	5	6
Protein	46	45	42	46	44	45
Fat	16.5	16	15	15	22	22
Carbohydrate	16.5	19	22.5	16.5	8.5	15.5
Ash	12.5	10	9	10	10	7
Moisture	8	10	10	10	10	9

* 1 = NRM Feeds Ltd; 2 = Moore-Clarke Select; 3 = EWOS; 4 = BP Nutrition Mainstream; 5 = Moore-Clarke Select; 6 = EWOS

Feed supply

Table 2 shows an approximation of the quantity of salmon produced in New Zealand each year since 1984 with the feed used, and predictions of expected production and feed requirements.

Do New Zealand salmon feed manufacturers have raw materials of adequate quality to meet current and future requirements?

Raw materials available locally and suitable for inclusion in fish feeds include fish meal, meat and bone meal, blood meal, milk proteins, rapeseed meal, wheat, wheat by-products, yeast, milk powders, and fish oil. Other raw materials which are regularly imported into New Zealand for inclusion in other stockfeeds include soybean meal, fish meals, synthetic amino acids, vitamins, and minerals. By far the most important raw material for inclusion in fish feeds is fish meal because the nutrients in it are in the correct proportions for fish. Research overseas to find a replacement for fish meal in salmon diets has met with limited success, and further research is needed.

At present, fish feed manufacturers use fish meal as their primary source of protein, and to meet future requirements will need 3300 to 5500 t annually (based on a planning figure of 50% inclusion in diets). Current figures from the four major fish meal suppliers indicate that they can produce about 4000 t annually suitable for stockfeeds. This is not enough to meet future needs, particularly when fish meal is also used in other stockfeeds. The importation of fish meal will be necessary in the future to make up the shortfall. It is important that import duty on fish meals should be removed to allow fish feed manufacturers to compete with currently imported fish feeds of over 50% fish meal which do not attract any duty.

Milk proteins, such as casein, are suitable for inclusion in salmon diets, but the supply of feed grade material is erratic and small, and too expensive to be justified economically. Other raw materials are high in carbohydrates (grain, grain by-products), are in limited supply (rapeseed meal and yeasts), or of questionable value (meat, blood, and bone meals).

In the future, New Zealand fish feed manufacturers may be faced with a limited supply of local raw materials. They may also become more selective in the quality of raw material they use, and will have to import suitable raw materials from overseas and/or encourage the manufacture of other suitable by-products, such as the extraction of milk protein from waste products of milk products manufacture. The search for alternative cheaper raw materials in New Zealand suitable for fish should continue to reduce the dependence on fish meal.

Table 2: New Zealand salmon production and feed requirements

	Salmon produced (t)	Feed used (t)
1984/85	200	800
1985/86	700	2 200
1986/87	800	2 400
1987/88	1 000	3 200
1988/89	2 000	4 500
Future	3 000–5 000	6 600–11 000

Raw material quality

As indicated earlier, raw material quality in the nutritional sense is taken as the balance of digested essential nutrients. For protein sources, such as fish meal, the balance of digested essential amino acids is important, and is the basis on which the distinction between one fish meal source and another is made.

Raw material quality also encompasses the presence or absence of antinutritional factors which may affect the acceptability of the feed to the fish (or impair performance), or contaminants which may have an effect on the acceptability of the final salable product. Heavy metals, such as mercury, are of particular interest to New Zealand fish farming operations.

Fish meal

Fish meal plays a major role in fish diets, and its quality is of major importance to fish feed manufacturers. So what are fish feed manufacturers looking for in a fish meal?

Fish meal

- must have a high minimum crude protein content (e.g., 68%);
- should be made from whole fish rather than from fish frames;

- should be stabilised with a suitable antioxidant (such as ethoxyquin; the normal recommended level is 200 $mg.kg^{-1}$);
- should be low temperature rendered, steam processed, and ground finer than 0.25 mm;
- should be free from mould and not caked or overheated; and
- should be low in heavy metals, such as mercury (less than 0.1 $mg.kg^{-1}$).

These criteria ensure the quality of the protein in the fish meal and that rancidity (and associated problems) do not occur. It is not sufficient for the amino acids just to be there, they have to be there in an available form so that they can be efficiently utilised. A major problem with high temperature rendered fish meal is that a degree of protein denaturation occurs (i.e., the protein remains in the meal, but in a form that is not freely available to the fish).

How do New Zealand fish meals compare with these standards? Most locally made fish meals are a by-product of the fishing industry. The fish meal is a by-product of fish for human consumption and is made primarily from heads and frames, although some is made from trash whole fish. The protein content varies from 60 to 65% and ash content from 19 to 21%. The fish meal is normally produced in a high temperature rendering plant and so some protein denaturation would be expected. Up to 12 months ago, fish meal was not stabilised with an antioxidant, but after close co-operation between fish meal suppliers and fish feed manufacturers, fish meal for salmon feed is now being stabilised. New Zealand fish meal is generally higher in heavy metals than that from many other fish meal producing countries, and this places limitations on its use, particularly in salmon diets.

Does this mean that New Zealand fish meal should not be used in diets for fish? Certainly not. We need to look to our initial nutritional objective. If we do not use local fish meal, what do we use and what will the alternatives cost? The ideal standard is there as a guide and as something to strive for. There is clearly a need to improve the standard of New Zealand fish meals. Some aspects cannot be altered because they are a function of the initial raw material going into the meal, but stabilisation with antioxidant, the cooking process, particle size, and streaming of material into low mercury and high mercury species can be improved. Separation of whole trash fish into a separate whole fish meal product is being done on a small scale, a positive sign that fish meal manufacturers are increasingly aware of the needs of their customers.

Measuring fish meal quality

Perhaps the main problem confronting quality control is to measure quality and to distinguish between the quality of one source and the next. The ultimate test is to feed it to the fish and measure its digestibility (*in vivo* methods), and performance of the fish. These methods, however, are too time consuming, expensive, and impractical for routine quality control. *In vitro* methods must be used which relate indirectly to fish performance. Such methods include pepsin digestibility, pronase digestibility, available lysine, total volatile nitrogen, and microbiological methods. All have limited success, and, whilst they appear to distinguish between very poor and very good protein quality sources (of the same raw material), lack the sensitivity to distinguish between minor changes in the quality of raw materials. The results are very dependent on the type of raw material being assayed.

Work is in progress at Lincoln College to develop a satisfactory routine method for determining the quality of fish meals. Results so far are promising; the method appears to distinguish between protein sources of similar quality and relates well to *in vivo* digestibility studies with rats. Further work is needed to quantify the method with amino acid levels and their digestibility. Until a suitable method can be developed for distinguishing more accurately between the quality of one fish meal source and another, nutritionists must rely on subjective assessments (such as low temperature rendered). The limitation this places on some sources of fish meal may be eliminated if a suitable screening method for meal quality is developed, as not all fish meal from one source may be unsuitable.

Fish oil

Fish oil is a major raw material of most fish feeds, including salmon feeds. The quality of fish oils and their suitability for fish feed depend on the fatty acid composition and the degree of rancidity that may have occurred during storage. Fish oil must be stabilised with an antioxidant.

Orange roughy (*Hoplostethus atlanticus*) oil, which is freely available in abundance at certain times of the year in New Zealand, could pose nutritional problems if included at high levels in fish diets (e.g., if used as the sole source of fish oil in the diet). It has two major disadvantages for fish; firstly, the omega 3 fatty acid composition is very low (about 1% compared with 25–30% for herring oil), and secondly, 95% of the oil is wax ester. Fish oil is added to the diet predominantly as an energy source, but it also provides most of the omega 3 fatty acids.

Pelleted versus extruded diets

Extruded diets are being used increasingly overseas and have a number of advantages over pelleted diets. Advantages include: the ability to increase the oil level in the final feed (by far the most important); increased digestibility of starch in the feed; slower sinking, so there is a greater chance that feed will be eaten; reduction in pollution; and improved feed acceptability. Their major disadvantage is that they are more costly to produce than pelleted feeds and require a high capital investment in special plant and machinery. Pelleted diets can be produced on existing equipment with slight modifications. Before embarking on such an investment a fish feed manufacturer would want to be sure that there would be sufficient tonnage and return. At the moment there is insufficient tonnage in New Zealand to warrant such an investment, even if the manufacturer were to get 100% of the fish feed market, and future tonnages (see Table 2) suggest that such a venture would be very risky. Feed costs would certainly go up substantially and this cost rise would have to be compared with the expected return in performance one could expect from the fish. It comes back to fulfilling our original nutritional objective.

Importation of feeds

In the last year a number of salmon companies have imported feed from Australia. There are two main reasons for this: first, there is a perception that the product from Australia is superior, and second, advantage is being taken of the strong New Zealand dollar against the Australian dollar. In the short term this may be economically sound, but the long term implications may not. Fish feed manufacturers in New Zealand have invested time and money to supply fish feed to the local fish farming industry, and in return expect a degree of support so that they can continue to do this in the future. If, however, the salmon industry continues to source a major proportion of its feed overseas, then manufacturers may be forced to re-examine their position with regard to fish feed manufacture. I suggest it is not in the long term interest of the fish farming industry to be completely dependent on importation of fish feed; it certainly weakens the case for further expenditure in fish feed manufacture, such as on extrusion equipment. However, New Zealand fish feed manufacturers do accept there is a responsibility on their part to manufacture a feed of equivalent or better quality at a competitive price, and many are fully committed to supplying the fish farming industry.

References

Cowey and Sargent 1979: Nutrition. *In* Hoar, W.S., Randall, D.J., and Brett, J.R. (Eds.), "Fish Physiology — Bioenergetics and Growth — Volume VIII", pp. 1–69. Academic Press, New York.

Halver, J.E. 1972: "Fish Nutrition". Academic Press, New York and London.

National Research Council 1981: "Nutrient Requirements of Coldwater Fishes". *Nutrient requirements of domestic animals series.* National Academic Press, Washington D.C.

Whittemore, C.T. and Elsley, F.W.H. 1976: "Practical pig nutrition". Farming Press, Ipswich, U.K.

Discussion

Q. Has any attempt been made to use fish liquor for fish feed?

A. My company hasn't tried as there are problems handling it. It should be looked at as an alternative raw material.

Comment. You warned us that there could be a shortage of feed. There are resources, like mackerel, that could be turned in to feed here in New Zealand, rather than exporting fish meal and then importing the finished product.

A. I agree, but the quality of New Zealand made fish feed has to be improved.

Comment. Only one company brings fish feed into New Zealand, and under the terms of its licence that feed cannot contain New Zealand meal.

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Induced spawning of snapper, *Chrysophrys auratus*: prospects for aquaculture

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Introduction

All aquaculture operations are dependent, at some level, on the reliable supply of fertilised eggs, or fry. Sometimes it is possible to maintain viable aquaculture operations based on the harvest of naturally occurring eggs or fry. In Southeast Asia, for example, about 400 000 t of milkfish (*Chanos chanos*) are cultured annually from fry captured from the wild. However, fry availability is highly variable, and even in this successful industry considerable research is directed at artificial propagation in an attempt to stabilise fry production (Marte 1987). In most aquaculture operations, fertilised eggs are obtained from sexually mature adults captured shortly before natural spawning, or maintained year round as brood stock. Fertilisation may be achieved by establishing conditions where spontaneous spawning occurs, or by some method of induced gonadal maturation.

Spontaneous spawning

Certain species may undergo spontaneous gamete maturation and spawning in an approximation of the natural reproductive cycle when held in captivity. Spontaneous reproductive activity is usually dependent on the provision of adequate nutrition, suitable water quality, and holding conditions which, in addition to providing the appropriate spawning cues, generate low stress in brood stock (Reay 1984).

Culture of fish under conditions that promote spontaneous maturation has the advantage of requiring minimal handling of fish, which minimises stress effects and may save on labour costs. However, for spontaneous spawning to occur holding volumes may have to be quite large, and stocking densities low, with associated high capital costs. In addition, the timing and duration of spawning may be difficult to predict in advance. Reproductive cycles of temperate fish are largely synchronised by interactions between photoperiod and temperature (Lam and Munro 1987). Culture techniques using water at ambient temperature are likely to be subject to the same variations in the timing and duration of spawning that occur in wild populations. Some species may not spawn in captivity under any conditions, or only a proportion of the stock population may mature; then artificial induction of spawning may be required.

There is little information on the reproductive activity of captive snapper, although a number of fish have been observed to spawn in the Napier Aquarium in a large tank (12 m diameter by 3.5 m deep) (Smith 1986). Some other sparids undergo normal maturation and spawning in captivity. Culture of red sea bream (*Pagrus major*) in Japan is dependent on spontaneous spawning of fish held in concrete ponds, the fertilised eggs being collected in egg traps built into tank outflows (Smith and Hataya 1982). Gilthead sea bream (*Sparus aurata*) will also spawn in captivity, but spawning is described as "not dependable"; oocytes of a high proportion of females develop to the final stage of vitellogenesis and then rapidly become atretic (Zohar *et al.* 1987). Similarly, only 25% of hatchery populations of the two banded bream (*Diplodus vulgaris*) typically show spontaneous spawning (Jug-Dujakovic and Glamuzina 1988). These reports suggest that at least a proportion of a population of captive snapper may undergo spontaneous maturation under suitable conditions, but the critical requirements for spawning are still not known.

Induced spawning

Environmental manipulation. Experiments with classical freshwater culture species (salmonids and cyprinids) have shown that spawning can be induced or synchronised by manipulation of physical variables. Salmonid reproductive cycles can be entrained by photoperiod manipulation, whereas combinations of photoperiod and temperature regimes are required to initiate spawning in cyprinids (Lam and Munro 1987). Many species also have specific substrate requirements for spawning (Stacey 1984). Studies on marine species also indicate that photoperiod and temperature can be used to regulate gonadal cycles, and some European commercial units routinely use photoperiod manipulation and regulated temperatures to induce spawning at required times (Bye 1987).

Environmental manipulation has the advantage of being non-invasive (low stress effects on fish) and is generally not labour intensive. Maintaining multiple brood stocks on differently phased environmental cycles may also allow extended or year-round production of eggs. The provision of regulated environments does, however, require greater capital investment than maintenance of fish under ambient conditions.

There is no information on the effect of environmental variables on the reproductive activity of snapper. Snapper display consistent seasonal reproduction with peak spawning occurring in November and December (Crossland 1977), indicating that seasonal cues are important for the timing of spawning. The nature of the cues is not known. In other sparids, temperature and photoperiod appear to be the significant environmental factors in regulation of reproduction. Brood stocks of gilthead sea bream produce viable ova at temperatures of 16–25 °C, but ovulation does not occur below 15 °C. Spawning may be advanced by up to 6 months if fish are exposed to "short day" photoperiods, whereas "long days" during autumn and winter delay spawning. Out of season spawning times can be stabilised with phase-shifted 12 month photoperiod regimes, and keeping a number of brood stocks on different annual cycles allows year round production of eggs (Bye 1987). Onset of maturity in juvenile gilthead sea bream can be delayed by constant exposure to long days (Micale and Perdichizzi 1988).

Recent work has shown that snapper undergo juvenile sex inversion as 2+ to 4+ year old fish, and there is some evidence that the proportion of fish that inverts (all fish are initially "female") is not constant, and may be regulated by environmental factors (Francis and Pankhurst in press). Should this prove to be so, environmental manipulation may also have potential as a tool for regulating sex ratios of hatchery stocks.

Hormone treatment. Fish may complete gametogenesis but fail to spawn in captivity. Where this is due to the failure of the fish to ovulate (in turn due to absence of a preovulatory gonadotropin (GtH) surge, reviewed by Peter *et al.* (1987)), final gamete maturation can sometimes be induced by hormone treatments. Artificially ovulated fish may then spawn spontaneously, or hand stripping and artificial fertilisation may be required. Older maturation techniques (reviewed by Lam 1982) generally used pituitary extracts and mammalian GtH. More recent studies have shown that synthetic analogues of gonadotropin-releasing hormone (GnRH) are highly effective ovulatory agents. In a number of species, GtH release from the pituitary is under inhibitory control by a GtH release inhibitory factor (GRIF). Current studies suggest that GRIF is probably dopamine, with the result that the efficacy of GnRH treatment is greatly increased when GnRH is administered in conjunction with a dopamine antagonist (Peter *et al.* 1987).

Hormone treatments probably offer the highest guarantee of spawning success, and, once the dynamics of hormone uptake and action have been determined, usually allow precise prediction of the timing of ovulation. Artificial maturation may also be successful in a more modest culture system than might be required for spontaneous or environmentally induced spawning. The techniques do require higher technical expertise, and some handling of fish, although the use of time release pellets rather than injection can obviate the need for repeat treatments. Treatment costs can be relatively high, and species that are stress-sensitive may not spawn naturally and so require hand-stripping.

Culture conditions that induce stress in brood stock may result in fish failing to undergo gonadal development, or being unresponsive to hormone treatments. Stress is known to cause falls in GtH, gonadal steroids, and the development of gonadal atresia (de Montalembert *et al.* 1978, Stacey *et al.* 1984, Sumpter *et al.* 1987). The effects of stress on the reproductive system may be mediated by corticosteroids, the plasma levels of which are elevated by stress (Sumpter *et al.* 1987). Measurements of plasma cortisol levels in brood stock offer a method for routinely assessing the suitability of aquaculture regimes.

Pilot studies with snapper indicate that at least some freshly captured wild fish will respond to treatment with GnRH. In November 1987, 7 out of 11 sexually mature unovulated females ovulated within 24 h of injection with 25 $\mu g.kg^{-1}$ Des Gly^{10}(D-Ala^{6}-)LHRH-ethylamide, and in December 1987, 7 out of 16 treated fish ovulated. Fish were held for up to 1 week before treatment during which none underwent spontaneous ovulation (authors' unpublished data). Gilthead sea bream treated with lower doses of GnRH (7.5 $\mu g.kg^{-1}$) showed a large GtH surge which initiated a long term cycle of daily ovulation. The response was not enhanced by co-treatment with dopamine antagonists (Zohar *et al.* 1987). Similar critical experiments remain to be done on snapper, but it is already clear that hormonally induced ovulation has potential as a tool for the management of brood stock.

Consequences of egg size

In general terms, species with high fecundity (such as snapper) have small eggs (Pankhurst and Conroy 1987), and consequently larvae are small at hatching and first feeding (Table 1). High fecundity means that fewer brood stock need to be maintained, but if high fecundity is coupled with small egg size, then the small progeny which arise are likely to be less viable and harder to rear than those of species with large eggs (Reay 1984). Small

Table 1: Egg volume, hatching size, and size at first feeding for some teleost species

Species	Egg vol. (mm^3)	Size at Hatching (mm)	Size at First feeding (mm)	Reference
Sand flounder	0.14	1.8	3.09	Robertson & Raj (1971)
Black sea bream*	0.38	2.2	3.19	Fukuhara (1987)
Snapper*	0.45	1.9	3.09	Cassie (1956)
Two banded bream*	0.52	2.6	3.8	Jug-Dujakovic & Glamuzina (1988)
Triplefin	0.70	4.8	5.89	Unpublished data
Atlantic cod	1.43	4.5	4.89	Yin & Blaxter (1987)
Herring	3.05	8.8	9.79	Yin & Blaxter (1987)
Flathead sole	6.35	6.3	7.29	Alderdice & Forrester (1974)
Yellow perch	8.16	5.7	13.0	Heidinger & Kayes (21986)
Rainbow trout	47.60	12.0	22.0	Tanaka (1969)
Cherry salmon	65.30	17.0	32.0	Govoni *et al.* (1986)

* Sparids.

larvae are likely to require several changes in food supply of increasing particle size, and may need extended rearing on live rotifer or copepod starting diets. This increases both the complexity and cost of the culture system. In contrast, species in which hatching size is relatively large (such as yellow perch) can be successfully reared on granulated or pellet diets from first feeding (Heidinger and Kayes 1986).

Snapper eggs are at the lower end of the size range found among externally fertilising teleosts, and at hatching larvae have minimal development of sensory, motor, and digestive systems (authors' unpublished data). Pilot studies on rearing larval snapper (authors' unpublished data) and experience with other sparids (Smith and Hataya 1982) suggest that snapper will require rotifer diets for at least 20–30 days post-hatching.

A number of New Zealand fish with actual or potential market value have relatively large eggs. For example, telescope fish, blue cod, and red gurnard have egg volumes of 0.5–1.0 mm^3, and black cod, monkfish, warehou, and John dory have egg volumes greater than 1 mm^3 (Robertson 1975). Information on the larvae of most of these species is not available, but larger eggs should yield larger (hence easier to rear) larvae. If the cost of larval rearing limits the commercial viability of culturing species with small eggs (e.g., snapper), attention should be directed at species with larger eggs.

Growth rates

Assuming that the technical aspects and costs of larval rearing are tractable, the viability of culturing a species will be determined by a combination of rearing costs, growth rates, and final product value. A comparison of times for fish to reach 50% and 75% of asymptotic mean length (Table 2) shows that snapper perform poorly in comparison with freshwater species and a number of marine species for which growth data are available. Snapper culture would appear to be viable only if the final product value is high with respect to other species, and/or culture operations are large enough to simultaneously encompass at least five age classes to ensure an annual return for investment. Lower product values of other species (based on current prices) may be offset by more rapid growth (i.e., a greater proportion of a culture facility could be dedicated to market size fish while still maintaining annual returns). Species, such as red gurnard, which combine rapid growth and large egg size (egg volume thrice that of snapper) appear to have considerable potential as culture species. Reproductive characteristics and growth rates of many New Zealand marine species have yet to be adequately described, so the comparative data presented here may omit species which are also suitable for aquaculture.

Table 2: Time (years) to reach 50% (T_{50}) and 75% (T_{75}) of asymptotic length in a number of New Zealand populations of freshwater and marine species

Species	T_{50}	T_{75}	Reference
Rainbow trout	1.5	2.5	McCarter (1986), Fish (1968)
Brown trout	1.5	2.5	McCarter (1986)
Yellow flounder	1.5	2.5	Colman (1974)
Red gurnard	1.5	2.5	Elder (1976)
Sand flounder	2.0	2.5	Colman (1974)
Red moki	2.5	4.5	McCormick (1986)
Tarakihi	2.5	4.5	Tong & Vooren (1972)
Kahawai	3.0	6.5	Eggleston (1975)
Goatfish	3.0	–	Ayling (1978)
Blue cod	3.5	7.0	Mutch (1983)
Blue moki	4.0	10.0	Francis (1981)
Snapper	5.0	15.0	Paul (1976)

References

Alderdice, D.F. and Forrester, C.R. 1974: Early development and distribution of the flathead sole (*Hippoglossoides elassodon*). *Journal of the Fisheries Research Board of Canada 31*: 1899–1918.

Ayling, A.M. 1978: Cape Rodney to Okakari Point, Marine Reserve Survey. Leigh Laboratory Bulletin, University of Auckland. 98 p.

Bye, V.J. 1987: Environmental management of marine fish reproduction in Europe. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Physiology of Fish 1987", pp. 289–298. Memorial University, St Johns.

Cassie, R.M. 1956: Early development of the snapper, *Chrysophrys auratus* Forster. *Transactions of the Royal Society of N.Z. 83*: 705–713.

Colman, J.A. 1974: Growth of two species of flounders in the Hauraki Gulf, New Zealand. *N.Z. Journal of Marine and Freshwater Research 8*: 351–370.

Crossland, J. 1977: Seasonal reproductive cycle of snapper *Chrysophrys auratus* (Forster) in the Hauraki Gulf. *N.Z. Journal of Marine and Freshwater Research 11*: 37–60.

De Montalembert, G., Jalabert, B., and Bry, C. 1978: Precocious induction of maturation and ovulation in northern pike (*Esox lucius*). *Annales de Biologie Animale Biochimie et Biophysique 18*: 969–975.

Eggleston, D. 1975: Determination of age of kahawai *Arripis trutta* (Bloch and Schneider). *N.Z. Journal of Marine and Freshwater Research 9*: 293–298.

Elder, R.D. 1976: Studies on age and growth, reproduction and population dynamics of red gurnard *Chelidonichthys kumu* (Lesson and Garnot), in the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin No. 12.* 77 p.

Fish, G.R. 1968: An examination of the trout population of five lakes near Rotorua, New Zealand. *N.Z. Journal of Marine and Freshwater Research 2*: 333–362.

Francis, M.P. and Pankhurst, N.W. (in press): Juvenile sex inversion in the New Zealand snapper *Chrysophrys auratus* (Bloch and Schneider, 1801) (Sparidae). *Australian Journal of Marine and Freshwater Research.*

Fukuhara, O. 1987: Larval development and behaviour in early life stages of black sea bream reared in the laboratory. *Nippon Suisan Sakkaishi 53*: 371–379.

Govoni, J.J., Boehlert, G.W., and Watanabe, Y. 1986: The physiology of digestion in fish larvae. *Environmental Biology of Fishes 16*: 59–77.

Heidinger, R.C. and Kayes, T.B. 1986: Yellow perch. *In* Stickney, R.R. (Ed.) "Culture of Nonsalmonid Freshwater Fishes", pp. 103–114. CRC Press, Boca Raton, Florida.

Jug-Dujakovic, J. and Glamuzina, G. 1988: Preliminary studies of reproduction and early life history of *Diplodus vulgaris* (E. Geoffroy Saint-Hilaire 1817) in captivity. *Aquaculture 69*: 367–377.

Lam, T.J. 1982: Applications of endocrinology to fish culture. *Canadian Journal of Fisheries and Aquatic Science 39*: 111–137.

Lam, T.J. and Munro, A.D. 1987: Environmental control of reproduction in teleosts: an overview. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Physiology of Fish 1987", pp. 279–288. Memorial University, St Johns.

McCarter, N.H. 1986: Food and energy in the diet of brown and rainbow trout from Lake Benmore, New Zealand. *N.Z. Journal of Marine and Freshwater Research 20*: 551–559.

McCormick, M.I. 1986: Spatial and temporal patterns of abundance of *Cheilodactylus spectabilis* (Pisces: Cheilodactylidae). Unpublished MSc thesis, University of Auckland, Auckland. 113 p.

Marte, C.L. 1987: Milkfish culture and artificial propagation. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Physiology of Fish 1987", pp. 89–93. Memorial University, St Johns.

Micale, V. and Perdichizzi, F. 1988: Photoperiod effects on gonadal maturation in captivity-born gilthead bream, *Sparus aurata* (L.): early findings. *Journal of Fish Biology 32*: 793–794.

Mutch, P.G. 1983: Factors influencing the density and distribution of the blue cod (*Parapercis colias*) (Pisces: Mugiloididae). Unpublished MSc thesis, University of Auckland, Auckland. 75 p.

Pankhurst, N.W. and Conroy, A.M. 1987: Size-fecundity relationships in the orange roughy, *Hoplostethus atlanticus*. *N.Z. Journal of Marine and Freshwater Research 21*: 295–300.

Paul, L.J. 1976: A study on the age, growth and population structure of the snapper, *Chrysophrys auratus* (Forster) in the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin No. 13.* 62 p.

Peter, R.E., Lin, H-R., and Van Der Kraak, G. 1987: Drug/hormone induced breeding of Chinese teleosts. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Physiology of Fish 1987", pp. 120–123. Memorial University, St Johns.

Reay, P.J. 1984: Reproductive tactics: a non-event in aquaculture? *In* Potts, G.W. and Wootton, R.J. (Eds.), "Fish Reproduction: Strategies and Tactics", pp. 291–310. Academic Press, London.

Robertson, D.A. 1975: A key to the planktonic eggs of some New Zealand marine teleosts. *Fisheries Research Division Occasional Publication No. 9.* 19 p.

Robertson, D.A. and Raj, U. 1971: Egg and yolk sac stages of the sand flounder (Teleostei: Pleuronectidae). *N.Z. Journal of Marine and Freshwater Research 5*: 404–414.

Smith, P.J. 1986: Spawning behaviour of snapper, *Chrysophrys auratus*, in captivity (Note). *N.Z. Journal of Marine and Freshwater Research 20*: 513–515.

Smith, P.J. and Hataya, M. 1982: Larval rearing and reseeding of red sea bream (*Chrysophrys major*) in Japan. *Fisheries Research Division Occasional Publication No. 39.* 19 p.

Stacey, N.E. 1984: Control of timing of ovulation by exogenous and endogenous factors. *In* Potts, G.W. and Wootton, R.J. (Eds.), "Fish Reproduction: Strategies and Tactics", pp. 207–222. Academic Press, London.

Stacey, N.E., McKenzie, D.S., Marchant, T.A., Kyle, A.L., and Peter, R.E. 1984: Endocrine changes during natural spawning in the white sucker *Catostomus commersoni*. I. Gonadotropin, growth hormone, and thyroid hormones. *General and Comparative Endocrinology 56*: 333–348.

Sumpter, J.P., Carragher, J., Pottinger, T.G., and Pickering, A.D. 1987: Interaction of stress and reproduction in trout. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Endocrinology of Fish 1987", pp. 299–302. Memorial University, St Johns.

Tanaka, M. 1969: Studies on the structure and function of the digestive system in teleost larvae. I. Development of the digestive system during prelarval stage. *Japanese Journal of Ichthyology 16*: 1–9.

Tong, L.J. and Vooren, C.M. 1972: The biology of the New Zealand tarakihi *Cheilodactylus macropterus* (Bloch and Schneider). *Fisheries Research Bulletin No. 6.* 60 p.

Yin, M.C. and Blaxter, J.H.S. 1987: Feeding ability and survival during starvation of marine fish larvae reared in the laboratory. *Journal of Experimental Marine Biology and Ecology 105*: 73–83.

Zohar, Y., Pagelson, G., Tosky, M. and Finkelman, Y. 1987: GnRH control of gonadotropin secretion, ovulation and spawning in the gilthead sea bream *Sparus aurata*. *In* Idler, D.R., Crim, L.W., and Walsh, J.M. (Eds.), "Reproductive Physiology of Fish 1987", p. 106. Memorial University, St Johns.

Discussion

Q. Could dolphinfish (mahi mahi) be a candidate for aquaculture here? Their growth rate is amazing and they are found off north-eastern New Zealand.

A. The fecundity is high, the egg is large, and the larvae are easily reared. They are definitely a candidate.

The impact of salmon farming on Big Glory Bay, Stewart Island

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Introduction

Recently the Water Quality Centre, DSIR, was engaged by MAFFish and the Southland Catchment Board to carry out studies on sea cage salmon farms operating in Big Glory Bay, Stewart Island. Chinook salmon (*Oncorhynchus tshawytscha*) have been farmed in the bay since the early 1980s by several companies (O'Sullivan 1985). Production has steadily increased to the level where for the last annual harvest (1987–88 season) it was about 800 t for the whole bay. The studies by the Water Quality Centre were aimed at assessing the impact of existing farms on the benthic ecology and water quality of Big Glory Bay, and at making recommendations on future environmental management. This paper briefly describes some of these studies and highlights some of the major findings. The full reports of these studies can be obtained from MAFFish (Rutherford *et al.* 1988) and the Southland Catchment Board, Invercargill (Roper *et al.* 1988).

Background to studies

There are two main ways in which sea cage farming may affect the environment. The first results from the accumulation of uneaten food and fish faeces on the sea bed under the cages. These accumulations consume oxygen, generate gases such as methane and hydrogen sulphide, and can harbour disease forming organisms. The consumption of oxygen can potentially reach the level where depletion occurs in the cages causing fish to die from anoxia (Weston 1986). Methane itself is not harmful, but the bubbles provide a potential vehicle for carrying pathogens from the bottom back into the stock. Hydrogen sulphide is very toxic to fish and has been linked to gill damage (Braaten *et al.* 1983). As well as these effects on fish, the waste accumulations cause changes in benthic invertebrate communities (Brown *et al.* 1987) and sediment microbiological characteristics (Kaspar *et al.* 1988).

The other way in which farms may exert an environmental effect is through the release of nutrients into the water. The nutrients are derived from fish metabolism and feed leachates. It has been suggested (Rosenthal *et al.* 1988) that given suitable hydrographic conditions the increased nutrient concentrations produced by farms could stimulate phytoplankton production and result in nuisance blooms. Phytoplankton blooms might become a problem for fish farmers if they were to deplete dissolved oxygen concentrations, if they were of species which can cause physical damage to fish gills, or if they were of species which produce toxins (Rosenthal *et al.* 1988). Algal blooms have resulted in fish deaths overseas (e.g., Jones *et al.* 1982) and possibly also in New Zealand (P.R. Todd, MAFFish, pers. comm.). As yet there is no evidence to suggest that such blooms have been caused by fish farms (Gowen and Bradbury 1987). It appears that these blooms have been natural phenomena, but whether their intensity was magnified by nutrients released from salmon farms is not known.

The environmental effects associated with the sea cage rearing of salmon have been reviewed by Weston (1986), Gowen and Bradbury (1987), and Rosenthal *et al.* (1988). Thrush (1986) considered the environmental problems which might arise from salmon farming in Big Glory Bay and described severe accumulations of uneaten food and fish faeces which had formed under two cages. Some of the effects of farms at shallow sites at the head of the bay (where farming has now ceased) were studied by Gillespie and MacKenzie (1982).

During November 1987 and February 1988 scientists from the Water Quality Centre made the following measurements in Big Glory Bay, Stewart Island: water soluble nutrients around two farms, nutrient and chlorophyll *a* concentrations along the length of the bay, phytoplankton growth rates, dissolved oxygen concentrations near two farms and in the middle of the bay, oxygen uptake rates of sediment along transects under five farms, vertical profiles of current speed at several points around the bay, the residence time of the bay, sediment composition along transects under three farms, benthic invertebrate communities along transects under two farms, and flux of sulphate into and sulphide out of sediment. The results were used to develop models (e.g., to predict levels of fish production which would not cause eutrophication) and to make assessments of the present impacts (e.g., on benthic ecology).

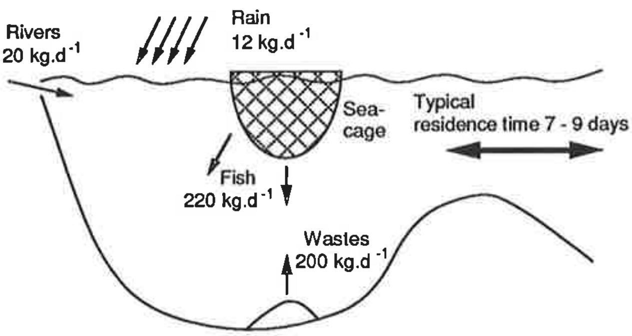

Figure 1: Estimated available nitrogen loads to Big Glory Bay: inputs include rain, river inflows, nutrient release from farms (including uneaten food and fish excretion and egestion), and re-release of nutrient from the waste patches under farms.

Results

Eutrophication model. The potential for the development of algal blooms was modelled, taking into account nutrient dynamics, hydrodynamics (in particular, flushing of the bay), and algal growth. Nutrient modelling focused on nitrogen because this nutrient commonly limits phytoplankton growth in marine waters and its supply relative to phosphorus (another potentially limiting nutrient) was low. The various inputs of nitrogen to the system are represented in Figure 1.

It is currently impossible to predict with confidence the timing and species composition of phytoplankton blooms. It is possible, however, to predict the maximum chlorophyll concentration which is likely to occur during a bloom. We chose an upper limit for an acceptable chlorophyll *a* concentration (15 mg.m^{-3}) and adapted the methods developed by Pridmore and McBride (1984) for use when nitrogen is the limiting nutrient, and modelled phytoplankton growth allowing for tidal flushing of the bay. The results suggested that, allowing a wide margin of safety, if annual salmon production in the bay was restricted to 3000 t.yr^{-1}, it was unlikely that the critical chlorophyll *a* concentration would be exceeded, and therefore blooms would be unlikely to occur as the result of farming.

Sediment chemistry. Waste accumulations were found under all the sea cages examined by divers. Typically, these accumulations were 15–20 cm deep. Analysis of sediment chemistry showed clear gradients with distance away from the farms (Figure 2). However, the elevations in various chemical concentrations measured near the farms extended only 25–50 m from the farm edge; beyond this distance there was no measurable change in sediment chemistry. We observed that small food particles and faecal material sank at about 3.5 cm.s^{-1}, that depth-averaged currents seldom exceed 10 cm.s^{-1}, and that there was typically 10–15 m of water under the cages. In these conditions solid wastes would be expected to spread 30–40 m, which matches the estimate based on the observed sediment composition.

The changes in sediment composition correlated well with changes in benthic community structure. Such a relationship should prove useful (and cost-beneficial) if the environmental effects of salmon farms are monitored.

Oxygen consumption. The rate of oxygen consumption was measured in undisturbed sediment cores and showed a gradient with distance from the farms (Figure 3). Within 50 m of the farms rates approached 5 g.m^{-2}.d^{-1}, but beyond this distance seemed to be at "background" levels. Given the currents in the bay and the depth of water under the existing farms, these oxygen consumption rates did not result in any serious oxygen depletion. Measurements of the dissolved oxygen concentration under the farms showed that it was usually over 95% saturated.

Hydrogen sulphide production. Hydrogen sulphide (H_2S) production was measured in two sediment cores, one collected from under a farm and another 50 m from the farm edge. The measured efflux of H_2S under the farm was 0.81 g.m^{-2}.d^{-1}, which is within the range found by others in

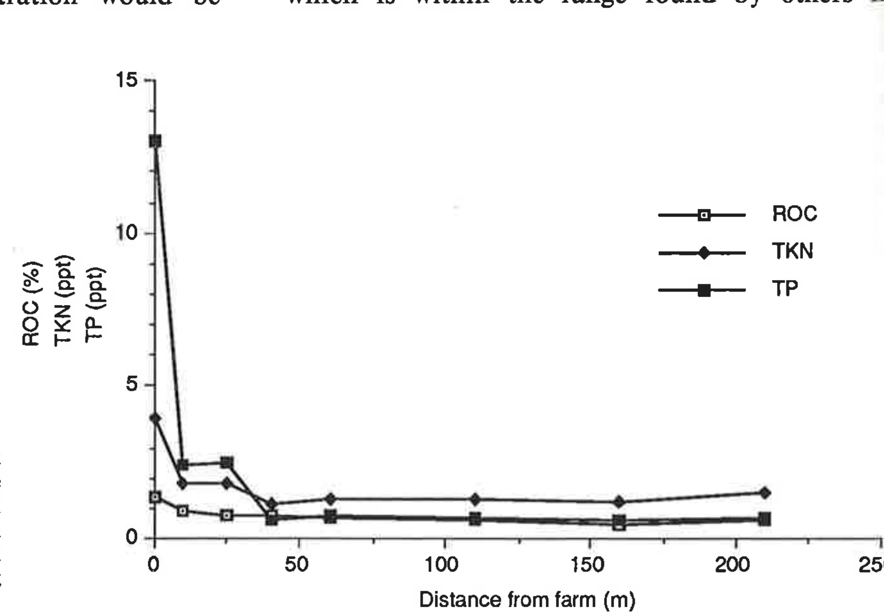

Figure 2: Changes in sediment concentrations of readily oxidisable carbon (ROC), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) with distance from the edge of a salmon farm in Big Glory Bay.

organically enriched marine sediments (Bella 1975, Jorgensen 1977, Hansen *et al.* 1978). Hydrogen sulphide evolution was low ($0.055\ g.m^{-2}.d^{-1}$) 50 m from the farm. These measurements were used in a simplified model, together with measured dispersion coefficients and published values for the oxidation rate of H_2S in sea water, to predict H_2S concentrations in the water column under salmon farms. These predictions have a high uncertainty, but they suggest that under worst-case mixing conditions there is a potential for H_2S problems at the existing farms. We could find no direct evidence of H_2S toxicity problems during field studies, but these preliminary results suggest that H_2S evolution from the bed should be studied further.

Ecological effects. Ecological impacts of salmon farms were studied by sampling benthic species along transects away from two farms. Changes in benthic invertebrate communities were summarised in terms of abundances of species and total numbers of individuals. Similar changes were found at the two large farms examined in detail. Within a few metres of the edge of the farms many species were excluded or had very low densities. Within this area the accumulations of farm wastes were greatest and the sediment surface was covered with a mat of the filamentous bacterium *Beggiatoa*. Numbers of individuals and species were high between 50 and 110 m from the farms and dropped slightly at 210 m (Figure 4). These changes correspond well with the established responses of benthic invertebrates to gradients of organic pollution (Pearson and Rosenberg 1978). The zone within a few metres of the farm edge, where few species survive and only pollution tolerant ones are abundant, represents severely polluted conditions. Further away, where species and individual abundances have increased, is a transition zone which merges into probably normal conditions at about 200 m from the farm edge. Within the transition zone the benthic community is enriched, with species and individual abundances above "normal" levels. Pollution sensitive species were also present there.

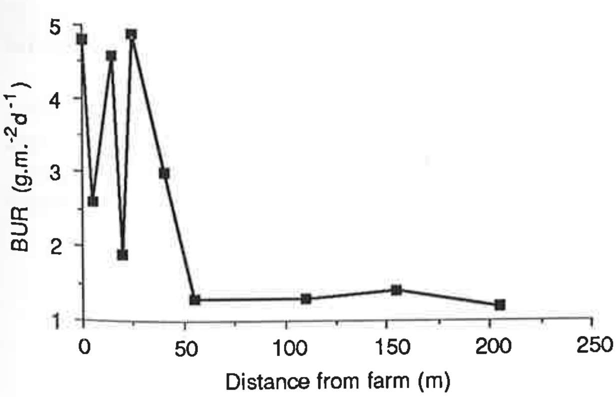

Figure 3: Sediment oxygen consumption or benthic uptake rate (BUR) with distance away from the edge of salmon farms. Data are averaged from transects at five different farms.

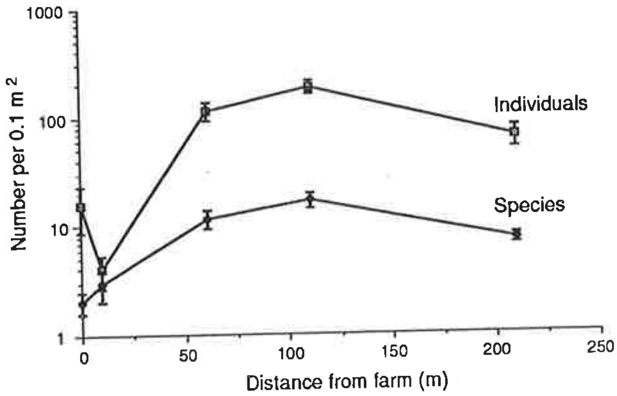

Figure 4: Abundances (means standard errors) of benthic invertebrate species and total individuals with distance from the edge of a salmon farm in Big Glory Bay.

Summary

The studies in Big Glory Bay have made it possible to recommend a limit ($3000\ t.yr^{-1}$) on the annual production of salmon so that phytoplankton blooms will be avoided. It has also been shown that the environmental impacts of the present farms appear to be limited to the immediate vicinity of the farms. Changes in sediment chemistry and deleterious ecological effects both occur within about 50 m of the edge of a farm, and some effects can be detected beyond this distance; for example, changes in benthic invertebrate community structure appeared to extend out to 200 m at the sites studied. That ecological effects can be detected this distance from farms could be cause for concern if biological resources of special significance occur near farms. Surveys in the bay identified various habitat types and species which should be given special protection; these included extensive areas of the bottom covered in the seaweed *Lenormandia chauvinii*, mud habitat where dense brachiopod communities occur, and scallop beds.

The potential for hydrogen sulphide evolution, which should be of concern to farmers in light of the effects on fish health, warrants further study.

Acknowledgments

We thank Dr P.R. Todd (MAFFish) for information on algal blooms and Mr K.J. O'Sullivan (Big Glory Salmon Ltd.) for permission to cite Gillespie and MacKenzie (1982).

References

Bella, D.A. 1975: Tidal flats in estuarine water quality analysis. Report EPA-600/3-75-025. United States Environmental Protection Agency, Corvallis, Oregon.

Braaten, B., Aure, J., Ervik, A., and Boge, E. 1983: Pollution problems in Norwegian fish farming. Report CM 1983/F:26. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Brown, J.R., Gowen, R.J., and McLusky, D.S. 1987: The effect of salmon farming on the benthos of a Scottish sea loch. *Journal of Experimental Marine Biology and Ecology 109*: 39–51.

Gillespie, P.A. and MacKenzie, A.L. 1982: Investigation of the environmental impact of sea cage rearing of salmon in Big Glory Bay, Stewart Island. Unpublished report to BP Chemicals Ltd.

Gowen, R.J. and Bradbury, N.B. 1987: The ecological impact of salmonid farming in coastal waters: a review. *Oceanography and Marine Biology Annual Review 25*: 563–575.

Hansen, M.H., Ingvorsen, K., and Jorgensen, B.B. 1978: Mechanisms of hydrogen sulphide release from coastal marine sediments to the atmosphere. *Limnology and Oceanography 23*: 68–76.

Jones, K.J., Ayres, P.A., Bullock, A.M., Roberts, R.J., and Tett, P. 1982: A red tide of *Gymnodinium aureolum* in sea lochs of the Firth of Clyde and associated mortalities of pond reared salmon. *Journal of the Marine Biological Association of the U.K. 62*: 771–782.

Jorgensen, B.B. 1977: The sulphur cycle of a coastal marine sediment (Limfjorden, Denmark). *Limnology and Oceanography 22*: 814–832.

Kaspar, H.F., Hall, G.H., and Holland, A.J. 1988: Effects of sea cage salmon farming on sediment nitrification and dissimilatory nitrate reductions. *Aquaculture 70*: 333–344.

Pearson, T.H. and Rosenberg, R. 1978: Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review 16*: 229–311.

Pridmore, R.D. and McBride, G.B. 1984: Prediction of chlorophyll *a* concentrations in impoundments of short hydraulic retention time. *Journal of Environmental Management 19*: 343–350.

O'Sullivan, K.J. 1985: The BP-FRD sea cage rearing project. *In* Taylor, J.L., Ogilvie, R.M., and Todd, P.R. (Comps.), Proceedings of the salmon farming conference, pp. 28–30. *Fisheries Research Division Occasional Publication No. 47.*

Roper, D.S., Rutherford, J.C., and Pridmore, R.D. 1988: Salmon farming water right studies, Big Glory Bay, Stewart Island. Unpublished report to the Southland Catchment Board.

Rosenthal, H., Weston, D., Gowen, R., and Black, E. 1988: Environmental impact of mariculture. Cooperative Research Report XXX. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Rutherford, J.C., Pridmore, R.D., and Roper, D.S. 1988: Estimation of sustainable salmon production in Big Glory Bay, Stewart Island. Unpublished report to MAFFish.

Thrush, S.F. 1986: Report on the management and environmental implications of eutrophication owing to salmon farming. Ministry of Agriculture and Fisheries, Fisheries Management Division, Southern FMP Team Series 3.

Weston, D.P. 1986: The environmental effects of floating mariculture in Puget Sound. Unpublished report to Washington Department of Fisheries and Washington Department of Ecology.

Discussion

Q. The bubbles of biogas you mentioned are probably of methane and hydrogen sulphide, and indicate an excessive buildup under the cages. Is there any system of rotation of the cages?

A. The licence areas are probably large enough to allow some movement. The biogas was most noticeable at the larger farms with large units which are not easily moved.

Q. In Australia, salmon farms are often criticised for polluting the environment, so your work will be very useful to us. Do you find recreational fish species are attracted to farm areas?

A. There are lots of spotties under the cages, but no desirable species.

Q. To minimise pollution in the bay you could spread the farms out or clump them together. What would you suggest?

A. I think our work shows that accumulations on the bottom are not a big event. We are recommending to the catchment board that salmon farming be controlled through water rights and that they designate a mixing zone (i.e., an area in which you can change the water classification standards). We believe the farmers can meet the standards. I don't think the spacing of farms will affect the nutrient levels. The mixing in the bay is sufficient to prevent isolated pockets of high nutrient concentration.

Q. In Chile, high levels of nitrogen and phosphorus beneath the cages lead to excessive growth of *Macrocystis*. Why not encourage a two- or three-tiered operation along with salmon farming? Perhaps the *Macrocystis* could be used in other forms of aquaculture.

A. The problem lies in using those nutrients. Once the sediments are disturbed dissolved oxygen is greatly reduced and the fish would have to be moved completely out of the area. I would recommend not moving a farm until you had to. The recovery rate for the bottom patches is unknown, but is certainly several years.

Q. Can your model suggest what might happen on farmed sites in 5, 10, 15, 20 years' time?

A. No. We can't model the ecology so we've assumed it attains stability. We know the rate at which waste builds up under the farms. Beyond 50–100 m it is being respired faster than it accumulates.

Disease control in aquaculture: new perspectives

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For the last 21 years live animals have been imported into New Zealand under the Animals Act 1967 (AA).

Next year new legislation is to be introduced to control the importation of animals, plants, micro-organisms, and genetically modified organisms (or GMOs). This is because the AA deals primarily with risk and disease; references to environmental concerns, such as Section 14 (which prohibits any animal "likely to become a nuisance or to cause injury or damage" are legally ambiguous; and because special legislation is needed to ensure the responsible introduction and field testing of GMOs in the New Zealand environment.

A large interdepartmental steering group has been meeting this year under the chairmanship of the Ministry for the Environment (MFE), to develop a policy on which this legislation may be based, and released a discussion document in July.

The discussion document presents options for assessing and expediting the introduction of exotic biota and the introduction and field release of GMOs, and actively seeks public feedback on these issues. [Submissions closed on 9 September 1988. Ed.]

Unlike the AA, it proposes risk be assessed in relation to benefit, risk being both disease and environmental risk. No criteria for risk or benefit are presented. Essentially, importation proposals will be classified into different degrees of risk which will be assessed by different procedures.

1. Low risk proposals may be dealt with simply and a permit issued.
2. Moderate risk proposals may require an Environmental Impact Assessment (EIA) detailing environmental and disease factors of the proposal in relation to the site at which the species will be introduced. This would be widely circulated among all interested parties before a recommendation is made.
3. A high risk venture may require that a more thorough document, an Environmental Impact Report (EIR), be prepared and sanctioned by the Parliamentary Commissioner for the Environment or her staff.

Until the new legislation comes into effect those wishing to import aquatic organisms may be required to prepare an EIA.

The EIA may be one (or more) of three types.

1. An EIA to import an exotic species will give details on the biology and diseases of the species. If approved, the proponent moves on to a phase II EIA.
2. The phase II EIA is needed to import the species approved in the first EIA into a specific site. The first EIA may be incorporated into the phase II EIA, but further details are required on the site at which the organism will be held in quarantine before release and introduction into the country.
3. A third, and lesser, type of EIA will be required for introduction of the animal into other catchments.

After wide circulation of the EIA by MAFFish, the fisheries business of MAF, a recommendation is made to MAFQual, the quality control branch of MAF, which supervises all aspects of importation and quarantine.

Details on disease required in EIAs include the origin and history of the stock, the composition of the stock to be imported, all known diseases and parasites in the organism's home range, and all known diseases in aquaculture overseas. This, taken with the biological parameters of the host, allows an assessment of disease risk to be based on several factors:

High risk	**Low risk**
Temperate temperature tolerance	High or low temperature tolerance
Virulence high	Virulence low
Direct transmission	Indirect transmission
Obligate pathogen	Facultative pathogen
Untreatable	Treatable
Many reservoir hosts	No reservoir hosts
Long survival outside host	Short survival outside host
Difficult to detect/latent	Readily detectable
Little information available	—
Destroys product quality	No effect on product quality
Threatens exports	No threat to exports

When there is a dearth of information, more caution has to be exercised in assessing the proposal.

Because the diseases of many aquatic animals are only poorly known, it is necessary to examine animals in quarantine after they have arrived in the country as well as requiring certification for freedom from disease before they are introduced into New Zealand.

While policy and legislation revision are underway it is timely to consider other aspects of importation such as the trade in tropical fish.

Currently, imported tropical ornamental fish are held in quarantine for 6 weeks before release. It was thought that during this time acute and chronic infections would become apparent. Recent research shows that stress causes a rise in plasma cortisol (Pickering and Stewart 1984), a drop in leucocytes (Angelidis *et al.* 1987), a drop in leucocyte function (Thomas and Lewis 1987), and the appearance of disease (Pickering and Pottinger 1985). It has become apparent that acute infections will probably occur soon after transport, whereas the slow-growing organisms associated with chronic infection will not become manifest in 6 weeks. There is, therefore, reason to consider reducing the holding period, possibly to 2–3 weeks. Over the current 6 weeks, stressed fish might succumb to pathogens acquired after importation.

Control of disease within the country is also important. Currently, the legislation (Marine Farming Act, Fisheries Act) contains provisions that allow unequal, and often insufficient, control. We have legislation that is concerned mainly with fresh water (particularly salmonids) and is not uniform in its application throughout the country. What we need is a uniform, nationwide policy that is flexible and wide ranging and incorporates the power to take or destroy stock, or to prevent the movement of infected stock when necessary. To achieve this, a system of disease control needs to be developed that, in general, can be applied to all the different aquacultural operations, in all waters, as and when necessary, and so consideration is being given to including provisions for disease control in the Aquaculture Bill.

References

Angelidis, P., Baudin-Laurencin, F., and Youinou, P. 1987: Stress in rainbow trout, *Salmo gairdneri*: effects upon phagocyte chemiluminescence, circulating leucocytes and susceptibility to *Aeromonas salmonicida*. *Journal of Fish Biology 31 (Supplement A)*: 113–122.

Pickering, A.D. and Pottinger, T.G. 1985: Cortisol can increase the susceptibility of brown trout, *Salmo trutta* L., to disease without reducing the white blood cell count. *Journal of Fish Biology 27*: 611–619.

Pickering, A.D. and Stewart, A. 1984: Acclimation of the interrenal tissue of the brown trout, *Salmo trutta* L., to chronic crowding stress. *Journal of Fish Biology 24*: 731–740.

Thomas, P. and Lewis, D.H. 1987: Effects of cortisol on immunity in red drum *Scianenops ocellatus*. *Journal of Fish Biology 31 (Supplement A)*: 123–127.

Discussion

Q. What information have you on diseases already in New Zealand?

A. We have good information on species that are already being cultured, but not on others which may have potential. It is difficult to find money for research on currently non-commercial species.

Q. By "genetically modified organisms" do you mean organisms modified by recombinant DNA techniques?

A. Genetically modified organisms includes the products of recombinant DNA techniques.

Q. Are these organisms considered to be more of a threat than other genetically changed organisms?

A. The U.S. and some European countries have brought in legislation to ensure these organisms are tested under contained and field conditions before general release. There is concern for their possible effects and most governments, including ours, are proceeding cautiously. I think that's reasonable.

How clean are our waters anyway?

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New Zealand already has a fine reputation for producing high quality seafood from unpolluted waters, and naturally producers use that fact whenever they can. Just about every pamphlet you pick up advertising New Zealand seafood will either mention New Zealand's clean environment directly or will allude to it indirectly by using beautiful scenic photography.

The joint New Zealand Fishing Industry Board/Mussel Industry Advisory Council's recent video about mussels has won a long list of prizes already. The image it gives is one of fresh wholesome seafood grown in sparkling clean waters. And the greatest thing of all about it is that it's all — true! This is honest advertising at its best. We really do have some superb seafood, and we really do have some of the cleanest waters in the world which are ideal for the culture of many aquaculture species.

But I believe the fact that we do have such clean water is more a matter of luck than good management. When I say that, I am not casting aspersions on those people whose job it is to protect the quality of our water. What I am saying is that we are lucky to have areas of minimum or no habitation where we can establish marine farming. We are lucky we don't have many of the nasty beasts that affect aquaculture industries overseas, such as toxic dinoflagellates. We are very lucky to have world class experts on diseases and pollution. We are lucky to have a good shellfish sanitation programme the U.S. recognises — that's an important point because only a couple of countries are allowed to sell shellfish live in the States. So all in all, New Zealand is pretty lucky. But believe me, we will be extremely lucky to retain all these advantages if we don't start actively fighting to maintain the water quality that we have. We cannot assume that large bodies of unpolluted ocean and estuarine water will continue to be available to aquaculture.

To illustrate my concern, I am going to point out a few potential threats to our unsullied, pristine image. There is no better way to illustrate the threat of pollution than by looking at bivalves.

Bivalves are so vulnerable to pollution because of the way they feed. They have two hinged shells, and when underwater the shells will be slightly apart so they can filter their food out of the water. They suck in large amounts of water through their gills (up to 40 $l.h^{-1}$). Any particles in the water are trapped in the mucous membranes of the gills and are passed by ciliary action up towards the mouth. Any large bits of grit are sorted out and removed and the rest passes in through the mouth to the gut. In effect, they are biological filters, straining and consuming whatever is in the water whether it be tasty and wholesome phytoplankton or whether it be viruses, bacteria, chemical contaminants, or anything else. Not only do they filter out whatever is in the water, they also concentrate everything — so whatever is in the water is likely to be up to 20 times more concentrated in the shellfish. Then, to make it worse, we often eat them raw, complete with their little stomachs which are bulging with all the plankton, bacteria, whatever they had recently eaten.

So it is essential that bivalves are grown in very clean water. And that statement is the bottom line of the New Zealand shellfish sanitation programme. No amount of post-harvest treatment such as depuration will compensate for poor quality growing water. To be allowed to harvest the shellfish, the water **must** be clean, and there has to be a statement on the export certificates to that effect.

So what is threatening our clean image?

Threats to water quality

1. Toxic chemicals such as TBT. Toxic pollutants are an obvious threat. I won't discuss TBT because Peter Smith will address this matter.
2. Accidental imports of animals and associated diseases. Many of our own aquaculture species are relatively free of the diseases which afflict overseas industries. Mike Hine has already talked about the methods we use to prevent importation of diseased or noxious animals. But what about unintentional imports? There is already plenty of evidence that we have some accidental imports to New Zealand. A current concern is what we may be importing in ships' ballast water. The list of things that survive transport across the world in a ballast tank is enormous (Carlton 1985, Hutchings *et al.* 1987). A couple of years ago the Tasmanian shellfish industry suffered its first toxic red tide incident, and it is now clear that the causative organism arrived in the ballast water of a Japanese wood-chip boat (G. Hallegraeff, pers. comm.). We cannot afford to have the same thing happen here.
3. Changes in adjacent land usage.
4. Any increase in point-sources of pollution.

I will deal with the last two together because they're related to each other.

I will use the Marlborough Sounds as an example because that region encompasses such a wide range of land and water uses. It is one of the few places in New Zealand where marine farming, forestry, commercial fishing, tourism, and recreation are all living side by side. It is also the centre of a large and growing bivalve industry, and, as we've seen, bivalves need very clean water.

Before a marine farming licence is issued to our hypothetical farmer in the Marlborough Sounds, there is a lengthy procedure to ensure that the proposed area is not polluted and is suitable for growing and harvesting shellfish. It must also be in an area designated suitable for marine farming by the Maritime Planning Authority. Our farmer gets his licence. He installs several thousand dollars worth of longlines, buys a boat, and over the years builds his farm up into a profitable unit. Now what happens to the marine farm when the county council decides to re-zone the adjacent land to allow a resort hotel to be built, or a plantation of *Pinus radiata*? (Marine planning is not administered by the same body as is the planning of land usage, so it is possible that such a situation could occur.)

A quick look at some figures in the New Zealand Official Yearbook for 1986–87 gives a hint of what might happen to our farmer. Under "earnings for the year ended June 1985" we find

Tourism:	$1750 million
Forestry exports:	$796 million
Fish & rock lobster exports:	$367 million

Fish and shellfish are at the bottom of the list, and aquaculture products are only a small percentage of this figure.

If such statistics are used, then some of the other users of the Marlborough Sounds appear to be powerful lobby groups, and aquaculturists need to be aware of where they stand in the national scheme of things.

However, these figures are misleading. I give them because they are typical of the sort of argument used when there is a conflict of interests anywhere. These are national figures, but if you consider the Marlborough Sounds themselves, then marine farming becomes one of the largest industries there.

However, don't assume that because our friend's marine farm is already there that he has rights extending to perpetuity. Occupation is not nine-tenths of the law.

Aquaculture does have a rightful place in the Marlborough Sounds and in many other locations in New Zealand. Aquaculturists have to overcome some pretty strong public antagonism towards marine farming. Aquaculture in New Zealand often seems to be automatically and irrationally opposed on principle. The granting of a marine farming licence is seen by many as a capricious act by MAFFish to donate public areas to an individual for selfish exploitation.

Aquaculture is as much an activity of national importance as tourism or forestry. The argument used by such bodies as the Marlborough Sounds Maritime Planning Authority that "it's the most recent activity, therefore it has lower priority than existing uses" (e.g., forestry and recreation) is not acceptable. Nor is the argument that if there are several users of a body of water, they are automatically in conflict. I contend that forestry, tourism, recreation, marine farming, and commercial fishing can all co-exist in places like the Marlborough Sounds.

Maritime plans are being written which set in concrete where marine farming and all those other activities may or may not take place. The approach seems to be to allow marine farming only in areas where the shellfish cannot become polluted. Surely, the obvious way to deal with potential pollution of the water is not to remove everything that can be harmed by the pollution, but to remove the sources of pollution!

Maritime planners need to be made aware that if maintenance of water quality is their Number 1 objective, then everyone can use the Sounds.

Marine farming, or any other activity, does not necessarily require exclusive use of the water. If we were really smart, we would use marine farms as a tool to prevent pollution, because if the water has to be kept clean enough for shellfish, then it is clean enough for every other use. It's a bit like a canary down a coal mine; if you see a mussel farm, you know the waters are clean enough to swim in and that you're bound to catch a snapper.

Taking this approach may mean an increased cost to all the users, and there would undoubtedly be squeals of protest, but our clean environment is New Zealand's best asset and the resource which sells our seafood, our tourist spots, our fruit and meat. And it is the clean environment which we must fight to maintain.

Everyone is responsible for maintaining our clean environment.

- Tourist accommodation and bach and home owners must treat their sewage adequately.
- Local bodies must ensure polluted wastes do not enter the water.
- Boat owners must not dump their wastes nor foul the water with toxic antifouling paints.
- The foresters must use milling techniques which have the least environmental impact (e.g., skyline cable logging and the use of barges and shore loading to keep logs out of the water).
- And we must do our best to avoid accidental introduction of harmful species and diseases.

This does not mean that marine farmers should get off scot-free either. Marine farmers have to pay for the privilege of using the water and, I imagine, will do so increasingly. They also must ensure that they are not harming the environment, nor restricting other users of the water. It is a shared resource, so the responsibility and cost of maintaining the resource should also be shared. Those vested with the responsibility of maintaining the quality of our water should be urged to do so in the ways that I have suggested, but they should also be made aware that marine farming makes many positive contributions other than the obvious ones of bringing revenue and employment to an area.

- Most species, especially bivalves, need clean water, so marine farms can and should provide a reason to prevent pollution.
- Activities such as mussel farming are attracting fish back to over-fished recreational areas.
- Marine farms provide interesting things to visit in areas which can't promise tourists tropical sunshine, sandy beaches, or reliable weather.

In other words, aquaculturists have to get out and sell themselves — to the public, to the politicians, and especially to the control agencies.

Here are a couple of quotes to raise your ire and get you out there to take up the challenge. The first is from Philip Tortell, who is with the Department of Conservation although he was with the Ministry for the Environment when he said this: "It is heartening to note recent moves to establish the credibility of marine farming in New Zealand. However, the case for aquaculture, in the face of competing uses of water, is at present so weak that in any planning exercise marine farming is reluctantly tolerated only in those areas which are of little use for anything else." (Tortell 1982).

The second is from the *Dominion* newspaper a month ago when a planning officer for the Marlborough Sounds Maritime Planning Authority was acknowledging that the planning process does not always produce good results. He said "If there are failures in the system much of the blame may lie with the [various communities involved] for not making [their] views sufficiently explicit." (*Dominion* 1988).

Complacency on the part of both the industries and the control agencies will be the ruin of existing aquaculture industries and prevent the development of new ones.

I will finish by reminding you what a fantastic asset our clean water is, but please don't just sit back there and assume that it will be there for ever, because if you do, it won't.

References

Carlton, J.T. 1985: Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. *Oceanography and Marine Biology Annual Review 23*: 313–371.

Dominion. 28 July 1988, p. 11. *Dominion* Newspaper, Wellington.

Hutchings, P.A., van der Velde, J.T., and Keable, S.J. 1987: Guidelines for the conduct of surveys for detecting introductions of non-indigenous marine species by ballast water and other vectors — and a review of marine introductions to Australia. *Occasional Report of the Australian Museum 3.*

Tortell, P. 1982: Environment. *In* Smith, P.J. and Taylor, J.L. (Comps.), Prospects for snapper farming and reseeding in New Zealand, pp. 33–36. *Fisheries Research Division Occasional Publication No. 37.*

Discussion

Comment. The Taranaki Regional Water Board has sent two senior staff to this conference to ensure it understands the needs of aquaculture, especially in terms of water quality. I applaud your comments that overseas perception of our products as coming from some of the cleanest waters in the world is one of our best marketing attributes. I urge delegates to this conference who may be thinking about establishing an aquaculture facility to talk to their regional water boards about water quality and ensure that they use only the best and cleanest sites. The Taranaki board is currently determining the best sites on the Taranaki coast for aquaculture ventures and the Department of Trade and Industry is also involved.

Comment. Marine farmers in the Marlborough Sounds have been critical of present effluent disposal systems. As a result, the Marlborough County Council has recently resolved to hold a public forum on water quality, to examine the disposal systems, and to call in experts from around the country. It proves you get things done if you try.

Comment. Your list of water users omitted local bodies, who I think are the chief polluters. Wanton pollution of water by sewage seriously militates against fish culture in this country and we should never forget it.

Comment. In Europe, the EEC have introduced designated shellfish growing areas with very strict limits on pollution levels. There are 22 such areas in Britain and they are very useful in maintaining high quality water. I believe you are being realistic in anticipating increased pollution from sewage in the future.

Organotin antifouling paints and the health of the marine environment

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Introduction

Organotin antifouling paints are widely used throughout the world. In the past few years marine scientists have expressed considerable concern over the use of these paints as they have detrimental effects on non-target organisms (that is, organisms located away from the vessel or structure being protected). Very low concentrations of organotin in sea water are toxic to shellfish: larvae are killed, reproduction is inhibited, and shells deformed. The purpose of this paper is to outline the overseas evidence for a problem with organotin and to describe the local situation and what is being done about it in New Zealand.

What are antifoulants?

Antifoulants are applied to surfaces which will be submerged in water for long periods of time. They are applied to prevent the growth of fouling organisms such as slime, weeds, barnacles, mussels, and oysters. Their most obvious, and major, use is on shipping, from yachts to supertankers, but the paints are used on buoys, sea cages, and marine farming structures.

There are two basic categories of antifoulant available: copper and organotin. Both depend on a toxic compound to prevent the attachment of fouling organisms. Other chemicals such as lead, mercury, and arsenic have been used in the past, but their use has been discontinued because of the potential long term damage to the environment.

Copper-based antifoulants have been used for generations. The Phoenicians nailed copper strips to the hulls of their vessels to reduce the growth of fouling organisms. Nowadays copper is mostly applied in the form of cuprous oxide mixed in a paint matrix. The disadvantage of copper-based antifoulants is that they are effective only for about 2 years. The advantage is their relatively low toxicity to non-target organisms. The organotin antifoulants were developed in the 1960s and extensive use started in the 1970s. Elemental tin has a low toxicity to marine organisms, but organic tin in which a tin atom is bonded to a butyl, or organic, group has very high toxicity. Tributyl tin (TBT) is the most commonly used and most toxic, but dibutyl and monobutyl tins are available. Organic tins are fat soluble, unlike elemental tin, and rapidly penetrate biological membranes, accounting for their high toxicity. The disadvantage of organotin antifoulants is their high toxicity to non-target organisms, that is they can affect organisms located several hundred metres from the vessel. The advantage is their long service life of up to 5 years.

Types of organotin antifoulants

There are three organotin formulations; they have different release rates of organotin and may require different management strategies.

Free association (or contact leaching). In free association antifoulants the organotin is packed into an insoluble matrix and simply leaches out in water leaving a skeletal matrix. The pores in this matrix become clogged and fouling organisms settle on the surface. A lot of organotin is left on the hull, deep in the paint matrix (Figure 1), and is not released until the vessel is scraped down in a boatyard where, unfortunately, paint residues are washed into the sea. This class of antifoulant has a high initial release rate and a short period of protection (about 2 years).

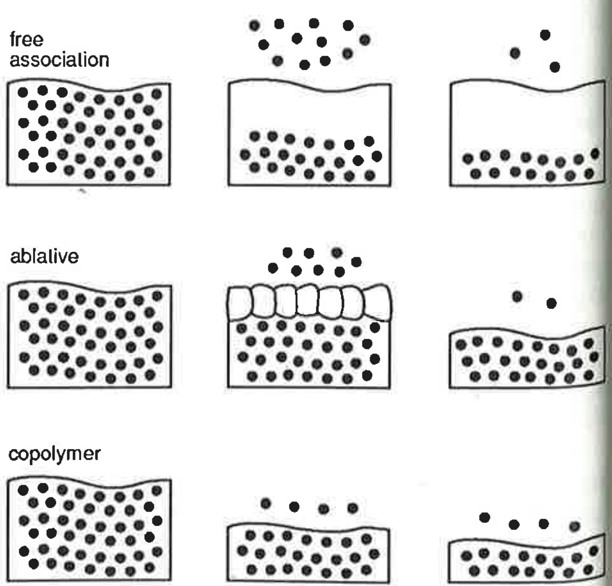

Figure 1: Release patterns of organotin from the three types of antifoulant. The boxes represent the paintfilm on the hull of a vessel and the black circles organotin.

Ablative. In ablative antifoulants the organotin is packed into an insoluble matrix which breaks down in sea water allowing the release of organotin deep in the paint matrix (Figure 1). They tend to have an erratic release rate and an effective period of protection of about 2 years.

Copolymer. Copolymer antifoulants represent a breakthrough in antifoulant technology. The organotin is chemically bonded to the paint matrix. This bond breaks down at the paint surface by hydrolysis in sea water, releasing a small amount of organotin and exposing a fresh layer below (Figure 1). Copolymer paints can be formulated to give high or low release rates and have an effective life of about 5 years.

Release rates in general vary with the speed of the vessel and water conditions. Many amateur craft are painted with high release antifoulants to provide adequate protection while the vessel spends long periods of time on a sheltered mooring. In contrast, commercial vessels in continuous service gain adequate protection from low release copolymer antifoulants.

What is the problem with organotin antifoulants?

In the late 1960s French scientists noticed shell thickening in Pacific oysters, *Crassostrea gigas*, introduced to the Atlantic coast of France. This shell thickening occurred only in oysters grown in estuaries with a large number of pleasure craft, or in oysters grown close to marina sites. Similar shell thickening was found in *C. gigas* growing near marinas in England. Considerable debate followed these observations: was shell thickening caused by something leached from pleasure craft, or was it due to sediment loading in the water?

Laboratory experiments showed that low levels of organotin, leached from antifoulants, were responsible for this condition, and subsequently that extremely low levels of organotin in sea water, of the order of micrograms per litre (a microgram is 10^{-6} g), are toxic to a wide range of marine organisms (Table 1). Less than 2 $\mu g.l^{-1}$ of organotin in sea water is sufficient to kill shellfish larvae, and less than 1 $\mu g.l^{-1}$ is sufficient to inhibit growth in larvae and reduce growth in spat and adults.

There are obvious implications for marine farming of shellfish. At about 1–2 $\mu g.l^{-1}$ spat failures would be experienced. At lower levels reduced growth in juveniles and shell deformities in adults with corresponding reduced meat yield would be experienced. How do these laboratory experiments relate to what is happening in the coastal environment?

What is the extent of the organotin problem?

There have been two approaches to measuring or estimating the extent of the organotin problem in coastal waters: analysis of sea water samples for levels of organotin, and the use of indicator organisms which have a measurable and biologically significant response to the presence of low levels of organotin. Both types of investigation have their limitations. Sea water samples provide a "one-off" picture of organotin levels, and the usefulness of indicator organisms is limited by their natural distribution. Nevertheless several critical observations have been made.

Sea water samples. Organotins are detected only in sheltered waters not subject to extensive tidal flushing (Cleary and Stebbing 1985, Environmental Protection Agency 1987). The highest levels have been found in marinas and yacht basins. There is no detectable increase from naval shipping or merchant shipping in docks or on commercial moorings (Cleary and Stebbing 1985). Concentrations of organotins in areas of commercial shipping are low compared with areas where small craft are abundant (Cleary and Stebbing 1987, Environmental Protection Agency 1987).

In estuaries, organotin levels reach a maximum in spring when pleasure craft are returned to their moorings (Waldock and Miller 1983, Environmental Protection Agency 1987, Langston

Table 1: Organotin levels (measured as tributyl tin chloride in $\mu g.l^{-1}$ sea water) recorded in selected localities in New Zealand and examples of effects from laboratory experiments

Location	Organotin ($\mu g.l^{-1}$)		Example of laboratory experiments
		1.6	Growth inhibition in oyster (Waldock & Thain 1983)
Westhaven Marina (Auckland)	1.4		
Evans Bay yacht basin (Wellington)	1.1		
Port Nicholson Marina (Wellington)	1.1		
Picton Marina	1.0	1.0	Mussel larvae die in 10 days (Beaumont & Budd 1984)
Evans Bay (Wellington)	0.4		
Havelock Marina	0.3		
		0.15	Poor growth and shell thickening in Pacific oyster (Waldock & Thain 1983)
		0.10	15 day LC_{50} mussel larvae* (Beaumont & Budd 1984)
		0.5	Imposex in dogwhelks (Bryan *et al.* 1986)

* 15 day LC_{50} is lethal concentration at which 50% of animals die in 15 days.

et al. 1987). Unfortunately this is also the time when many estuarine species reproduce, and it is the larval and juvenile stages that are most sensitive to organotins.

Improvements in water quality have been found in France following a partial ban on the use of organotin antifoulants on boats under 25 m.

Indicator organisms. Two indicator organisms have been used to measure the extent of the organotin problem. The first of these, the Pacific oyster, develops a deformed shell and rounded shape when exposed to low levels of organotins. The industry have named this condition "balling" (Figure 2). Deformed oysters have thickened shells containing a series of cavities and a much reduced meat yield (Figure 3). There is a strong correlation between shell thickening and proximity to pleasure craft moorings. As an example, in isolated bays on the west coast of Scotland, marked shell thickening occurs in *C. gigas* grown within 200 m of salmon sea cages painted with organotin antifoulants, detectable shell thickening at 1 km, and none at 5 km (Davies *et al.* 1987).

The second indicator organism is the dogwhelk, which may show a condition known as imposex in which the female develops male characteristics, most notably a penis. Dogwhelks are small gastropods which live in the intertidal zone where they feed on barnacles and mussels. British scientists noticed a decline in dogwhelk populations in parts of southwest England and that in these declining populations most of the females carried a penis. Laboratory experiments have shown that very low levels of organotin induce imposex in dogwhelks (Bryan *et al.* 1986). A similar condition has been noted in mud-snail populations on the east coast of North America (Smith 1981). By surveying populations for the percentage of females exhibiting imposex, it is possible to build up a picture of the extent of the organotin problem. However, in some areas all the females show imposex and scientists have resorted to using an index of relative penis size based on the bulk of the female penis expressed as a percentage of the mean bulk of the male penis (Gibbs *et al.* 1987). In severely affected populations imposex leads to sterilisation of the females.

Imposex is widespread in southwest England. Populations closest to centres of boating and shipping activity show the highest degrees of imposex (Gibbs *et al.* 1987).

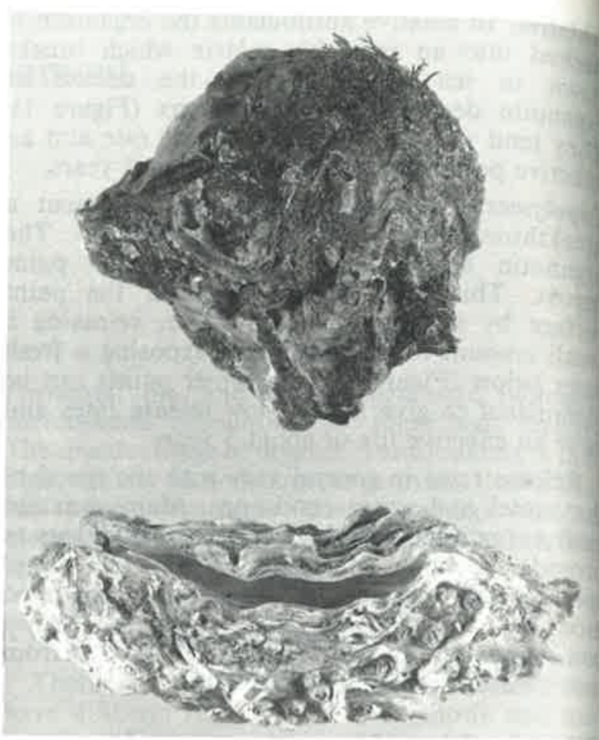

Figure 2: A rounded, or ball-shaped, *Crassostrea gigas* (top) compared with a normal oyster.

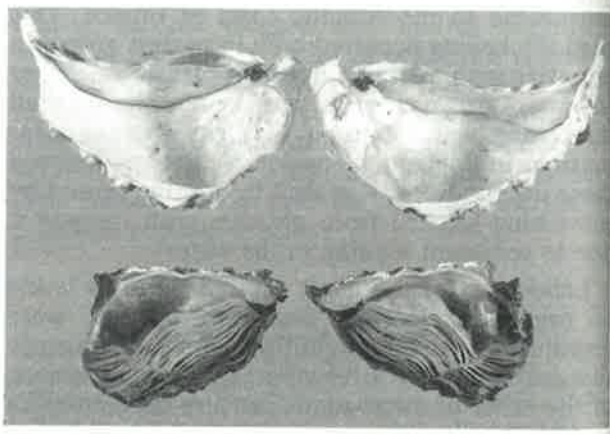

Figure 3: An abnormally shell-thickened *Crassostrea gigas* showing shell cavities (bottom) compared with a normal oyster (top).

Is there an organotin problem in New Zealand?

A few sea water samples were collected in 1985 from the potentially worst sites to see if there could be a problem with organotins in New Zealand. There were biologically significant levels of organotins in marinas at Evans Bay and Port Nicholson in Wellington, at Halfmoon Bay and Westhaven in Auckland, and in Picton, but not at Havelock (Table 1).

At about the same time, oyster farmers were asked to look out for deformed Pacific oysters. None were reported until 1986 when MAF staff found shell-thickened *C. gigas* in Halfmoon Bay. All the *C. gigas* growing in this yacht basin showed evidence of shell thickening. Subsequently, moderate shell thickening has been found in *C. gigas* from Fuller's slip in Russell and the Waikare Inlet in the Bay of Islands. In both areas it is associated with a high density of pleasure craft.

Table 2: Location of dogwhelk samples tested for imposex and the percentage of females exhibiting a penis. A minimum of 20 females was tested from each location

Location	Females with penis (%)	Comment
Parengarenga	0	No permanent moorings
Kaipara	0	No permanent moorings
North of Greymouth	0	Open coast
Mahurangi	36	Permanent moorings
Opua	96	Permanent moorings
Orongo Bay	100	Permanent moorings
Russell	100	Boatyard
Whangaroa	90	Permanent moorings
Auckland	100	Yacht basin
Wellington	100	Yacht basin

In late 1986, after hearing of imposex in European dogwhelks (Bryan *et al.* 1986), MAF staff collected dogwhelks from the Evans Bay yacht basin in Wellington. All the females showed imposex. This year samples of dogwhelks have been collected from a variety of sites and the results are shown in Table 2. On open coastal sites, or areas away from large numbers of pleasure craft, imposex is not detected. In sheltered waters with moderate to large numbers of pleasure craft imposex is common, and at several sites all the females exhibit a penis (Table 2).

What is being done about the organotin problem in New Zealand?

In 1986 MAF issued guidelines on the use and handling of organotin antifoulants to reduce the input of organotin into the coastal environment. In 1987 MAF banned the use of organotin antifoulants on salmon sea cages. A ban on the use of organotin antifoulants is being considered as part of the conditions of issuing all marine farm licences. In addition, last year a working party was set up by the Ministry for the Environment "to determine the extent to which restrictions on the use and/or availability of antifoulants containing organotins are necessary and the ways in which such measures can be effectively implemented". Members of the working party were unable to reach unanimous agreement and make a single recommendation to Government. Instead the report, produced in July 1988, identified three options for future management. These options can be summarised as follows.

- An immediate total ban on the sale and use of organotin antifoulants. That foreign vessels coated with organotin antifoulants remain in port only for essential activities and away from sensitive areas such as marine farms. That provision be made for the management and safe disposal of existing stocks of organotin antifoulants.
- A progressive total ban. An immediate ban on the sale and use of all free association and ablative organotin antifoulants. Low release organotin copolymer antifoulants could be applied to vessels by approved boatyard operators until October 1990 when these antifoulants would be totally banned.
- Progressive partial ban. An immediate ban on the sale and use of all free association and ablative organotin antifoulants. Low release copolymer antifoulants to be made available only to approved boatyard operators, and their use restricted to vessels greater than 25 m. All other uses of the copolymer antifoulant to be banned, with an exemption for craft with aluminium hulls or outdrives. As of October 1990 the continued use of organotin copolymer antifoulants be subject to review of the extent of the problem in New Zealand and the availability of suitable, proven alternative antifoulants.

Currently this working party report is about to go before Cabinet for a decision. Marine scientists and environmentalists hope that the politicians will act quickly on this issue and that a ban will be imposed in the near future. It is essential that the levels of organotins are reduced in our coastal environment if we wish to continue producing high quality seafoods for the export market.

References

Beaumont, A.R. and Budd, M.D. 1984: High mortality of the larvae of the common mussel at low concentrations of tributyltin. *Marine Pollution Bulletin 15*: 402–405.

Bryan, G.W., Gibbs, P.E., Hummerstone, L.G., and Burt, G.R. 1986: The decline of the gastropod *Nucella lapillus* around south-west England: evidence for the effect of tributyl tin from antifouling paints. *Journal of the Marine Biological Association of the United Kingdom 66*: 611–640.

Cleary, J.J. and Stebbing, A.R.D. 1985: Organotin and total tin in coastal waters of south-west England. *Marine Pollution Bulletin 16*: 350–355.

Cleary, J.J. and Stebbing, A.R.D. 1987: Organotin in the surface microlayer and subsurface waters of south-west England. *Marine Pollution Bulletin 18*: 238–246.

Davies, I.M., Drinkwater, J., McKie, J.C., and Balls, P. 1987: Effects of the use of tributyl tin antifoulants in mariculture. *In* Proceedings Oceans '87 Conference Vol. 4, International Organotin Symposium: 1477–1481.

Environmental Protection Agency 1987: Tributyl tin technical support document. Position document 2/3. Office of Pesticides Programs, Washington, D.C.

Gibbs, P.E., Bryan, G.W., Pascoe, P.L., and Burt, G.R. 1987: The use of the dogwhelk, *Nucella lapillus*, as an indicator of tributyl tin (TBT) contamination. *Journal of the Marine Biological Association of the United Kingdom 67*: 507–523.

Langston, W.J., Burt, G.R., and Mingjian, Z. 1987: Tin and organotin in water, sediments, and benthic organisms of Poole Harbour. *Marine Pollution Bulletin 18*: 634–639.

Smith, B.S. 1981: Male characteristics on female mud-snails caused by antifouling bottom paints. *Journal of Applied Toxicology 1*: 22–25.

Waldock, M.J. and Miller, D. 1983: The determination of total and tributyl tin in sea water and oysters in areas of high pleasure craft activity. *ICES CM 1983/E*: 12.

Waldock, M.J. and Thain, J.E. 1983: Shell thickening in *Crassostrea gigas*: organotin antifouling or sediment induced? *Marine Pollution Bulletin 14*: 411–415.

Discussion

Editor's note: There was considerable discussion on TBT, its effects on shellfish, and the desirability of controlling its use. While these proceedings were being prepared for publication regulations were being drafted which will prohibit the sale and use of all the contact leaching, soluble matrix/ablative, and high release copolymer organotin antifoulants. They will allow the sale and use of low release copolymer organotin antifoulants on craft greater than 25 m in length, and on all craft with aluminium hulls. The continued use of these antifoulants will be reviewed as at 1 December 1990. Accordingly, most of the discussion on TBT antifouling paints has been omitted.

Q. Oysters and other shellfish accumulate heavy metals. Is there any information on the effects of TBT on consumers of shellfish?

A. Very little. Levels of TBT in salmon flesh are low and give no cause for concern, given average consumption rates. The question is clearly one to concern consumers of large amounts of seafood, like the Japanese.

General discussion on Sessions 2 and 3

To Dr D.S. Roper

Comment. I understand that when the Norwegians move their cages they mechanically stir up the bottom below where the cages have been to accelerate the cleaning process.

A. As far as I know, this practice is confined to Norway. Perhaps our industry should look at it. Our farmers are likely to be told that any problems they create are theirs to deal with, and perhaps they will run out of licence areas if the wastes aren't removed.

Comment. Waste material is broken down very quickly if it's spread thinly — which can be achieved by raking or moving the cages. If the cages are moved around there should be no significant build-up of wastes.

Comment. Most salmon farm sites allow for some rotation, but the size of many cages means they can be moved perhaps once every 5 years.

A. The accumulation rates we measured were very significant — about 30 cm in 3 years, although it's difficult to measure accurately. Our estimates of oxygen consumption of the wastes suggest that recovery will take years rather than months.

Comment. Accumulation rates can depend on management regimes. Norwegian farmers used wet food originally which dropped straight to the bottom. They are restricted to 8000 m^3 farms, so they farm very intensively and that leads to waste accumulation. They have used propellers on the bottom to move waste away.

To Dr P.M. Hine

Q. Did the steering group consider the risk of importing pathogens in flesh products such as Canadian salmon?

A. No, that was not within the group's brief.

Comment. Lime and other chemicals used to treat disease outbreaks can affect domestic or industrial water supplies. Water boards must be able to contact users and shut off supplies in an emergency if necessary. Boards have fairly wide discretionary powers already and are not normally unreasonable. It should be possible to build provisions for emergency control measures into the reformed environmental law.

A. A national plan for control of disease outbreaks will require co-operation between water boards, acclimatisation societies, and other people with expertise.

To Ms B.J. Hayden

Q. The limit for copper in shellfish is 30 ppm under the food and drug regulations. This is supposedly set on public health considerations. Could you comment on the relevance of this, as there are oysters in parts of the north which are close to or exceed that limit?

A. I'm not fully familiar with that area, but in other parts of the country natural populations of shellfish have high levels of some heavy metals. We don't know why. As far as I know the Health Department often monitors heavy metals in shellfish and is satisfied that in most areas where there are marine farms the WHO recommended limits are not exceeded. Possible pollution from a wide range of sources is considered during the licence application stage for marine farms.

Comment. Algae grown in polluted water may strip out various nutrients, but the alginates or other products may be unsalable because of the heavy metal content. For sewage contamination of shellfish, bacterial counts are used as the indicator, but we find that you can have a bacterial count of almost zero associated with a very high viral count.

A. Because bacterial counts don't necessarily give an indication of viral contamination, they are not used on their own to assess the suitability of areas for growing shellfish. A "sanitary survey" is undertaken of the surrounding catchment which considers any present or potential source of pollution. If anything, including viruses, shows up as a threat to human health, then the area is not approved for shellfish growing.

Comment. I can't comment on alginates, but DSIR Chemistry Division found no problems with heavy metals in the agar extracted from *Gracilaria* grown in the Manukau sewage trial.

Q. Is a water right needed to discharge ballast water into our harbours?

A. Yes, though in practice it doesn't apply to small vessels. Ballast water from oil tankers is passed through separators to reduce the hydrocarbon level to about 5 ppm, and a water right is needed to discharge. Boards don't usually look for protozoa or micro-organisms that might affect aquaculture operations. This is an area where MAF should become active. Existing legislation is really quite powerful.

The New Zealand oyster farming industry

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Introduction

The northern oyster farming industry is small by world standards. It is limited by the area of physically suitable ground and by the proportion of this that may be available for leasing.

Annual production is estimated at 4000 t whole shell weight. The Pacific oyster (*Crassostrea gigas*) became the dominant farmed species in the 1970s, replacing the New Zealand rock oyster (*Saccostrea glomerata*). Some growers are again cultivating the rock oyster, unintentionally, as it has re-emerged in some east coast catching areas over the past 2 years. A third oyster, possibly the tropical *Saccostrea echinata*, is now present in large numbers in far northern harbours and in lesser numbers further south.

For basic cultivation, material is set out on both coasts in summer to attract natural spatfall. Soon afterwards this is moved to growing areas, mostly on the east coast, where the oysters are grown to maturity, either attached or as single seed, supported on structures at an optimum level on the intertidal shore. Some deepwater farming is carried out, mostly to gain condition and to delay spawning. Growth is regulated to enable crops to be sold 12 months after settlement through to 2 years. Farmers buying in advanced stock achieve a much faster turnover.

At present 430 ha of suitable ground have been leased, of which 300 ha are fully developed. If the remainder, and some 140 ha possibly available, were developed, then annual ex-farm value would increase from the present $4.5 million to $10 million.

Contrary to world trends 50% of farmed oysters are exported, mostly to Australia, the Pacific Islands, and Asia. On the local market they compete with the large, seasonal, southern flat oyster and with imported oysters.

Industry structure

Until recently the industry was structured into two groups; the six larger growers who also operated their own processing facilities (export/local packhouses) and the remainder, who held 70% of the growing ground and who sold almost exclusively to the big six.

Over the past few years larger operators have experienced problems that have resulted in some consolidation of processing capacity. It has been difficult to arrange satisfactory forward exchange cover for the free floating New Zealand dollar relative to a continuing daily sales operation on export markets; premises built on an interest rate of 8% have been required to service a rate of three times that; it has been difficult to increase sales of half-shell oysters; there have been massive failures in the material on which oysters were grown with a resulting loss of mature crops; and some operators were slow to move to the west coast for spat catching. Consequently, the smaller supplier growers' expectations of automatic price increases have not been realised. Some are receiving less than they were 3 years ago ($1.50 down to $1.35 per dozen).

These events have led to the emergence of a growing third group of farmers who have their own smaller processing operation supplying the local market with fresh meats (plus some whole shell). The larger Pacific oyster makes the meat trade more attractive. It offers a similar margin for profit as half shell and allows most farmers to move up to the wholesale level and above. It presents a larger range of prospective consumers who can now buy oyster meats at the same price per kilogram as medium grade fish species.

The industry was originally structured to supply half shell rock oysters to the restaurant market. In this select trade it is difficult even for large growers to move past the wholesale level, beyond which the greatest increase in price takes place. This structure will continue at least at the present volume, but there is a definite trend to move into local meat sales. All this follows, on a small scale, the operations of the southern oyster fishery.

Biological problems

Unlike farmers elsewhere, those in New Zealand do not have to contend with the problems of *Bonamia*, MSX, QX, dermo, winter mortality, summer mortality, toxic algal blooms, predation, or major industrial or human pollution. Fouling by other species can be avoided or controlled by appropriate farming methods. The industry does, however, suffer from the self-inflicted problem of mudworm (*Polydora* sp.) infestation simply because some farmers have chosen to grow too low and others have allowed oysters to become covered in mud — and all against the best advice. It is disappointing that little is being done to remedy this, the generally held opinion being that the problem will go away. This opinion is based on hope rather than fact.

The problems associated with tributyltin antifouling paints are evident in northern waters. At this stage, oyster farmers can only hope that the relevant authorities will take corrective measures in line with the working party's report on the matter.

Other problems and responses

Lease tenure. Industry considers the lease tenure of 14 years to be too short and too insecure for the investment required to develop it. Lenders of funds tend to regard the considerable expenditure as being of little value without firmer tenure. This perceived lack of security has resulted in many operations taking on an untidy, temporary appearance.

Responses

To take the initiative to tidy up farms and depots.

To arrange with local authorities to have oyster farming activities incorporated into district scheme plans as a predominant use.

To encourage MAF and local authorities to agree on locations where future applications could be considered.

To approach Government to grant more favourable and secure lease terms, as provided for in the legislation.

Sanitation controls. Based on the U.S. National Shellfish Sanitation Program, these controls require oysters for export to be grown in waters of high quality, sanitary facilities on farm barges and farm depots, farmer documentation, and so on. Industry sees few problems in these being applied at a local level: they do see as unfair competition oyster farmers in other countries supplying raw oysters to New Zealand not having to similarly comply.

Response

To seek assurance that requirements imposed on local farmers be also imposed on foreign farmers supplying the New Zealand market.

Water quality testing. Those local bodies responsible for water conservation legislation do not usually carry out sufficient testing to provide a complete picture of water quality in their areas, no doubt due to lack of funds. An oyster farmer entering, and remaining in, the sanitation programme must pay for additional testing by a Government agency.

Responses

To seek co-ordination in local and central Government testing programmes.

To seek a broader base for payment funded by all users who have an interest in maintaining water quality and by potential polluters who hold a permit to discharge.

Future expansion

As increased production does not necessarily equate with increased profit, it is unrealistic to expect that every farm will constantly operate at maximum capacity. Nor can we expect production to run too far ahead of market capacity. On this basis most farmers are making good use of their areas.

The major increase in development must come from the remaining remote areas in the far north. Resident Maori interests are best placed to take advantage of this opportunity. There is a need for them to work together in integrated operations to make best use of the land on both coasts. To this end, training and development programmes are now underway.

There is no complaint that these activities are Government funded at this early stage. However, when they become commercial they should operate from a financial base similar to that of established private industry, otherwise public-funded, uneconomic pricing could develop to the eventual detriment of all.

Conclusion

The current euphoria for deregulation has not yet extended to the granting of leases for oyster farms. If developed areas are to be held and full potential reached via additional areas, then a united effort by all is required

- to make local authorities aware of the value of oyster farming to the local economy;
- to convince conservation groups that a well run oyster farm does not damage the marine environment;
- to assure all that farming is compatible with the activities of other users of the outer tidal lands;
- to ensure water quality is maintained; and
- to work together on product quality, to develop new product, and to attain some order in price stability.

Discussion

Q. Has anyone tried suspended tray culture of Pacific oysters in Northland?

A. Yes, they grow well and make a good product.

Q. Is there still a problem with spatfall in Northland? Is the industry still interested in a hatchery?

A. Spatfall is adequate, but the pattern is changing. Spat failures have occurred in the downstream east coast areas and some farmers have been slow to move to upstream areas or over to the west coast. There is certainly the potential for hatchery production, especially for triploids which don't depend on the sexual cycle for fattening. It could be possible to have oysters in good condition all year round.

Comment. In joint work between a commercial farmer and the University of Washington there have been difficulties in confirming triploidy. The oysters did not grow faster than normal, but they were sweeter and salable out of season.

A. Here we don't have to grow Pacific oysters faster — we try to slow them down. The important thing is that they are fatter and available out of season.

Q. Have there been any changes in the ecology of Kaipara Harbour as a result of the number of Pacific oysters there?

A. No. There are massive numbers of oysters there and in the Hokianga Harbour. There are large catches each year, especially low down, but there is also heavy mortality from, I think, mudworm. Others die from overcrowding.

Q. Is there much interest in triploid oysters?

A. There is among the larger growers, but even they won't pay too much for hatchery produced oysters.

Trial commercial aquaculture of black-footed paua (*Haliotis iris*)

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Introduction

Between the stage of proving that it is technically feasible to grow an animal under artificial conditions and the founding of an industry it is obviously beneficial to demonstrate that the organism can be grown on a commercial scale. Although it has been shown previously that, at least on a small scale, the New Zealand black-footed paua, *Haliotis iris*, can be on-grown from the larval stage (Tong and Dutton 1981), it remained to be shown that it could be done successfully on a commercial scale. The present study reports the preliminary results of the attempt by Crystal Park Marine Farms (a partnership company owned by Wilson Neill Ltd. and R.E. and P.D. Brown) to commercially farm *Haliotis iris*.

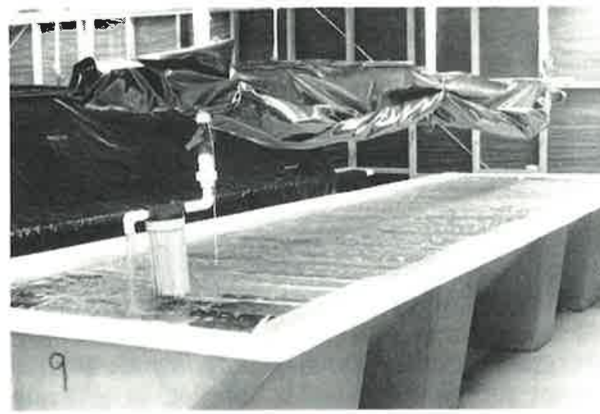

Figure 2: A V-shaped tank for early rearing (the black plastic is used for periodic shading).

The paua farm

Crystal Park Marine Farms is on the Wairarapa coast (the southeast coast of the North Island), just north of the holiday community of Riversdale. The farm (Figure 1) is supplied by a flow-through sea water system with an intake about 2.7 m below mean low water on a rocky coastline. Intake pumps are located inshore, but not far from mean high water mark; they push the sea water through nylon washer filters and then on to a large sea water holding tank. Sea water is then gravity fed to a large shed housing V-shaped tanks (Figure 2) where the paua are grown from larval settlement to about 5 mm. The sea water is also gravity fed to outside "on-growing" tanks (Figure 3) where paua are placed when they reach about 5 mm.

A small laboratory for spawning, fertilising, hatching, and rearing the larvae until they are ready to settle can also be supplied with sea water from the holding tank. Between the storage tank and all rearing tanks, as well as the laboratory, the sea water undergoes additional filtration. All waste sea water flows through tanks growing the seaweed *Gracilaria* sp. (Figure 4) before discharge back into the sea.

Figure 1: Crystal Park Marine Farms. Midcentre is the shed housing the V-tanks, the outside on-growing tanks are to its left. Centre right are the sea water holding tank, the manager's accommodation, and a shed for holding live rock lobsters.

Figure 3: A U-shaped tank used for on-growing beyond 5 mm. PVC pipe sections provide artificial habitat.

The paua larvae produced at the farm or bought in from MAFFish's Mahanga Bay shellfish hatchery in Wellington are settled in the V-shaped tanks in the large shed. Just before adding the larvae, the tanks are seeded with a culture of diatoms (mostly *Navicula* spp.) obtained from the Mahanga Bay hatchery. Diatom growth is carefully controlled in the tanks by periodic shading with black polythene sheeting. Surface area in the tanks for both the diatoms and the grazing paua is increased by the use of vertical triangular plates running across the width of the tanks (Figure 5). The tanks are about 6 m long, 1 m wide at the top, and 0.6 m high, and are continuously aerated. The paua feed solely on the benthic diatoms until they are about 2 mm long, when mashed *Gracilaria* sp., collected from the on site growth ponds as well as a nearby estuary, is added as a supplement.

At 5–10 mm the paua are transferred to outside tanks where lengths of PVC piping are used as an artificial habitat. From here onwards they live on the surfaces of the PVC piping (Figure 6) and are fed a mixed diet of macroalgae (mostly *Gracilaria* sp., *Pterocladia lucida*, and *Durvillea antarctica*). Except for *Gracilaria*, the seaweed is generally collected from the beach as drift material. The outside tanks are either U- or V-shaped, are of similar dimensions to the inside tanks, and are continuously aerated.

Figure 4: Tanks used for cultivation of *Gracilaria* sp. and for nutrient stripping.

Figure 5: Plate used to increase surface area for rearing in the V-tanks; dark regions on the plate are diatoms "seeded" on to the plates and grazed by the juvenile paua.

Results and discussion

Growth rate of the farmed paua over the first 13 months of the farm's operation has been variable and lower than anticipated. Figure 7 shows length frequencies of four separate populations aged 13, 12, 11, and 8 months sampled in August 1988. Comparisons of these growth rates with those found in the wild suggest that the animals are quicker growing in their natural habitat.

Although first year growth in juvenile *Haliotis iris* at Banks Peninsula (Sainsbury 1982) and at Kaikoura (Poore 1972) had a high variability like the farmed populations, the mean growth rate was invariably higher. One population showed a mean growth rate of over 30 mm for the first year (Sainsbury 1982).

Why animals grow faster in the wild is unclear. It is possible that wild juvenile animals on the Wairarapa coast show the same relatively low mean growth rate as our farmed animals because of less favourable environmental conditions on the Wairarapa coast. However, clearly some wild juvenile populations can grow faster, and it is important to ensure maximum growth rates are being achieved on the farm. Future work will, therefore, concentrate on increasing the mean growth rate and reducing the variability. At present the following means of achieving this are being considered; more intensive size grading, altering food regimes, altering the artificial

Figure 6: Paua (13–21 mm long) growing on PVC piping from outdoor U-shaped tanks (colour bands are related to diet).

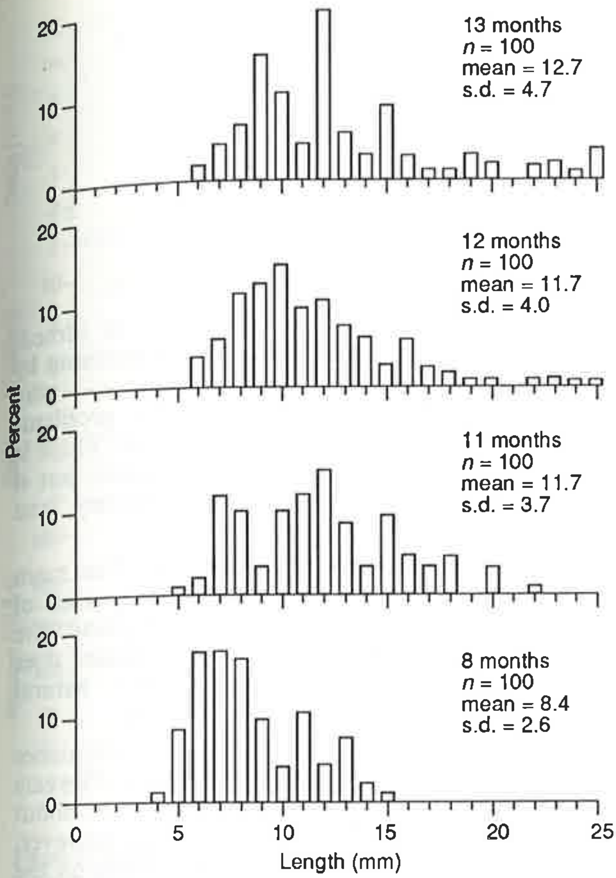

Figure 7: Length frequencies of four paua populations sampled in August 1988.

substrate, selective breeding, genetic engineering, and, finally, using a faster growing species of *Haliotis*.

Clearly, the path to successfully farming on a commercial basis a species which has never been farmed before is fraught with considerable difficulty.

References

Poore, G.C.B. 1972: Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 3. Growth. *N.Z. Journal of Marine and Freshwater Research 6*: 534–559.

Sainsbury, K.J. 1982: Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *N.Z. Journal of Marine and Freshwater Research 16*: 147–161.

Tong, L. and Dutton, S. 1981: Growth of post-larval paua. *Catch 8(5)*: 18–19.

Discussion

Q. Do you manage to filter out plankton blooms? What volume of water is pumped through the system in 24 hours?

A. The 1 μm filters take out everything except the very smallest bacteria. The pumps deliver 16 $l.s^{-1}$ [equivalent to almost 1.4 million litres a day].

Q. Are there any differences in growth rates among the different seaweeds?

A. We haven't checked that. At the moment we're ascertaining the viability of the system; we'll do the more sophisticated work later.

Q. How many paua can you produce with your present 16 $l.s^{-1}$ water flow, and how much water will you need when the animals reach 50–60 mm?

A. We hope to produce about 1 million cocktail size paua, and we believe our present flow will cope with the larger animals.

Q. Your growth rates are low. Have you experimented with alternative feeds?

A. No, but artificial feeds may be a way to increase growth rates.

Species enhancement in the natural environment

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Introduction

There are various ways of going about aquaculture and increasing the production of desirable species. Each of these has been mentioned during this conference, and there are some rather fundamental differences between them. I will discuss some ways in which species enhancement in the natural environment can be applied in New Zealand.

The critical features in aquaculture are the control of the biology of the animal, and control of the environment in which it grows. Land-based systems, those that make extensive use of hatcheries and rearing ponds, exert a large degree of control both over the biology of the species (that is, its breeding cycle, growth, and condition) and over the environment (such things as the water temperature, flow rates, and amount of available food). Prawns and abalone are examples of organisms raised in this way. A second type of system uses modified sea environments to grow a species. Much of the work for these industries is done in land-based facilities, but the growing is done in the sea. For example, longlines are used for mussels, and racks are used for rock oysters. This category falls under the heading of "sea farming". The third type is more like "sea ranching"; it is primarily sea-based. The initial condition of the animals is controlled, but once they are placed into natural sea habitats there is virtually no control at all over the animal or the environment.

The first two of these have been discussed by others at this conference. This paper is concerned mainly with the third category, species enhancement in natural habitats. Aquaculture scientists are often approached by people who are enthusiastic about the prospects of seeding natural areas with desirable species, with the aim of letting nature take her course and do the work of growing the animals to marketable size. This has been suggested for many species, paua, scallop, flat oysters, and snapper, to name a few. The argument commonly goes that "if we just get more fertilised eggs, or more recruits of these species, into the natural environment, then it's bound to increase the population size of the larger animals. It can't fail, can it?"

The simple answer is "Yes, it can fail", for a large variety of reasons, and so we are continually being put into the position of taking the wind out of people's sails, of dampening their enthusiasm for this sort of venture. This talk is aimed, however, at rekindling some of this enthusiasm by discussing population enhancement — why attempt it?; what are some of the problems encountered?; and what can be achieved? There is plenty of scope for hope and enthusiasm, but it should be informed, so that time, money, and opportunities are not wasted.

Why attempt species enhancement? The main reason is that most of the marine species of commercial importance in New Zealand are heavily exploited and, unfortunately, nature does not always do her part and replenish natural populations to the extent we might like.

This is illustrated by the scallop fishery. Catches have been quite variable for the past 20 years (Figure 1A). There was a peak harvest of about 10 000 t greenweight in 1975. Last year, however, only 2800 t were landed, which was down on the previous year. Export earnings have tended to go upwards since 1982, but have fluctuated with the catches (Figure 1B). They were down last year to $5.6 million from a high of $8 million the previous year. Figure 1C shows what a determined programme in species enhancement has done. The Japanese harvest for scallop hovered around a few thousand tonnes until 1970, when an enhancement programme was begun on a large commercial scale. Total production today is about 200 000 t. Also notice how long it took to get the catches to this level, a fairly concerted effort for about 18 years.

A similar pattern is seen for New Zealand paua: fluctuating catches over the past 20 years (they now stand at about 1000 t; Figure 2A), but a rather abrupt increase in export earnings, reaching $14 million last year (Figure 2B).

Here then are two highly valued species, both of which have problems in their fisheries and variable and unpredictable recruitment from year to year. This can have immense ramifications for the fisheries, and consequently on people's livelihoods. In situations like these, and there are certainly other species this applies to, there are essentially two choices. Either an attempt can be made to "manage" the fisheries by monitoring catches and effort (this means waiting an indeterminate time for natural recruitment to occur and restricting catches accordingly); or enhancement of the fisheries can be attempted using aquaculture techniques to increase the total catches.

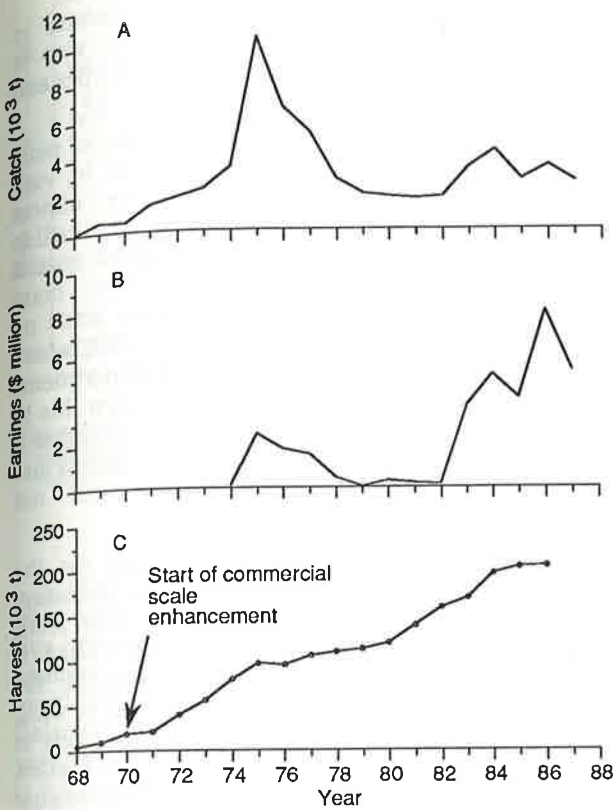

Figure 1: Total green weight of scallop catches in New Zealand since 1968 (A), export earnings (B), and the total green weight harvest for scallops in Japan since 1968 (C).

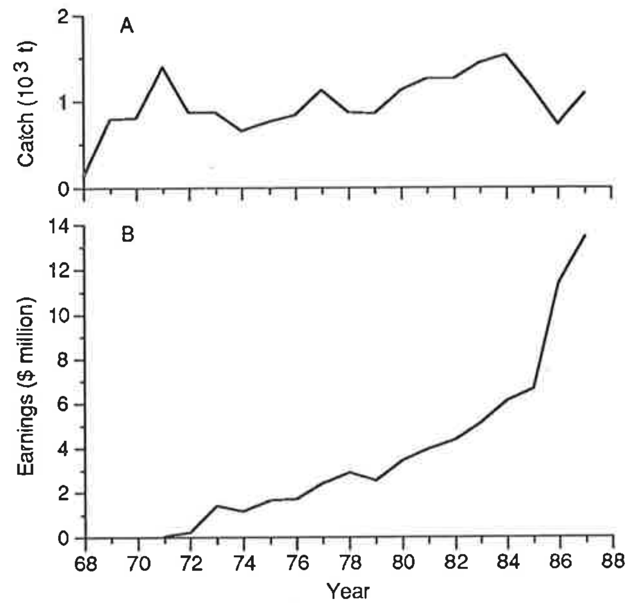

Figure 2: Total green weight catches for paua in New Zealand since 1968 (A), and export earnings for paua meat (B).

If enhancement is opted for, some fairly critical assessments must be made about a project before deciding whether or not "it's on". The biology of the target species must be understood, because certain phases of its larval development, settlement, or growth will need to be controlled. There must be considerable knowledge about the environment where it normally lives, whether growth and survival can be optimised by identifying and choosing the best sites and habitats. There is usually some technology associated with any type of aquaculture venture, a hatchery for paua; rafts and longlines for mussels; settlement surfaces for scallops, are examples. When all this is worked out and optimised, a critical assessment must be made of whether the financial returns are worth the expense and effort of the entire exercise. And finally, this is all done against a legal background of permits and licences. Having decided, on these criteria, that a species is worth the attempt, the two most critical initial phases are understanding the biology and environment of the target species.

The various life stages of the target species must be understood and it must also be recognised that each stage will have different physical requirements and may respond to the environment differently. Larval stages are notoriously difficult to work on: they are usually difficult to sample because they occur in the open water and can be quite patchy in their distribution. This can be circumvented by using a hatchery to produce larvae. At the moment, however, most marine aquaculture industries in New Zealand, such as rock oysters and mussels, rely on catching natural larvae.

As animals reach their late larval stage, they require a suitable surface on which to settle, metamorphose, and grow. They may prefer some sorts of surfaces. They may survive and grow better in some conditions. After they begin growing, they may have different requirements again, and occupy different portions of their habitats as juveniles. These two phases are critical to enhancement, because if the animal is introduced to the best habitats and sites there will be a better chance of high survival and good growth. Finally, for some species there may be another change in habitat requirements as adults.

To complicate the problems of understanding the requirements of each life stage of target species, even when the right sort of locality for a species is found, a range of factors will be encountered that may vary considerably over small spatial scales. The substrata, or bottom characteristics, may change from place to place, there may be predators such as fish, starfish, or whatever happens to eat the target species. There are potential competitors (that is, organisms similar to the target species) that have the same requirements and may affect the outplanted species. Furthermore, all these characteristics may change at different depths and from site to site.

Faced with all these potential influences, the goals and objectives of enhancement must be kept in mind. The goal is to increase significantly the number of the target species in selected sites — you are going to counteract nature's indifference in not providing the natural recruitment necessary to sustain the fishery. The objectives along the way are to increase the predictability of results (you want certain numbers to survive in selected habitats) and you also want to make your results reliable (i.e., less variable) so that there is a reasonable chance of enhancing populations to the desired levels every time the attempt is made.

This approach has been applied to two marine species in New Zealand — scallop and paua. The research programme for scallops was jointly funded by MAF and the OFCF (Overseas Fisheries Cooperation Foundation) of Japan (co-ordinated by Dr. M. Bull) and has produced some very encouraging results. This programme is now in its commercial phase.

Scallops occupy benthic areas with a predominant cover of sand and mud. It was discovered that scallop larvae were generally abundant in areas like Golden Bay, but the sea bottom was usually so disturbed that larvae did not settle successfully over wide areas. The main requirement was to develop and provide good and plentiful surfaces on which the scallops could settle and then grow past their most vulnerable small stages.

A longline device was used to provide the settlement surfaces for scallops. It also allowed them to grow for a few months to a size large enough that they could survive on the sea floor. The nuts and bolts of this do not need to be discussed here. The main important feature is that millions of larvae settle successfully in cages, which are spaced along a longline placed in the sea. Many of these longlines can be put out so there is a very large catch of scallops.

One method of reseeding these scallops is to strip them from the cages after a few months of growth, transport them by boat to outplanting sites, and spread them over a wide area by pouring them over the side of the moving vessel. Two to three years later, they are harvested. An example of how well the experimental trials of this programme have worked is a 1 km^2 area that was seeded with about 10 million spat (scallops of about 10 mm shell height). Two years later, 1.5 million scallops were harvested.

Most enterprises of this nature start off with smaller experimental trials and then scale these up to a large commercial level. The economics of this scallop enhancement look very favourable.

The paua enhancement programme is at an earlier stage of development, and has its own particular suite of problems to overcome. Paua, unlike scallops, live in a very complex reef environment, with different types and sizes of large foliose algae. Many mobile predators are present, such as banded wrasses (*Pseudolabrus fucicola*), spotties (*P. celidotus*), and blue cod (*Parapercis colias*), which are very common in shallow reef environments. There is also a heterogeneous substratum with different types and sizes of rocks and boulders.

Two main features of the interactions of paua with their environment have proved to be very important. One is that paua settle almost exclusively on encrusting and articulated coralline algae which are very common in shallow coastal areas where paua live. The other main characteristic is that once juvenile paua settle on rocks, they crawl around to the undersides, where they live for a few years. Numerous experiments along the Wellington coastline have shown this to be a major habitat requirement of paua, and that if the habitat shifts or changes because of storms and substratum movement, small paua will not survive.

There are some very clear messages for the enhancement of paua populations. It is necessary to find the right sort of general habitats with reefs, boulders, smaller rocks, and large brown algae. If larvae are being seeded into natural areas, the parts of habitats with coralline algae must be used, because that is where the larvae are most likely to settle successfully. It is better done in shallow water. Also, there is a technological side because there is a need to raise good, healthy, active larvae and juveniles. There must also be good handling techniques if there is to be any hope of real success. "Real success" means that results are both predictable and less variable, so that enhancement levels can be reliably repeated. That, in a nutshell, is the main advantage in approaching the problem of enhancement scientifically — if it works, you know why it worked, and if it fails to work, you also know why, and presumably can do something about it.

Finally, when there is a reasonable knowledge of the biology of a species and its natural requirements, there should be enough information to judge the economic viability of an enhancement venture. There are trade-offs between the initial size of outplanted animals, their subsequent survival in nature, and the costs to get them there. Taking paua as an example (Figure 3), larvae can be put into natural habitats; the larvae are relatively cheap to produce, but they also have a low survival rate. Only a very small percentage of larvae, perhaps about 0.2%, will ever make it to be juveniles. Say you want to harvest and market the paua at a size of 50 mm. This will take 2.5–3 years in natural habitats. Will the returns be enough to make a profit at that stage?

An alternative is that paua can be raised to a larger size (10–20 mm) in a hatchery. There will be a better survival rate after outplanting them, maybe as high as 10–15% annually, but the cost of producing the paua will also be greater. They will have to be kept in tanks and fed. A larger facility will probably be necessary for this, so capital costs will be high.

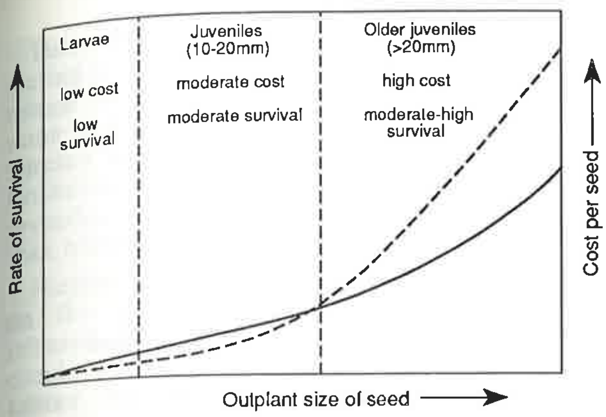

Figure 3: Schematic representation of trade-offs that must be made among the variables of size of outplants, survival rates (solid line), and cost of production per seed (broken line).

A third option is to try what the Japanese do. They grow abalone to about 30 mm in hatcheries; this process takes 2 years, so the cost is high. The abalone are then put into natural habitats for another 2–3 years before they are harvested. Balanced against the rearing costs, however, is a survival rate of up to 18% annually. This method is seen as economically viable in Japan.

The important point here is that there is no single answer or strategy for all species, or even for a single species. These are the sorts of trade-offs, however, that must be considered before deciding the best strategy for outplanting a species. These trade-offs will be different for each species because of its biology, the environment, the cost of technology, and, perhaps most importantly, the value and market return of each species.

Conclusions

Three main conclusions arise from this paper.

1. Species enhancement is complicated, but is also achievable.
2. It does take some time, usually several years.
3. The decisions along the way must be based on good scientific studies of the target species and its environment.

It is also noteworthy that this information is quite useful, indeed necessary, to manage fisheries for these species.

As a last thought, I'd like to reiterate what other speakers have pointed out: that aquaculture is going ahead in a big way in many countries of the world. New Zealand has some very strong selling points: clean water, good species, a knowledgable workforce, and the scientific expertise to solve the biological and technological problems. We can either be innovative and pursue these goals or stand and watch as the rest of the world zooms past.

Discussion

Q. How will you prevent amateurs from removing your outplants?

A. That's a complicated problem being considered by legal people at the moment, but I think there are ways.

Q. Do you favour the low, moderate, or high cost outplanting system?

A. That depends on what facilities already exist. If you have a hatchery and can produce larvae or juveniles, then some of the capital costs can be offset. Generally, I advocate putting the animals out as small as possible and keeping costs down. We have had 50% survival rates with 8 mm (6 month old) animals after a year, which is encouraging.

Q. Are there any alternative methods for scallop fishing that don't disturb and damage the bottom?

A. Much of Japan's 200 000 t annual production is from pearl nets. They were tried here in the OFCF programme, but there were problems with heavy fouling.

Q. Is any work being done on yellow-footed paua?

A. Yes. Spawning is difficult to control, but with new temperature control equipment we hope to make progress soon. It's a good example of how important it is to understand the biology of your species.

Shellfish developments in Britain and Ireland

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Introduction

Increasing quantities of shellfish are now being produced in European waters by aquaculture techniques. Molluscan shellfish, like oysters and mussels, have been farmed for generations in Holland, France, and Italy. The Dutch now produce over 100 000 t of cultivated mussels each year and the French are renowned for their large scale oyster production.

In Britain and Ireland an increasing number of shellfish growers concentrate on mussel and oyster cultivation, and there is both experimental and commercial production of clams and scallops. The future offers exciting potential: there is considerable scope to increase production for both home and overseas markets, but we also have our problems.

My career during the past 30 years has been closely associated with the shellfish industry in Britain, Ireland, and other parts of the world. My interest as a marine biologist has been mainly in developing new fisheries and applying R & D results to commercial needs. During the past 5 years, as Director of the Shellfish Association of Great Britain, I have had even closer ties with the commercial world. Our association actively helps shellfish growers with their day-to-day problems, campaigns on their behalf, and promotes their interests whenever possible.

In this address I will try to highlight some of the more interesting developments taking place in the British Isles; these cover lobsters, oysters, mussels, scallops, and clams. Mention will be made of some problems we suffered from organotin (TBT) antifouling paints and coastal sewage pollution. Finally, I will turn to a subject which concerns us all — shellfish marketing and the promotion of seafood.

Background

Aquaculture is assuming an increasingly important share of the U.K. fisheries sector and has developed rapidly since the mid 1970s, encouraged by the scarcity and increasing costs of traditional fish supplies and consumer demand for choice and quality.

The turnover of the U.K. aquaculture industry was estimated as £60 million in 1986. This is equivalent to almost one-fifth of total fish landings by U.K. vessels, and is expected to at least double during the next 5 years. Production is largely geared to the intensive rearing of salmon and trout and to shellfish cultivation, principally oysters, mussels, scallops, and clams (Table 1).

Table 1: U.K. aquaculture: present farmed output and production estimates (t)

Species	1986	1991
Salmon	10 500	60 000
Brown trout	250	300
Rainbow trout	10 500	16 000
Marine finfish	100	1 000
Shellfish		
flat oysters	100	330
Pacific oysters	600	3 000
clams	10	250
mussels	3 350	14 000
scallops and queens	30	5 250
crayfish	2–4	10
lobsters	0	1 000 000

Source: Ministry of Agriculture, Fisheries and Food.

In Ireland, aquaculture developments since the 1970s have been boosted by strong government aid. The results of their Sea Fisheries Development Programme have been remarkable and show a rapid growth in fish farming to a current value of over IR£4 million.

Crustacean culture

Present interest in crustaceans is mainly confined to crayfish farming; about 40 commercial sites in England and Wales produced an estimated 2–4 t in 1986.

However, there has been research on lobsters and tropical prawns. Tropical prawns need warm water, and maintaining a captive brood stock was found to be too difficult and expensive; research for the present has been discontinued. Lobster rearing does appear to have some potential. Research at the Shellfish Culture Unit (Conwy, North Wales) by the Ministry of Agriculture, Fisheries and Food (MAFF), has helped to develop successful rearing techniques for the European lobster (*Homarus gammarus*). Lobsters can be reared from the egg to commercial size, but because each lobster has to be held in a separate compartment to prevent fighting, and must have fresh food at least once a week, the economic viability is not yet right. However, research into a complete compounded diet is going ahead and the position could change.

There are now four hatcheries in the U.K. rearing juvenile lobsters to about 25 mm length for release in stock enhancement trials. Since 1982, some 30 000 tagged lobsters have been released at selected sites around Britain. The aim is to use hatcheries to restock coastal lobster fisheries with juveniles, which stand a better chance of survival than releasing them at the smaller larval stages.

Hatchery-reared lobsters are now being retaken on the grounds where they were originally released. The numbers returned during the next couple of years will determine whether or not lobster restocking is a viable proposition. Whatever the results, these trials have helped to consolidate the techniques used for lobster rearing and the way is being opened up for commercial lobster culture some time in the future.

Mollusc cultivation

Oysters and mussels have been harvested from estuarine waters around our coasts since Roman times, and we have vivid descriptions of a massive oyster fishery going back 300 years with landings of up to 30 million oysters a year. The industry soon realised that molluscs are ideally suited for farming, and cultivation techniques have been gradually developed over the years to help boost production.

Oysters. In the U.K. and Ireland native oysters (*Ostrea edulis*) and the Pacific oyster (*Crassostrea gigas*) are grown.

The European flat oyster was once so common that it formed a major part of the diet of the poor. Increased fishing effort in the late 1800s, aided by better transport facilities for marketing, seriously reduced stock levels. In 1920–21 a virus infection of oysters decimated the beds throughout Europe, and in Britain and Ireland they have never really recovered.

Efforts to revive Britain's native oyster industry have been hindered by poor natural spatfalls, pollution, and, in 1982, the introduction of the parasitic disease *Bonamia* from Europe. Production in Britain is now only 500 t a year and the native oyster has become a high priced seafood, often selling at £2 each in London restaurants.

In Ireland, there have been valiant efforts to redevelop the oyster fisheries in Galway Bay, Tralee Bay, and along the western seaboard. In Tralee Bay, Co. Kerry local fishermen formed a society backed by the Irish Sea Fisheries Board, received rights to manage the beds, and introduced a development plan which was funded by a European Commission award. They have laid mussel shells to aid spat collection and have accepted closed seasons and other fishery regulations. The result is a viable and well run oyster fishery — probably now the largest in Europe.

At Cork, on Ireland's south coast, Atlantic Shellfish Ltd. turned to the pond culture of native oysters. There were encouraging results between 1970 and 1985, but in 1986 *Bonamia* arrived. Mortality levels are now reaching 70% and the future for Atlantic Shellfish Ltd. is not bright. The threat of *Bonamia* spreading to other major oyster beds also concerns Irish producers.

The Pacific oyster is becoming more and more important to the U.K. and Irish producers. Although the species does not breed naturally in our cold waters, hatcheries can produce the seed easily and economically. Some 200 sites now produce about 10 million oysters a year. They are bought from the hatcheries at a weight of 10–15 g and on-grown in trays or plastic net bags set on trestles at low tide level. Some growers hang the seed from rafts, but, as our coastlines have much larger areas of sheltered shoreline than suitable deep inlets, beach culture is preferred to hanging culture.

The Pacific oyster can be grown to salable size (90 g) in 24 months, but up to 3 years is more usual. Unfortunately, the species we hoped would revitalise our oyster industry suffers badly from the effects of organotin (TBT) antifouling paints. Growers at yacht-mooring sites found their oysters became deformed, had poor meats, and were unsalable. Perhaps, now that TBT is banned in the U.K., we can grow top quality "*gigas*" which will get a better market response.

Although most oyster eaters prefer the native oyster, sales of *gigas* have been boosted by the scarcity of the flat oyster, and enterprising growers have introduced frozen oyster dishes which are slowly finding favour. The native oyster industry is in decline and the future really rests with the Pacific oyster.

Mussels. Mussels are gaining in popularity in Britain. They are ideal for large-scale culture and have three special features which, in Europe, give *Mytilus edulis*, our common mussel, a biological advantage and a fishery potential greater than that of other bivalves. These are: an abundance of natural seed supplies for cultivation, high productivity and rapid growth rates in culture, and their byssus threads, which enable them to clump together, thus making them easier to dredge or facilitate their attachment to the sea bed, or ropes or other materials used in culture.

In Britain and Ireland, mussels are either harvested from wild mussel beds in estuaries or grown at sheltered sites on plots on the sea bed or by hanging culture methods.

In Wexford Harbour, Ireland experiments with reseeding depleted mussel beds, i.e., relaying small seed at the correct density on suitable ground, have been successful. One company now transplants 2000–3000 t of seed mussels a year and in the 1986–87 mussel season processed over 5000 t of mussels and sold their products in the

U.S., Britain, and Europe (Lett 1987). Their four main points to remember for success are volume, processing efficiency, quality, and markets. Inspired by this success story, other mussel growers in Britain and Ireland are increasing their output by using the bottom culture system which has been used successfully by the Dutch for years. Production is expected to reach 15 000 t a year by 1991.

Mussel farming on rafts and longlines is also becoming an increasingly important source of revenue on the west coasts of Scotland and Ireland. Irish producers grew over 1000 t of rope-grown mussels in 1986, and in Scotland about 500 t will be available this year. Rope culture is more expensive than bottom culture.

The main problems faced by growers are continuity of seed supplies and the effects of predation by crabs and starfish. In Europe, the shore crab (*Carcinus maenas*) causes widespread, sometimes severe, losses of small mussel seed on intertidal and deepwater lays in many estuaries. Mussels below 40 mm in length are vulnerable, particularly when relaying seed in the summer.

Scallops. Scallops (*Pecten maximus*) and queen scallops (*Chlamys opercularis*) have long been harvested by dredge or trawl from deep water. They formed the basis of a fishery worth over £9 million, but stocks in some areas have declined.

Copying the Japanese method of spat collection, scientists at the Marine Farming Unit, Ardtoe, Scotland have developed a system of scallop cultivation, used mainly along the west coast of Scotland, which is moving into commercial reality. Although only four or five farms are in commercial production, output this year is expected to be around 400 t of queen scallops and 15–20 t of the larger scallop.

The basis of the development of scallop cultivation in Scotland is the production and collection of naturally produced spat. The larvae are in the water column for about 3 weeks before they settle on to a suitable substrate and begin to change into scallops. It is at this stage that the growers interfere with the natural cycle by using spat collectors and starting the farming process.

A basic spat collector is a mesh sack with some sort of monofilament nylon netting packed inside it. The collectors remain in the sea for 3 or 4 months until the spat are big enough to handle. The collectors are then brought ashore and the spat removed simply by washing the netting in a tub of water.

The on-growing technique (which uses Japanese technology) starts when the collected spat are placed in lantern nets and suspended at growing sites for 2–3 years until the scallops reach salable size.

Trials show that many more queen scallop spat are caught than *Pecten* scallop. They are not worth as much, but are tougher and grow more quickly. Efforts are being made to market 15-month old queens as "Princess" scallops, thus reducing the capital costs of holding them until they reach full size. This new shellfish farming operation has attracted the interest of large seafood companies who can see potential in an attractive product which seems cheap and easy to grow.

Clams. The native clam, or European palourde (*Tapes decussatus*), is highly valued in Europe, but natural stocks are small around Britain and Ireland. Trials with the faster growing Manila clam (*Tapes semidecussatus*), which is similar in appearance to the native type, have interested our growers and a start is being made on their cultivation under the guidance of MAFF. The *Tapes* clam is easy to produce in the hatchery and there are two reliable suppliers of the seed in Britain.

The growing technique is simple: seed from the hatchery is "planted" on sheltered, muddy shores at a density of about 200–250 seed/m^2 (the seed clams are 8–10 mm long after a 6 month nursery stage to harden them off). A net cover (5 mm mesh) is essential to give some protection from predatory crabs (the main problem) and flatfish, but the clams also burrow and this helps to reduce mortality levels.

Trials in Britain suggest that salable size can be reached in 2–3 years. The commercial prospects are good as the clams can be sold at high prices in Spain, France, and Italy. However, competition from big aquaculture developments in France may deter some small growers, and there are not very many sites known to have the correct substrate type and the shelter.

Sea bed rights and conflict with other interests

Proper development of the British shellfish culture industry will not be achieved unless the definition and reservation of coastal areas suitable for aquaculture is considered a priority. This covers the "alternative use potential" of estuarine sites for navigation, recreational, and industrial uses, and as areas of nature conservation.

We realise that we cannot have unlimited use of the coastal areas, but applications for sea bed leases are subject to an intensive consultation procedure, involving conservation interests and others, which can take years. This affects investment and confidence in our industry.

Estuarine pollution

TBT. Scientific evidence has proved that organotin antifouling paints poison our coastal waters, and the Shellfish Association has campaigned vigorously since 1983 to have them banned. The French, in the 1960s, were the first to make the association between antifouling paints on yachts and damage to oyster fisheries.

There is now ample evidence that the direct application of TBT on yachts in shallow water close to shellfish-producing areas causes serious damage. Oysters develop shell thickening and deformities, larvae of all sorts die, and the reproductive cycle of some species is disrupted. It's no wonder we and the environmental lobby pressed hard for action to stop its use! We were successful.

In May 1987, legislation was passed in Britain which makes it an offence to supply for retail sale TBT paints for use on yachts. From 1 July 1987, even stronger laws were introduced which banned the use of any TBT-based antifouling paints on pleasure craft, or on nets and cages used in the fish farming industry. Indeed, its control on salmon cages was essential because many shellfish growers in Scotland suffered from the effects of this treatment. As salmon were also being contaminated with the organotin compounds, our government had to act fast. It is to the credit of our Department of the Environment that they did, eventually, bring in tough controls on TBT, an action which will benefit the shellfish industry considerably.

Sewage. The contamination of filter feeding molluscs by sewage bacteria and viruses is a problem worldwide. In Britain we have suffered several large outbreaks of gastro-enteritis caused by eating uncooked oysters. Most oysters in Britain are now purified with a 48 hour ultra-violet light treatment; the results are usually good.

Why do people sometimes suffer illness after eating purified oysters? It seems that under certain conditions all the virus particles are not passed out of the oyster during the usual cleansing process, but move into the tissues. Bacteria do not do this because they are too large. The problem seems worse in heavily polluted areas and we are looking at relaying in cleaner waters as part of the purification process.

Research is in progress on the virus problem and our growers will soon have a "Code of practice for the hygienic production and sale of bivalve shellfish".

Marketing

The main points I wish to make here are based on my 5 years as Director of the Shellfish Association, where I am involved indirectly with marketing and promotion.

We talk about a massive market for seafood, but the most important issue is: who is capturing it? At the end of the day will the consumer buy salmon or shrimp, oysters or lobsters? Fortunately, it is not an uninfluenced choice and those who are best at marketing usually get their product sold.

I do, however, find a lot of complacency in our industry. Producers believe that because they have a good product, it will sell. Unfortunately, to many people, the word shellfish conjures up mixed responses. Ask a few people not connected with the industry how they view shellfish. The comments can be disappointing and there are many misconceptions and uncertainties. In Britain, shrimp, crab, and lobster are favourites followed by mussels, scallops, and oysters. Oysters have a disappointing image with the average British person, but mussels and scallops are increasing in popularity.

Britain and Ireland both have the benefit of being in the European Economic Community and have neighbours who enjoy shellfish and will pay good prices for the right sort. Our home markets will grow as more supplies become available. The future for the U.K. shellfish industry looks brighter than it has done for many years.

Reference

Lett, J. 1987: Mussel culture — a market lead approach. *Proceedings of the Annual Shellfish Conference, Shellfish Association of Great Britain 18.*

Discussion

Q. In New Zealand, we operate under the FDA sanitation system. Depuration is considered insufficient to remove all bacteria and viruses. Could you comment?

A. The Seafish Industry Authority in Britain has been working on improved purification techniques. They believe some animals do not function properly during purification, perhaps because of rough handling. Such animals, if eaten, could be the cause of otherwise unexplained illnesses. In general, however, there is far more risk from eating chicken or milk products than from eating shellfish. If purification is done properly, there is little risk. In Britain, there is an increasing tendency to cook shellfish, and even partial cooking destroys most bacteria and viruses. Cockles heat-treated to 90 °C for 90 seconds are virtually sterilised.

Comment. We are aware, after several years of research, that depuration is not reliable where there is gross pollution or where viruses are present. That is why depuration doesn't guarantee you an export certificate. Shellfish growing is approved only where there is, at worst, only moderate pollution from rural run-off and no chance of viruses being present.

Q. Is the British shellfish industry self-supporting or does it depend on government subsidies? Does your association provide financial support for research?

A. The industry stands on its own feet. The association funds some R & D projects and also provides some studentships. We are asked to comment on research proposals and the planners and scientists do listen to us. We provide a strong representational role for our industry and I urge you to form a strong association of your own. Our association is not expensive, the equivalent of about $150 a year for trade membership and about $50 for individual growers and scientific membership.

Q. How did the 60 year rights for farmers in Britain arise, and do they include surrounding land?

A. Originally there were private rights for shellfish gathering. Since the Crown took over coastal areas it has been realised that tenure rights are needed for the shellfish industry to develop and thrive. I believe the maximum tenure is 60 years — it's certainly much more than your 14 years. As hanging culture methods have developed, the rights have been extended from the sea bed alone to include the water column. They do not include land, so access to the farm is important.

Comment. The species of *Bonamia* here is different from the European one, so our flat oysters would probably not be allowed in to European markets. We need freedom from *Bonamia* in our stock. The French industry has been ravaged by *Bonamia*; production has fallen from 37 000 t after the war to 8 t in 1987.

A. Nevertheless, the French industry has survived by turning to *gigas*, and although Britain was less severely affected the industry did not fail as some expected. In general, the industry can overcome these things.

Q. Where are the markets for cockles and crabs in Britain?

A. Cockles are used in seafood platters and in pub lunches so there is an increasing demand. Crabs have been less popular because the housewife hasn't the time or inclination to pick out the meat. The success of the British industry is based on export of live crabs to continental Europe.

Q. Why is chlorine no longer used in depuration plants?

A. It is still used, in association with sodium thiosulphate, to provide clean sea water for depuration, but large tanks are needed and they are expensive. Smaller growers are better served by u.v. lamps which are cheaper and require much less space.

Why farm seaweeds?

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Introduction

To understand the reasoning behind seaweed aquaculture or "phycoculture" one must first recognise the commercial value. Seaweeds are far more economically important than is generally realised.

Man has a long tradition of using seaweeds. Records indicate that they were collected for food as long ago as 2000 B.P. (Levring 1977, Tseng 1981). Over the centuries they have been used for human consumption, in agriculture as animal fodder, fertiliser, and soil conditioners, in medicine, and as a source of raw material for extraction of industrial chemicals and pharmaceuticals. Most people living in developed countries directly or indirectly consume or come in contact with some form of seaweed product every day (Abbott and Cheney 1982).

The products that most touch our lives today are the chemical constituents of seaweed cell walls that have commercial value. The term phycocolloids describes these polysaccharides, the three most important of which are agar, carrageenan, and alginate. Phycocolloids, found principally in certain orders of the red (Rhodophyta) and brown (Phaeophyta) seaweeds (Table 1), have many and widely varied uses (Table 2). In 1980, 270 000 t (dry weight) of seaweed was harvested worldwide for extraction of colloids and another 385 000 t (dry weight) was used as food for direct human consumption (McHugh and Lanier 1983). The annual market value of seaweeds for these uses combined is far in excess of US$1 billion (Evans 1986).

The primary source of the raw material for these various products has been, and still is, natural beds of seaweeds. Plants are harvested by hand, by gathering driftweed washed up on the shore, or by pulling material off the rocks at low tide, or they may be harvested mechanically (Fralick and Ryther 1976). Since the 1950s there has been an increasing demand for seaweeds and their products so that today demand exceeds supply (Mathieson 1975, Evans 1986). Any future expansion of the industry will depend on its ability to obtain a stable source of high quality raw materials. Improved management of existing sources will go some way towards solving the supply problem, but greater emphasis must be placed cn the economic production of harvestable seaweed crops by artificial culture.

Some of the problems associated with harvesting natural stocks and the advantages of phycoculture follow.

Sustainable yields

A major concern associated with harvesting wild stocks is the potential for overexploitation of the resource, leading to reduction in the size of the population and, inevitably, to smaller yields.

Table 1: Commercial sources of seaweed polysaccharides (after Gellenbeck and Chapman 1983, McLachlan 1985)

Alginate	Agar	Carrageenan
Order Laminariales	Order Nemaliales	Order Gigartinales
Ecklonia	*Gelidium*	*Chondrus*
Eisenia	*Pterocladia*	*Eucheuma*
Laminaria		*Furcellaria*
Lessonia		*Gigartina*
Macrocystis		*Hypnea*
		Iridaea
		Phyllophora
Order Fucales	Order Gigartinales	
Ascophyllum	*Gracilaria*	
Durvillaea		
Sargassum		

Table 2: End uses for the main seaweed polysaccharides (after Cottrell and Kovacs 1980, Guiseley *et al.* 1980, Meer 1980, Glicksman 1983, King 1983)

Product	Alginate	Agar	Carrageenan
Foods			
Canned foods	X	X	X
Dairy products	X	X	X
Bakery products	X	X	
Salad dressings	X		
Sauces	X		
Frozen foods	X	X	X
Soft drinks	X		X
Desserts	X		X
Confectionery		X	
Fruit analogues	X		X
Dairy analogues			X
Fish analogues	X		X
Pet food	X		X
Brewing	X		
Medical	X	X	
Pharmaceuticals	X	X	X
Cosmetics		X	X
Dental	X	X	
Paper making	X		
Paint			X
Textiles	X		X
Ceramic glazes	X		X
Adhesives	X		X
Microbiological media		X	

Growth of seaweeds is affected by environmental conditions and many species display distinctive seasonal patterns of growth and reproduction (Dring 1982). The timing of harvesting thus dictates the extent of recolonisation and hence the quantity available for subsequent harvests. Untimely harvests are likely to result in slower regeneration and increased competition from other species for space.

The method of harvesting is important. With seaweeds such as *Porphyra* and *Gelidium*, which can regenerate from small fragments of material (Roland and Coon 1984, Carter and Anderson 1985), small portions of plant material should be left. When no such regeneration occurs the whole plant, including the holdfast, should be removed. Hay and South (1979) found that leaving the holdfast of *Durvillaea antarctica* (bull kelp) attached to the substrate only delayed recolonisation since the holdfast took several months to decay.

Although a seaweed with economic potential may be present in an area, there may be insufficient biomass to support a viable industry (e.g., it is unlikely that there is sufficient *D. antarctica* on the entire east coast of the South Island of New Zealand to support an alginate industry (Hay 1979)).

Artificial substrates (ropes, nets, or semi-enclosed ponds) can extend the range of sites for growing seaweeds. Areas which do not normally support seaweed growth (such as deep water and open ocean sites) or where few species grow (such as shallow waters with muddy and sandy substrates) can be brought into production (Tseng 1984).

Because of the reduced competition from other species, it is possible to achieve higher yields of biomass per unit area than can be obtained from natural populations (Mumford 1977). By regulating stocking densities, conditions for growth can be optimised (Tseng 1984). The harvestable biomass of *Porphyra columbina* from a 30 km stretch of coastline in the south of the South Island (an area of about 15 ha) is about 4.7 t fresh weight (Frazer and Brown, unpublished results): a similar biomass could be grown on a 0.5 ha seaweed farm (Miura 1975).

There are two principal methods for stocking seaweed farms (Neish 1979). One is to vegetatively propagate small fragments of plants, as is done with *Eucheuma* in the Philippines (Doty 1977) and *Gracilaria* in Taiwan (Shang 1976). The other is to use spores, as for the cultivation of *Porphyra* in Japan (Miura 1975) and *Laminaria* in China (Cheng 1969). Both methods use wild plants for the initial seeding, but the amount required for stocking the farm is small compared with the amount removed in harvesting. Once established, the farm becomes its own source of seed stock.

Quality control

A second concern with harvesting wild stocks is variability of the plants and hence the product. Growth rate may change during the year, different populations of the same species can display differences in growth (Durako and Dawes 1980, Penniman *et al.* 1986), and the chemical properties of the seaweed may change between populations and seasonally (Dring 1982).

By screening seed stock for desirable characteristics (such as vigorous growth or high quality agar) this variation can be overcome. Specific strains are then propagated in the farm to provide a reliable source of a stable product.

Quality improvement

Virtually every major agricultural crop is the product of some degree of genetic improvement brought about by classical techniques such as inbreeding and mutation. Similar methods have been used on a very few seaweeds, most notably in Japan and China (Cheney 1984). In the future it should be possible to produce new and improved strains, with enhanced productivity and new products not available in wild plants, from conventional selective breeding methods and genetic engineering and recombinant DNA techniques. It will be necessary to perfect axenic callus and cell suspension culturing methods to allow rapid and large scale propagation of desirable new strains, the regeneration of whole plants from these, and the perpetuation of them by micropropagation (Evans 1986).

Conservation and environmental impact

In addition to being of commercial value, seaweeds are an integral component of marine communities, providing both food and cover for a variety of other organisms some of which may themselves be commercially important. The effects of harvesting (including removal of driftweed) on the community structure must be fully understood to ensure long term productivity of the seaweed population and to avoid ecological disasters. By farming seaweeds the potential for ecological disaster through overexploitation of natural stands can be avoided and the natural resource conserved.

But what impact do seaweed farms have on the environment? Phycoculture has a distinct advantage over other forms of aquaculture in that seaweeds, being plants, produce no waste products. Rather than having a detrimental affect on the environment, seaweed farms may be beneficial. Seaweeds thrive on nitrogen and phosphorus and, therefore, could be used as effluent "scrubbers" by removing nutrients from treated domestic sewage or animal wastes. The impact on wildlife and other marine plants can be kept to a minimum through careful site selection.

Farm structures are likely to have some visual impact, but depending on the method of farming and the species to be grown they could be removed on an annual basis. There would be certain unavoidable impacts on navigation and restricted recreational use immediately around the farm site, but by choosing the site carefully this could be minimal. Overall there would be little direct impact on the marine environment.

Disadvantages of seaweed farming

So far the advantages of phycoculture have been highlighted, but it would be unrealistic to assume that seaweed farming was devoid of problems. As with any system of monoculture, farmed seaweeds are more susceptible to disease than wild populations. None have yet been identified in New Zealand, but in other parts of the world seaweeds have been affected by fungal rots and viral and bacterial infections (Tseng 1981). Research on methods of control is currently underway (Tseng 1984). Epiphytes are also a cause for concern just as weeds are in terrestrial plant culture (Neish 1979). It is important to provide the desired crop with the maximal competitive advantage over other species.

Conclusions

Cultivation of seaweeds is becoming increasingly necessary as natural stocks continue to be exploited and the demand for seaweed products exceeds the supply. In addition to increasing production rates, seaweed aquaculture is attractive in that it can provide high quality raw material with specifically selected characteristics. The establishment of seaweed farms is technically feasible, but will ultimately be determined by the costs involved. However, if New Zealand aims to become a net exporter of seaweed products, can it afford not to invest in phycoculture?

References

Abbott, I.A. and Cheney, D.P. 1982: Commercial uses of algal products. *In* Rosowski, J. and Parker, B. (Eds.), "Selected Papers in Phycology, Vol. 2", pp. 779–787. Phycological Society of America, Lawrence, Kansas.

Carter, A.R. and Anderson, R.J. 1985: Regrowth after experimental harvesting of the agarophyte *Gelidium pristoides* (Gelidiales: Rhodophyta) in the eastern Cape Province. *South African Journal of Marine Science 3*: 111–118.

Cheney, D.P. 1984: Genetic modification in seaweeds: applications to commercial utilization and cultivation. *In* Colwell, R.R., Sinsky, A.J., and Pariser, E.R. (Eds.), "Biotechnology in the Marine Sciences", pp. 161–175. Wiley, New York.

Cheng, T.H. 1969: Production of kelp — a major aspect of China's exploitation of the sea. *Economic Botany 23*: 215–236.

Cottrell, I.W. and Kovacs, P. 1980: Alginates. *In* Davidson, R.L. (Ed.), "Handbook of Water-Soluble Gums and Resins", Chap. 5, pp. 1–43. McGraw-Hill, New York.

Doty, M.S. 1977: *Eucheuma* — current marine agronomy. *In* Krauss, R.W. (Ed.), "The Marine Plant Biomass of the Pacific Northwest Coast", pp. 203–214. Oregon State University Press, Corvallis.

Dring, M.J. 1982: "The biology of Marine Plants". Arnold, London. 199 p.

Durako, M.J. and Dawes, C.J. 1980: A comparative seasonal study of two populations of *Hypnea musciformis* from the east and west coasts of Florida, U.S.A. 1. Growth and Chemistry. *Marine Biology 59*: 151–156.

Evans, L.V. 1986: Seaweed bioproducts. *Science Progress (Oxford) 70*: 287–303.

Fralick, R.A. and Ryther, J.H. 1976: Uses and cultivation of seaweeds. *Oceanus 19*: 32–39.

Gellenbeck, K.W. and Chapman, D.J. 1983: Seaweed uses: the outlook for mariculture. *Endeavour 7*: 31–37.

Glicksman, M. 1983: Red seaweed extracts (Agar, Carrageenan, Furcellaran). *In* Glicksman, M. (Ed.), "Food Hydrocolloids, Vol. 2", pp. 73–113. CRC Press, Boca Raton, Florida.

Guiseley, K.B., Stanley, N.F., and Whitehouse, P.A. 1980: Carrageenan. *In* Davidson, R.L. (Ed.), "Handbook of Water-Soluble Gums and Resins", Chap. 5, pp. 1–30. McGraw-Hill, New York.

Hay, C.H. 1979: Growth, mortality, longevity and standing crop of *Durvillaea antarctica* (Phaeophyceae) in New Zealand. *Proceedings of the International Seaweed Symposium 9*: 97–104.

Hay, C.H. and South, G.R. 1979: Experimental ecology with particular reference to proposed commercial harvesting of *Durvillaea* (Phaeophyta, Durvillaeales) in New Zealand. *Botanica Marina 22*: 431–436.

King, A.H. 1983: Brown Seaweed Extracts (Alginates). *In* Glicksman, M. (Ed.), "Food Hydrocolloids, Vol. 2", pp. 115–188. CRC Press, Boca Raton, Florida.

Levring, T. 1977: Potential yields of European marine algae. *In* Krauss, R.W. (Ed.), "The Marine Plant Biomass of the Pacific Northwest Coast", pp. 251–270. Oregon State University Press, Corvallis.

McHugh, D.G. and Lanier, B.V. 1983: The world seaweed industry and trade: developing Asian producers and prospects for greater participation. *ADB/FAO Infofish Market Studies 6*: 1–30.

McLachlan, J. 1985: Macroalgae (seaweeds): industrial resources and their utilization. *Plant and Soil 89*: 137–157.

Mathieson, A.C. 1975: Seaweed aquaculture. *Marine Fisheries Review 37*: 2–14.

Meer, W. 1980: Agar. *In* Davidson, R.L. (Ed.), "Handbook of Water-Soluble Gums and Resins", Chap. 7, pp. 1–19. McGraw-Hill, New York.

Miura, A. 1975: *Porphyra* cultivation in Japan. *In* Tokida, J. and Hirose, H. (Eds.), "Advances of Phycology in Japan", pp. 273–304. Junk, The Hague.

Mumford, T.F. 1977: Growth of Pacific northwest marine algae on artificial substrates — potential and practice. *In* Krauss, R.W. (Ed.), "The Marine Plant Biomass of the Pacific Northwest Coast", pp. 139–161. Oregon State University Press, Corvallis.

Neish, I.C. 1979: Developments in the culture of algae and seaweeds and the future of the industry. *In* Pillay, T.V.R. and Dill, W.A. (Eds.), "Advances in Aquaculture", pp. 395–402. FAO, Rome.

Penniman, C.A., Mathieson, A.C. and Penniman, C.E. 1986: Reproductive phenology and growth of *Gracilaria tikvahiae* McLachlan (Gigartinales, Rhodophyta) in the Great Bay Estuary, New Hampshire. *Botanica Marina 24*: 147–154.

Roland, W.G. and Conn, L.M. 1984: Postharvest recovery of beds of the edible red alga *Porphyra perforata. Canadian Journal of Botany 62*: 1968–1970.

Shang, Y.C. 1976: Economic aspects of *Gracilaria* culture in Taiwan. *Aquaculture 8*: 1–7.

Tseng, C.K. 1981: Marine phycoculture in China. *Proceedings of the International Seaweed Symposium 10*: 123–152.

Tseng, C.K. 1984: Phycological research in the development of the Chinese seaweed industry. *Proceedings of the International Seaweed Symposium 11*: 7–18.

Farming the red seaweed *Gracilaria sordida* in New Zealand

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Red seaweeds of the genus *Gracilaria* are widely distributed in many parts of the world and have a long history of use as a source of the gelling phycocolloid, agar. In the past, demand for agar has been satisfied by harvesting wild seaweed stocks. However, during the last two decades the need for a stable supply of consistently high quality seaweed has led to the growth of seaweed farming industries in several countries, including Japan, China, Korea, Vietnam, India, the Philippines, and Taiwan.

In addition to its agar content, *Gracilaria* has value as a fodder for farmed paua (abalone), as a "nutrient-scrubber" for tertiary treatment of sewage effluent, as a household insulation, as an ornamental seaweed in the aquarium trade, as a fresh vegetable, and as biomass for methane gas production.

New Zealand could cash in on the increasing worldwide demand for *Gracilaria* as the genus is found growing in many parts of this country. It is most common in the intertidal and subtidal zones of sheltered coasts, harbours, and estuaries, often forming vast "meadows" on mudflats such as those at Auckland's Manukau Harbour (Terzaghi *et al.* 1987).

The environmental tolerances of *Gracilaria* seaweeds differ between varieties, but in general they prefer brackish water and can withstand long periods of very low salinities. The most rapid growth is attained at 25 °C, though growth is still good at 15 °C (McLachlan and Bird 1986). Temperatures above 30 °C can be lethal to the plants.

Gracilaria plants have the ability to take up nitrogen-based nutrients very rapidly, and can also store them for up to 2 weeks. Short, infrequent nutrient pulses can give *Gracilaria* a competitive advantage over competitors such as *Ulva* and *Enteromorpha*, which, although also capable of rapid uptake, are unable to store nitrogen for as long (Fujita 1985). *Gracilaria* can also tolerate lower light intensities than some competitors (McLachlan and Bird 1986).

Gracilaria often grows in intertidal areas, so the plants are exposed at each low tide to the drying effects of wind and sun. Such populations persist in spite of, rather than because of, these conditions. Although exposure to air can increase the rate of photosynthesis owing to better gas exchange, the damage to apical growth cells from drying means the growth rate of the plants is reduced (Hodgson 1984). Exposure of farmed *Gracilaria* plants should, therefore, be avoided, if necessary by building water-retaining earthworks.

Gracilaria plants can reproduce either from spores and gametes or vegetatively. In sexual reproduction, eggs produced by the female gametophyte are fertilised by spermatia from the male gametophyte and develop into carposporophytes. The microscopic carposporophyte plants are parasitic on the female gametophyte. They produce spores which settle on hard surfaces such as stones and cockle shells, form holdfasts, and grow into tetrasporophyte plants. When mature, the tetrasporophytes release spores which settle and develop into either male or female gametophytes, thus completing the life cycle (Trono 1986).

In vegetative reproduction, fragments of plants break off and are carried to other areas. If conditions are right, the fragments will develop into new plants, but they may just as easily encounter unfavourable conditions such as being washed high up the shoreline. Once plants are broken off from their holdfast they cannot reattach and will drift, unless they fortuitously become partially buried in the bottom sediment.

Aquaculture techniques can be divided into three broad categories, ranging from low-tech to high-tech. The first category is management and controlled harvest of natural stocks of the target species, and can include simple techniques for population enhancement. The second is farming the species in the marine environment by seeding stock on to or into man-made structures. The third is growing the species in a land-based artificial system, such as excavated ponds or in tanks.

Each subsequent system is more controlled, reliable, and efficient, but is also increasingly costly to set up and manage. As in real estate, there are three points to consider: location, location, and location.

Management of wild stocks is simply the harvest of a sustainable yield from a population of plants. Harvest may be by hand, using rakes, or by mechanical harvester. *Gracilaria* plants recover easily from this type of harvest, as broken-off plants leave behind their basal holdfast with its adventitious shoots. These regenerate quickly during summer, allowing multiple harvests in a single season (author's personal observation).

Such wild populations can be enhanced by providing more substrate for spore settlement and growth. Often the one factor preventing a mudflat from becoming a *Gracilaria* "meadow" is the sparse distribution of hard surfaces such as rocks and shells. By providing additional gravel or shell, the farmer can use the sexual reproduction capability of *Gracilaria* to enhance his stocks, though there will be a lag of a year or more before the settled spores grow into harvestable plants (Trono and Ganzon-Fortes 1981).

A quicker way of establishing a crop is to use the capability for vegetative reproduction. However, dumping fragmented plants into an area may only result in them being washed away. Some means must be found of keeping the plants in place within the growing area. In sheltered waters old fishing nets could be cast over the loose plants. Sand-filled plastic bag tubes could act as "paper-weights" to hold weed firmly against the bottom. If the location is a good one, the loose plants may simply stay in place without outside help, as has happened with the largely vegetatively reproducing *Gracilaria* population near the sewage works at Manukau Harbour.

More rapid weed growth can be attained by farming plants on structures held up in the water column, where they avoid being covered with sediment. Spores from fertile seed stock may be settled on to ropes or nets and grown in a longline system similar to the Asian method for *Porphyra* cultivation. The farm site need not be a mudflat; any sheltered coastal water body could be used. Harvesting is also simplified, as a barge with a mechanical weed trimmer could be moved down each longline. The disadvantages with such a system are the lag time for spores to grow, the expense of building a longline, and the need to maintain seed stock in a laboratory for seeding the nets.

The first and last of these objections can be dealt with by using vegetative reproduction, in which fragments of adult plants are inserted into the "twist" of ropes. However, this is labour-intensive and the amount of rope required is huge. Netlon bags of the type used for seeding mussel spat are much easier to set up than ropes, but growth is not as good because plants pack within the bag and harvesting is more complicated.

Land-based ponds offer the farmer more control over growth conditions than do the open-water methods, where careful site selection is really the only way of providing the right environment for good weed growth. The pond method has proved highly successful in Taiwan, where about 300 ha of culture area produces an average of 12 000 t fresh weight of *Gracilaria* annually. This output is used by the agar extraction industry, and by farmers of the herbivorous mollusc, abalone (*Haliotis diversicolor*) (Chiang 1984).

Site selection is still vital for reducing the running costs of a pond system. The Taiwanese ponds are usually located at river mouths, with channels bringing supplies of both fresh and salt water. These are mixed to the correct salinity by the farmer.

The culture method uses vegetative reproduction; wild plants are gathered, fragmented, and scattered on the pond bottom. Nets may be used to prevent weed piling up. The ponds are intertidal so as to allow water exchange without pumping. Water is retained for 2–3 days, then about half is drained off at low water and refilled on the incoming tide. This replenishes nutrients and compensates for rising salinity due to evaporation. Additional nutrients may be added in the form of urea or fermented pig manure.

The pond depth is regulated to control light and temperature. From a winter level of about 30 cm, depth is increased in summer to 80 cm, thereby preventing excessively high water temperatures. This also has the effect of limiting light intensity, enabling *Gracilaria* to out-compete some of the pest species of seaweed.

The profitability of *Gracilaria* ponds in Taiwan is greatly increased by polyculture in which fish and crustaceans are farmed in the same ponds. The grass shrimp (*Penaeus monodon*) and a crab (*Scylla serrata*) are farmed in this way. The milkfish (*Chanos chanos*) is used to control pest algae such as *Ulva* and *Enteromorpha*. These green, leafy algae can envelope *Gracilaria* plants if unchecked, but are the preferred food of milkfish.

Species present in New Zealand and suitable for polyculture include the paddlecrab (*Ovalipes*), yellow-eyed mullet (*Aldrichetta forsteri*), grey mullet (*Mugil cephalus*), common smelt (*Retropinna retropinna*), eels (*Anguilla* spp.), and rainbow trout (*Salmo gairdnerii*) (Slack 1974).

The most intensive method for growing *Gracilaria* is in aerated tanks or containers, either in a glasshouse or indoors under artificial light. A favourable climate for growth can be maintained year-round and weed quality can be closely controlled, though pumping of both air and water is required. Another possibility is to grow plants on trays under a fine spray of sea water, although initial trials with *Gracilaria* have been disappointing and this method has yet to be perfected. Such intensive growth systems are expensive to set up, and could only be realistic if a premium price were being paid for the product.

The particular method selected for *Gracilaria* farming will depend on the sites available and on the prices being paid for output. If a site is selected where growth conditions are naturally good, the seaweed will farm itself and need only be harvested. Consequently, production costs will be low, but output dependent on the vagaries of nature.

If more control over the quality and quantity of weed is needed, then a pond or tank system must be considered. In addition to achieving faster weed growth, a farmer may tailor his weed to suit particular market requirements (Pickering 1987). For example, paua (abalone) may find weed more palatable if it has been growing rapidly and contains a high percentage of young, tender shoots (Y-M. Chiang, pers. comm.). The quality of agar may also be improved by providing the right growth conditions in the weeks before harvest (Pickering 1986). The value thus added to the seaweed product may justify investment in a more controlled culture system.

Another advantage with land-based culture is that it is not necessary to modify and harvest large areas of ecologically sensitive wetlands, so farm permits may be easier to obtain. In this regard, seaweed farming is a benign operation compared with fish or shellfish cultivation. Seaweeds do not release toxins into the water, and can improve water quality by removing excess nutrient loadings from waste water. Seaweed farms need not have unsightly structures, and may improve the scenic value of an area by covering bare mud with vegetation. Such enhanced habitat complexity may also lead to increased species diversity in a wetland area. And lastly, farmed seaweeds are resistant to disturbance, so public access to a farm site could continue without greatly affecting seaweed production.

Gracilaria is well suited for commercial farming, and is the obvious choice for the establishment of a seaweed aquaculture industry in New Zealand. The remaining hurdles to be overcome are economic. In short, what does *Gracilaria* cost to produce? What price will it fetch?

The answer to the first question depends on the growing method, and this in turn depends on the characteristics of the sites available for farming. The answer to the second question depends on the quality of the variety being farmed, the extent of post-harvest "value-added" processing, and the flair with which the product is marketed. Some entrepreneurial spirit is now required if *Gracilaria* farming is to have a future in New Zealand.

References

Chian, Y-M. 1984: Seaweed aquaculture and its associated problems in the Republic of China. *In* Liao, I.C. and Hirano, R. (Eds), "Proceedings of ROC-Japan symposium on Mariculture". *TML Conference Proceedings 1*: 99–109. Tungkang Marine Laboratory, Tungkang, Pingtung, Taiwan.

Fujita, R.M. 1985: The role of nitrogen status in regulating transient ammonium uptake and nitrogen storage by macroalgae. *Journal of Experimental Marine Biology and Ecology 92*: 283–301.

Hodgson, L.M. 1984: Desiccation tolerance of *Gracilaria tikvahiae* (Rhodophyta). *Journal of Phycology 20*: 444–446.

McLachlan, J. and Bird, C.J. 1986: *Gracilaria* (Gigartinales, Rhodophyta) and productivity. *Aquatic Botany 26*: 27–49.

Pickering, T.D. 1986: Gracilaria — a food for cultured paua? *Shellfisheries Newsletter 31*: 7 (Supplement to *Catch 13* (6–7)).

Pickering, T.D. 1987: Growing a 'designer' seaweed. *Catch 14(2)*: 14.

Slack, E.B. 1974: "Sewage and aquacultural production". Section III Indo-Pacific Fisheries Council Proceedings, 15th Session, Wellington, New Zealand, 18–27 October 1972. *IPFC Proceedings 15(II)*: 70–76.

Terzaghi, B.E., Nelson, W.A., and Hollings, T. 1987: *Gracilaria*: cultivation, harvest and uses. N.Z. Ministry of Agriculture and Fisheries, *Fishdex FX 36*.

Trono, G.C. 1986: Seaweed culture in the Asia-Pacific region. Regional Office for Asia and the Pacific (RAPA) Publication 1987/8, Food and Agriculture Organization of the United Nations, Bangkok.

Trono, G.C. and Ganzon-Fortes, E.T. 1981: Report on the training course on *Gracilaria* algae. SCS/GEN/81/29, South China Sea Fisheries Development and Coordinating Programme, P.O. Box 1184, M.C.C., Makati, Metro Manila, Philippines.

Discussion

Q. In the last few years we have been told repeatedly by the Japanese that our *Gracilaria* species is inferior to others on the world market. What species should we be growing?

A. I think it's a myth that our species is inferior. My own work has shown that the quantity and quality of agar depends on the growing conditions and the variety. There are many ecotypes here in New Zealand and no-one has done a comprehensive survey. It will pay to select carefully. One Swedish company is setting up a pilot-scale plant using a strain from Manukau Harbour which they believe to be the best available, and I know there are Japanese buyers prepared to pay twice the going rate for certain strains.

Comment. The various Japanese companies have their own methods of processing, so, to some extent, acceptability may depend on which company you deal with. They generally express a preference for Chilean *Gracilaria*, which is very closely related to ours, if not identical.

Department of Conservation Marine Farming Policy

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Editor's note: The policy that follows was approved by the Minister of Conservation on 27 January 1989. It is a much refined version of the statement presented at AQUANZ '88, and takes into account many of the comments made at the Conference and in subsequent discussions with MAFFish staff. Consequently, the conference's discussions on the original statement are not included in these Proceedings.

1. Purpose

The object of the policy document is to assist an applicant and facilitate the development of marine farming in New Zealand by clarifying the role of the Minister of Conservation and identifying the criteria to which the Minister may have regard.

The document outlines the statutory role of the Minister of Conservation in "concurring to" the licensing of marine farms under Section 3(5)(a) and (b) of the Marine Farming Act 1971 and sets out matters the Minister may have regard to in exercising that statutory function. This policy document also outlines the role of the Director-General of Conservation arising under Section 6(2)(g) of the Marine Farming Act.

2. Background to marine farming in New Zealand

Marine farming is intended to provide a sustainable harvest from the sea and is now a recognised and legitimate use of the New Zealand coastal zone. Sustainability of both the harvest and environment in which it occurs are important considerations for the Crown in licensing marine farming ventures.

Marine farms can take a variety of forms, from the familiar mussel longlines to the developing innovations in paua farming. Marine farming usually involves the establishment of some structure on or over foreshore and sea bed and as a result may restrict or limit public rights of access to or use of the area in question.

Marine farming produces economic benefits for New Zealand and is of importance to small rural communities. At the same time marine farming may have undesirable effects on coastal environments and on other users. For example, marine farming may affect marine habitats, lower water quality, have significant visual effects, exclude other users or interfere with their rights, detract from the natural character and quality of the coastal environment, and conflict with other conservation values (e.g., wildlife feeding areas).

Marine farming must be well planned and managed in order to minimise negative impacts and maximise positive benefits. The existing legislation allows this through

(i) the setting aside of areas considered suitable for marine farming under Section 4 of the Act which are then made available to the public; or,

(ii) the closure of certain areas to marine farming, and

(iii) the licensing of individual farms, outside areas set aside under Section 4, within a clear set of policies and guidelines. Application is considered on its merits by MAF and the consenting agencies.

The setting aside of marine farming areas and the preparation of marine farming plans is a discretionary responsibility of the Ministry of Agriculture and Fisheries.

The Town and Country Planning Act also provides for the planning of marine farming by local authorities and maritime planning authorities. Planning carried out under the Town and Country Planning Act provides a forum for resolving conflicts of interest in relation to local planning issues.

3. The Marine Farming Act 1971

The long title describes the Marine Farming Act 1971 as "An Act to consolidate and amend the law relating to the establishment and development in New Zealand waters of an industry for the farming of sea fish, shellfish, oysters, and marine vegetation, the leasing and licensing of marine farms, and the marketing of fish, shellfish, and oysters reared and marine vegetation cultivated in marine farms."

Section 6 of the Act requires the applicant to publicly notify the proposal. Two months are allowed for objections. The applicant must also notify a range of public agencies specified in Section 6 of the Marine Farming Act 1971 including the Director-General of Conservation. Any objection must be to the Director-General of Agriculture and Fisheries or the "Controlling Authority" and a copy served on the applicant.

The Controlling Authority, in most cases the Minister of Agriculture and Fisheries, undertakes a consultative process to resolve objections in accordance with the provision of Section 7 of the Act. (This may include a reference to the Fisheries Authority established under the Fisheries Act 1983. Where such a reference is made to the

Fisheries Authority, there is then a further right of appeal to the Planning Tribunal.) Before granting a lease or licence the Controlling Authority shall obtain the necessary ministerial consent or concurrence, pursuant to Section 3(5)(a) or (b).

4. Role of the Minister of Conservation

The Marine Farming Act gives no clear indication as to the basis on which the Minister of Conservation's statutory "Concurrence" is to be exercised. It is reasonable to infer that in giving this statutory function to the Minister of Conservation the legislature intended the Minister to have regard to matters relating to conservation.

Under the Conservation Act the Minister of Conservation has a statutory responsibility to preserve and protect natural and historic resources to maintain their intrinsic values, provide for their appreciation and recreational enjoyment by the public, and to safeguard the options for future generations. In addition, the principles of the Treaty of Waitangi may also be relevant.

In practical terms, therefore, the Minister of Conservation, when evaluating a marine farming proposal for concurrence, will consider the policies and objectivès of the Marine Farming Act, including the matters referred to in Section 7(a), (b), (c), and (d) of that Act, in the light of the Minister's own statutory responsibilities as Minister of Conservation.

A special case exists where a marine farming proposal is within an area that has been designated for marine farming either under the provisions of the Marine Farming Act or within a district or maritime planning scheme. In the preparation of either the marine farming plan or the district or maritime planning scheme, a number of matters relevant to the Minister of Conservation's mandate may have been taken into account. When evaluating a marine farming proposal for concurrence within these areas, the Minister of Conservation will have regard to those matters that the administering body took into account in the preparation of the plan or scheme.

Marine farming operations (except for oyster farms) also require approval from the Minister of Conservation under Section 178 of the Harbours Act 1950. Under this Act the Minister is required to be satisfied that the work will not unduly interfere with or adversely affect the interest of the public.

In addition the Minister of Conservation has a general responsibility to advocate the conservation of natural resources and may play such an advocacy role to protect such resources even where there may be no specific statutory role. It is in this capacity as a general advocate for conservation that the Minister may become involved in the setting aside of areas for marine farming under Section 4.

5. Role of the Department of Conservation

The Marine Farming Act allows for objections to be made to any application for a marine farming lease or licence when first advertised. The Department of Conservation will participate in this process should it have concerns about the effects of the proposed farm on conservation values. This will allow for the resolution of issues at an early stage and assist proponents of marine farming schemes to plan effectively for their ventures. Such difficulties might otherwise become apparent only at the time of Ministerial concurrence, which is effectively the last stage of the consideration of an application by the Controlling Authority.

6. Matters relevant to the exercise of the Minister's statutory function

The Minister may have regard to the following objectives and policies when exercising statutory functions under Section 3(5) of the Marine Farming Act 1971, but it must be emphasised that *every case will be considered on its own merits and that the weight given to these various considerations and their precise relevance must be a matter for judgement in each particular case.*

To allow the Minister to consider the merits of individual marine farming proposals, applicants should provide the information requirements outlined in Appendix 1.

Objective 1: To conserve the natural character and quality of the coastal environment.

Comment: The difference between the highly modified shorelines of a commercial port area and the natural shorelines of New Zealand's coasts is dramatic and obvious. The natural character and quality of the coastal environment principally derives from unmodified physical and biological features, providing a recreational resource highly valued by New Zealanders.

Except where marine farming plans are prepared pursuant to section 4 of the Act, applications in respect of areas adjacent to National Parks, Marine Reserves, Scenic Reserves, or other areas where the aesthetic quality of the coastal environment is particularly high will not be encouraged. Within marine farming areas set aside pursuant to Section 4 marine farming developments proposed for areas of high aesthetic value require careful attention to visual impacts.

Policy 1: The Minister of Conservation may agree to marine farming in areas provided that the existing natural character and quality of the coast is not modified to an unacceptable level and high aesthetic values are not compromised.

Objective 2: To protect wildlife values and habitats of special significance.

Comment: Coastal environments support a wide range of species, some of which are of national or international significance. These range from Hector's dolphin to the primitive brachiopods of Patterson Inlet. Preservation of these species can only be ensured if their habitat is protected and high water quality is maintained. Some ecosystems and the communities which they support, such as estuaries and mangroves, are themselves of particular significance.

Certain marine habitats are important for the productivity of wider coastal systems. Some play an important role as nurseries for important fish species. Others provide important recreational values. The Minister of Conservation will support marine farming where it will not damage or destroy habitats of special significance.

The Department of Conservation is committed to the preparation of a comprehensive data base to assist marine farmers, as well as other users and managers of coastal resources, to locate their activities in the most appropriate locations. In particular, the Coastal Resource Inventory will identify areas of special ecological significance. These areas will be protected in order to ensure sustainable development of coastal resources. Marine farming will not be encouraged in these areas.

Policy 2: Marine farming applications may be agreed to in or near areas of special significance if the applicant can demonstrate to the satisfaction of the Minister of Conservation that the marine farming proposal will not adversely affect the habitat, its wildlife, or its special values:

(a) sensitive estuarine areas,

(b) shellfish beds considered to be of ecological or recreational importance,

(c) areas with outstanding, high, and moderate-high wildlife values (see Appendix 2 for criteria),

(d) habitats which are important to the feeding, reproduction, or other life stages of rare or highly valued marine species.

Objective 3: To foster the use of sea coasts and to provide for their appreciation and recreational enjoyment.

Comment: The coast is an important recreational resource. Many areas are used extensively for passive recreation or more active recreational pursuits such as boating and diving. Other areas of the coast that are not currently used for recreation may have a high potential for future recreational use or currently provide an important wilderness experience.

Public access to the coasts and to the sea is an important part of the New Zealand way of life. It is important that there is no undue restriction to this right.

Policy 3: The Minister of Conservation may agree to marine farming in areas of low recreational use or where the siting of a marine farm will not unduly affect the recreational values of an area.

Objective 4: To recognise areas of particular cultural or spiritual significance to the Maori people.

Comment: In Maori tradition the community has kinship linkages with the sea. Respect for the sea is based on the intimate relationship between society and the natural environment.

Each iwi (tribe) has defined areas (stretches of coastline, lakes, rivers and streams, and adjoining mudflats, reefs, and areas of open seas) with which they have been associated for hundreds of years. These are areas which have a wealth of tribal history and with which the tribe intimately identifies itself. Such areas are important sources of kaimoana.

Marine farming can have a significant impact on marine habitats. Some of these habitats provide those food resources essential to the mana of particular iwi. The establishment of marine farms can also impinge on important spiritual or cultural values associated with areas of the coast. The Treaty of Waitangi protects these taonga (treasures) for the Maori people.

Policy 4: The Minister of Conservation may agree to marine farming in areas where marine farming will not unduly compromise areas of particular spiritual or cultural significance to the Maori people.

Objective 5: To ensure that marine farming techniques and new species do not impact detrimentally on New Zealand's coastal and marine environments.

Comment: The potential for farming a wide range of marine fauna and flora in New Zealand is under investigation. Already salmon farming is well established with paua farming becoming a new focus for investment. Expansion of aquaculture into new species often involves developing techniques which are new to New Zealand. Each technique will have a different potential for environmental effects. The possible impacts of each technique should be fully explored at the same time the technique itself is being developed.

Under the Environmental Protection and Enhancement Procedures 1987, environmental assessment for marine farms remains the primary responsibility of the Ministry of Agriculture and Fisheries as the principal central government consent agency. The Department of Conservation will assist the Ministry of Agriculture and Fisheries to identify the appropriate scope of investigations to be undertaken for each new technique.

Policy 5: The Department of Conservation will advocate the thorough assessment of the environmental implications (including visual and recreational) of all new marine farming techniques (including the cultivation of new indigenous or exotic species) prior to their introduction.

Objective 6: To ensure that the techniques of sea cage marine farming in New Zealand develop with minimal degree of practicable impact to New Zealand's coastal and marine environments.

Comment: The marine farming of salmon may be the first of a number of similar rearing techniques based on the artificial feeding of fish and invertebrates in cage culture. This approach is a radical shift from the more familiar marine farming techniques based on filter feeding organisms. The input of nutrient rich material from these techniques can have significant local impacts on the marine environment.

The Minister of Conservation may give consideration to sea cage marine farming proposals where minimal adverse effects on marine habitat values can be demonstrated. Until better information is available on the impacts of such developments, the Minister will need to be satisfied that:

(i) the farms are to be located over marine habitats of low conservation value; and

(ii) an adequate monitoring programme will be established for each farm. Monitoring should provide information on any impacts and allow farmers to fine tune their farming practices so as to minimise adverse environmental effects. It will also allow licensing authorities to more precisely determine the effects of sea cage farming operations on the full range of environments.

Policy 6: The Minister of Conservation may agree to sea cage farming with artificial feeding in areas with low conservation values or where it can be demonstrated to the Minister's satisfaction that the impacts are likely to be minimal and an adequate monitoring programme will be put in place.

Objective 7: To facilitate the rational and orderly development of marine farming by promoting comprehensive marine farming planning studies.

Comment: Expansion of marine farming should occur in a planned and orderly manner to ensure that farms are not located where they may affect important conservation values or unduly interfere with the public interest.

In areas where there is interest in establishing a number of marine farming ventures, or where expansion of marine farming operations is proposed, it is clearly not appropriate to consider individual proposals in isolation. The commitment of areas to concentrated use for marine farming should be made in the context of an integrated and comprehensive planning study. It will be the Department of Conservation's concern to see identified and protected from development areas of high or special conservation value. The identification of areas available to farming by such a study will ensure a climate of certainty for the industry and encourage long term developments.

Policy 7: The Department will advocate the implementation of marine farming planning studies in areas where development or expansion of marine farming operations is proposed whether this be under Section 4 of the Marine Farming Act or the Town and Country Planning legislation.

Appendix 1

To enable the Department of Conservation to properly assess proposals and ensure an effective and efficient response to the request for ministerial concurrence the Department requires the following information. New farming techniques or particular circumstances may give rise to a need for additional information.

Information requirements for marine farming licence applications

Location

Name of Applicant

Address of Applicant

Marine Farming Proposal

(i) Description of species to be cultivated

Describe the species to be cultivated, the anticipated source of brood stock, the method of farming and the type and scale of structures to be used.

(ii) Description of ecological values

Describe the nature of the sea bed or foreshore included in the application and the immediate environs (e.g., intertidal sand flat, course gravel sea bed, rocky reef, etc.).

What is the proximity to saltmarsh, seaweed beds, mangroves, eelgrass beds?

What is the proximity to any shellfish beds?

What is the proximity to recognised coastal bird roosting/feeding/breeding grounds?

What is the proximity to marine mammal colonies and haul-out sites?

(iii) Access

How is it proposed to service the marine farming operation — by road, sea, or other? If by sea, what land access points will be used for servicing or supplying the barge or other vessel?

If other farms operate in the area, how do they service their operations?

(iv) Associated infrastructure

Describe what shore facilities will be used for storing equipment, for servicing the farm, and for processing of farm product.

Are these existing facilities or will new ones be built? Does this require reclamation of sea bed or foreshore?

(v) Disposal of waste

What provision has been made for disposal of farm waste material (e.g., shells, structural materials)?

(vi) Use of chemicals

What chemicals will be used in the management of the farm? What precautions will be taken to prevent accidental spillage of these chemicals?

(vii) Adjacent land use

Describe the predominant use of adjacent land (e.g., horticultural, production forestry, pastoral, reserve)?

What is the proximity of the site to residential or other developments?

Are there any historical or archaeological sites or sites of scientific interest in the vicinity?

Are there other marine farms in the vicinity of your proposed site? If so, how many and where are they located?

(viii) Aesthetics

Provide a description of the visual character of the surrounding area and indicate if the site is in an isolated locality (provide photos of the proposed site and surrounding features).

What is the likely visual impact of the proposed structures from any existing public road, and residential property and from the seaward side?

(ix) Existing recreational use

What forms of recreation occur either on site or in the vicinity of the site?

What is the frequency of these recreational uses?

(x) Cultural values

What are the views of the local Maori people in respect of your proposal? Who provided you with this information?

(xi) Marine Farming Plans/Maritime Planning Scheme

Is the site within an approved or proposed marine farming area under the Marine Farming Act?

Is the site within an area zoned for marine farming under a Maritime Planning Scheme?

(xii) Benefits

A description of the value of the development to the community plus any other supporting information deemed to be desirable (e.g., employment).

Appendix 2

Criteria for identifying wildlife values and habitats of special significance

The following lists those areas which are to be protected from marine farming. These areas are not all known by the Department, but an assessment of a proposed marine farming site will be made on a case by case basis.

1. Outstanding

(a) Presence of a breeding population of a highly endangered or rare endemic species.

(b) Presence of a population of an endemic species of very restricted distribution and which could become endangered.

(c) Areas essential to species from (a) and (b) for purposes other than breeding.

(d) Areas of vital importance to internationally uncommon species (breeding and/or migratory).

(e) Areas of vital importance to internally migratory species with very limited distribution or abundance.

(f) Largely unmodified ecosystem or example of original habitat type not represented elsewhere in the country, of large size and containing viable populations of all, or almost all, species which are typical of the ecosystem or habitat type.

2. High

(a) Site containing an indigenous species which has declined significantly as a result of people's influence.

(b) One of few or the only breeding area for a non-endemic indigenous species of limited abundance.

(c) Habitat of an uncommon species with restricted distribution and not adequately represented in a particular ecological region.

(d) Example of a largely unmodified site which is not represented to the same extent elsewhere in the ecological region and is used by most species which are typical of that habitat type for the region.

(e) Presence of a species of an endemic family which is of limited abundance throughout the country although adequately represented in one ecological region but whose habitat is at some risk.

3. Moderate — High

(a) Presence of a species which is still quite widely distributed, but whose habitat has been and still is being significantly reduced or modified as a result of people's influence.

(b) Areas containing high numbers of breeding or moulting birds or where breeding or moulting areas are of inter-regional significance to wildlife.

(c) A large and fairly unmodified site or ecosystem which is represented elsewhere in the ecological region and contains all, or almost all, species typical of that habitat type for a particular region.

(d) An area where any particular species is exceptional in terms of, say, abundance or behaviour, but which is otherwise widespread.

Note: The Department of Conservation's Coastal Resource Inventory will identify areas where wildlife values and habitats are of special significance. This information will be made available to marine farm applicants on request.

Aquaculture: initiatives in policy and administration

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In his introduction, John McKoy said this conference was to highlight the prospects for the future, expose barriers, and foster ideas.

Over the past day and a half many speakers have discussed the potential for aquaculture to expand and develop in New Zealand. Len Tong talked about New Zealand initiative and ingenuity, and reviewed successes in commercial operations and successes in technology development. Barb Hayden spoke of our worldwide reputation for high quality products and our clear clean waters. Eric Edwards reaffirmed this point, talking about the good reputation New Zealand mussels have in Britain and Europe. Dos O'Sullivan and Peter Todd spoke of the considerable potential for finfish farming.

In light of these positive comments, we might ask why there hasn't been more growth in New Zealand aquaculture up until now. We should ask what the barriers are to aquaculture expansion and diversification.

There are a number of reasons, but the one which concerns me is the assertion that MAF has not created a policy and legislative environment conducive to diversification, expansion, research, and investment.

This assertion leads to two questions — where are we now? and where are we going?

Where we are now, is that the industry has outgrown its legislation, our policies, and our administration systems. Aquaculture legislation and policy was developed principally for oyster farming, and was adapted to cope with development of the mussel industry.

Setting up a marine farm was designed to be quite straightforward. Leases were to be held for 14 years, they were to be run by the leaseholder, were not to be held for speculative purposes, renewal was virtually automatic, lease fees were negligible, and MAF was really the only group of bureaucrats anyone had to deal with.

It was a simple system that was easy to work. But pressure built up within the system: increasing numbers of applications, new species, new methods, new associated legislation. When pressures build up in a system, the tendency is to do something which reduces the pressure but doesn't substantially alter the system — loops work best. So, in establishing a marine farm today, you will deal with local government, water boards, conservation agencies, other marine users, and an array of government departments. Loops have been grafted on to the system. The problem with loops is that while they reduce the pressure on the system, it takes a lot longer to get from the start to the finish.

That's where we are now. The next question is, where do we go from here? I'll touch on two possible futures.

One, we continue to respond to pressures by building more loops. We draft new legislation and incorporate everything into one system. This would produce a very complex system, and the more complex a system becomes, the more difficult it is to operate. It becomes very difficult to get anything coherent out of the end.

The second possible future would require us to aim for a simple system which incorporates the following.

- Lead agency
- Planning for the future
- Clearly defined procedures
- Clearly defined information requirements
- Specified criteria to assess proposals
- Time constraints built into systems
- Simple lines of action
- Effective, friendly communication
- Minimum costs to applicant and agency
- Efficient operations

I envisage a system where MAF reasserts its role as the lead Government agency administering aquaculture — a system where MAF co-ordinates other required inputs and tightly controls the time in volved in consultation. I see procedures being clearly defined, information requirements being identified, and the criteria which will be applied to that information being specified. With these systems MAF will maintain good communications and develop a good working relationship with industry.

I expect that some people in industry will say "Great, forward looking initiatives are well and good, but what do we do about the inadequacies of systems and policies now?" I want to assure you that substantial progress is being made in improving our present systems.

- MAFFish is reviewing all outstanding applications. These applicants will be contacted shortly to clarify the status of their applications and get them on track for a decision.

- Marine farming staff from the MAFFish Central Region and Head Office are developing ways to streamline administration under existing legislation. This will be used as a model for the rest of the country.
- In the area of planning, MAFFish is preparing objections to the Marlborough Sounds Maritime Planning Scheme. We want planning to reflect the biophysical characteristics needed for different methods of aquaculture. Also we want planning studies to recognise the contribution a developing aquaculture industry will make to a region and the nation.
- MAFFish has developed a policy for the marine farming of salmon. It is now being used to process applications for outside Big Glory Bay.
- Fish contracted the DSIR Water Quality Centre to study the carrying capacity of Big Glory Bay. As you know, their first report is complete. After release of their second report to the Southland Catchment Board, decisions will be made concerning the sea pen operations in Big Glory Bay. When the final water quality report is out, Peter Todd and I will call a meeting of Big Glory Bay salmon farmers and discuss the implications of the study.
- MAFFish will use the information from the Big Glory Bay study to review, and perhaps change, the existing requirements in our salmon policy. We will also develop, in consultation with the Water Quality Centre, DOC, and the Southland Catchment Board, practical methods for monitoring sea pen operations.
- We have worked with DOC in their first attempt to develop a draft marine farming policy. We will continue to work with them to develop a policy which incorporates the principles for sound aquaculture policy.
- MAFFish is working with an interdepartmental committee to review importation of exotic species. MAFFish took the lead in this exercise by developing a protocol for importation of exotic species for aquaculture. The protocol was well received by all Government agencies. The final policy is now being completed and will be available shortly.
- The SPA group (Strategic Planning for Aquaculture), which includes some of the best brains in New Zealand aquaculture, is meeting regularly to think its way through the present problems and into the future.

The knowledge we are gaining by tackling these problems will be put to good use as we address principles and develop policies and legislation for the future, but at the end of the day it is always people that make or break a system.

One of my most important jobs is to assemble a team of people who have the skills, the background, and the energy to move us towards our common goals. I will now introduce you to three people who will tell you about the initiatives they are currently working on.

Rick Boyd — strategic planning and new legislation

I have recently taken up the position of strategic planner for aquaculture in MAFFish's policy group. In my new role, I will have particular responsibility for the development of new policies and legislation for aquaculture. I will briefly indicate what I hope to achieve over the next 12 months.

Aquaculture in New Zealand is close to entering a new era. The industry has now developed a strong base in such species as oysters, mussels, and salmon. New technologies are opening up exciting new opportunities for expanding production of these species as well as many others. There is tremendous growth in aquaculture throughout the world. Much as terrestrial agriculture has replaced the gathering of plants and hunting of game on land, we can now foresee that within the next century aquaculture will replace commercial fishing as the primary source of food production from the sea. New Zealand has clear clean waters which are ideal for aquaculture and which provide a tremendous opportunity for this form of economic development.

However, there are significant deficiencies in present legislation which need to be removed if New Zealand is to keep pace with world developments. The Marine Farming Act, especially, is outdated and no longer serves the needs of the industry. It operates too restrictively and now hinders rather than encourages aquaculture development. There is a need for a more positive legislative and institutional environment that accommodates innovation and new approaches to aquaculture. The industry must be given the opportunity to realise new opportunities without many of the unnecessary constraints and bureaucracy embodied in the present legislation. More efficient systems for planning for aquaculture in coastal waters and for licensing of marine farms are needed.

My immediate priority is to critically examine present legislation with a view to implementing a proposed new Aquaculture Bill. Over the next few months I will be assessing what the needs of the industry are, and how new legislation might better provide for its development in the future. The industry will be consulted in the process of preparing new policy and legislation. Proposals for new aquaculture legislation should be available for detailed discussions early in 1989. I am confident that with the industry's support new legislation can be in place in the very near future.

Erin Wynne — developing the One Stop Aquaculture Shop concept

The aim of the One Stop Aquaculture Shop (OSS) is to provide centralised, up to date, and relevant information.

All general information will be held by the OSS and, if specialised information is required, the inquirer will be told then and there who to contact in a one stage referral process as opposed to the various people and pieces of information interested parties are currently faced with. Business development in the 20th Century is about effective communication, obtaining information quickly, confident it is accurate, and feeling supported because you, the farmer or investor, are willing to risk new initiatives which could have positive spin-offs for New Zealand as a whole.

The OSS person will act in a number of ways to achieve the objectives:

- as a proponent's agent consulting with the various statutory bodies and research staff to achieve results and/or answers.
- to collate knowledge from scientists, industry, and university sources.
- meet with a proponent to sort through issues in detail to help someone reach a decision on a project's feasibility.
- ensure aquaculture interests are represented on all planning studies and run seminars on relevant issues such as legal procedures.

John Schellevis — commercial manager, MAFFish

Many business people seem to believe that Government officials don't live in the real world, but all the MAFFish aquaculture research I've seen is designed to bring practical results. Research proposals now include a commercial appreciation section. This helps to ensure that the only proposals to be approved will have the potential to contribute to the economy.

User-pays research had come in by default because of a decrease in Government funding. Most scientists are acutely aware that user-pays means payer-owns, and that research with results confidential to individual firms may not always be in the best interests of "New Zealand Inc.". Wide industry participation in most commercial research is practicable, but has to be built into research proposals to industry.

Traditional Maori fishing rights and aquaculture in New Zealand

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Traditional Maori fishing rights were broadly based and involved a form of ownership of, and control over, fishing grounds and fishing places and the fisheries resources in the inland waterways and coastal waters around most of New Zealand. The fishing grounds, fishing places, fisheries resources and the water itself were regarded as tribal property, and such property was often delineated by a series of stakes or stones in inland and nearshore areas. The property more distant from the tribal base, both inland and offshore, was maintained through a regular and well established pattern of use. In the South Island, the Ngaitahu Maori maintained property in inland lakes and rivers far distant from their coastal bases through regular visits during well established seasonal rounds. The same people maintained property in offshore fishing grounds through regular seasonal use of those grounds. The process was essentially one of maintaining the tribal territory, of territorial occupation. The inland places were delineated by river courses, lake boundaries, hills, mountain ranges, and other topographical features. The offshore grounds were located by tohu or signs (landmarks), one lined up with another, as viewed from the sea. All fishing grounds and places were named and were often recognised in story, song, and proverb.

The traditional Maori placed his fishing areas, devices, the water, and even the fish, under the protective care of his gods. Kiwa was the guardian of the oceans; Tangaroa the regulator of tides and the god who presided over the dwellers of the oceans. Hine-moana, as wife of Kiwa, was also guardian of the oceans, and Tinirau, son of Tangaroa, was closely connected with fish in Maori myth. Takaaho was the god of sharks and Te Puwhakahara the god of whales (Best 1929).

The fisheries resources and the fishing areas were considered to have been bequeathed to the traditional Maori by the gods. The Maori, through a system of tapu rules, usages, beliefs, and ceremonies, brought order to the use of resources and areas which served

"... to protect those resources [and areas] from improper exploitation and the avarice of man. To disregard or to disobey any of the rules of tapu was to court calamity and disaster." (Waitangi Tribunal Hearing 1988, p. 179).

Traditional Maori fishing rights were as ancient as the creation. As pointed out by the Waitangi Tribunal (Waitangi Tribunal Hearing 1988, p.179):

"The North Island is a fish in their legends... creation was one total entity — land, sea and sky were all part of their united environment, all having a spiritual source. It was by divine favour that the fruits from these resources became theirs to use."

The fishing rights were both physical and metaphysical, and encompassed past, present, and future, history, legend and myth, inherited guardianship and possession, resources and resource use, exploitation and conservation, fish and fishing grounds in the sense not just of tenure, or "belonging", but also of personal or tribal identity, blood and genealogy, prestige and mana, emotional and spiritual strength. The fishing rights combined all of these living and non-living elements into one holistic body (Waitangi Tribunal Hearing 1988, p. 180).

When put together, the physical and metaphysical elements form a cosmic picture which at once constitutes the ancient world view of the Maori, and the present day view of the traditional Maori. The fish and the fisheries and the fishing areas, and the areas of water associated with these things, were once critical components of the Maori world, as they may well become again in the future.

Government is expected to recognise, in some measure, traditional Maori fishing rights and to accommodate Maori tribal fishing aspirations within the existing structures of fisheries research, management, and development.

What has all this to do with aquaculture?

Aquaculture is perceived, both by the Maori and Government, as one of the parts of the fishing industry in which Maori aspirations can be accommodated. There is already some Maori involvement with aquaculture, e.g., oysters in the far north, oysters and mussels on the Coromandel, and mussels at Great Barrier Island and on the Hokianga Harbour. Pilot aquaculture projects involving marron (an Australian freshwater crayfish) near Warkworth and paua in Taranaki are being promoted by Maori entrepreneurs. In addition, there is widespread Maori interest in the culture of kina, paua, and marine lobster (at Tokomaru Bay, Gisborne, Great Barrier Island, Stewart Island, and Bay of Plenty), eels and freshwater crayfish (at Te Kaha, Bay of Plenty, on the East Coast, in Northland, and in the Waikato), silver carp (in Northland, Auckland Province, the Bay of Plenty, and the East Coast/Hawke's Bay), salmon (Picton, South Canterbury, Stewart Island), trout (Chatham Islands), and various shellfish such as scallops, cockles, toheroa, and tuatua (in Northland, Auckland Province, Otago, and Southland) (Habib 1987). Seaweed culture, too, has attracted some interest.

Even finfish culture is being considered, particularly in the far north, where the large semi-enclosed harbours could lend themselves to the cage culture of high value species such as snapper and kingfish.

The ancient Maori practised a primitive form of aquaculture, transferring shellfish such as mussels, cockles, scallops, tuatua, toheroa, and pipis, in particular, from areas of abundance to areas which had been depleted. In their own way, they understood reproductive cycles and the regenerative processes, born of centuries of close observation of the processes of nature. These practices might have bloomed had the Maori retained the control of his fisheries, but he could not and so they did not.

But the ancient practices live on in Maori minds, and the age-old imperatives of use and replenishment continue as primaeval drives, especially for the coastal tribes. In ancient times, resource use and replenishment were largely in balance and the need for human interference with the cycles of replenishment were few. It was more a matter of fine-tuning, compared with today, when major surgery is often required to reverse the effects of overexploitation.

The Maori has played little part in the process of resource depletion. The industrial-scale operators have done the damage to the inshore fisheries. The industrial and agricultural developers have irreversibly altered the inland and estuarine waterways, through processes of land development, sedimentation, reclamation, and pollution. Many of the old fisheries have gone forever, and most of the others are but shadows of their former selves.

So, today, we look to aquaculture as part of the answer to the depletion of the natural fisheries resources. This is a process which has already occurred in many places elsewhere in the world and is now taking place in New Zealand. The Maori want to be part of the aquaculture drive.

Why should Maori, in particular, be given support in the development of aquaculture in New Zealand? There are several parts to the answer to this question.

First, the Maori are tangata whenua in New Zealand, that is, the first people of the land, the first occupiers. As such, they have certain internationally recognised customary rights in respect of land and other resource use.

Second, the Maori were one of two parties who signed the Treaty of Waitangi in 1840. The Treaty, which guaranteed Maori the possession of their lands, estates, forests, fisheries, and other properties, so long as it was their wish and desire to retain the same in their possession, was, on the one hand, declarative of the ancient Maori customary rights, in that it gave formal recognition to those rights (McHugh 1984; p. 257), but was also an agreement which required the Crown to actively protect the Maori people in the use of their lands and waters to the fullest extent practicable (Mr Justice Cook *in* New Zealand Maori Council *v* Attorney General 1987, p. 37).

Third, the Maori have consistently, since 1840, considered the Treaty to be a living document, and one that is always speaking. Pakeha, on the other hand, and the courts, have consistently denied the Treaty any significant status, but the tide of public and court opinion is on the turn. Justice Cooke, in the New Zealand Maori Council case (p. 15), supported the concept of the Treaty as a living instrument, capable of taking into account developments of international human rights norms since 1840. He took the argument further by describing the Treaty as an embryo not yet fully developed and integrated, and as signifying a partnership between Maori and Pakeha (p. 35).

Fourth, Maori Treaty rights were to remain theirs for as long as they wished, although the rights could be alienated through abandonment or waiver, or they could be given away or sold. The Crown had a duty to protect those rights and Maori were not to be relieved of their important properties without an agreement (Waitangi Tribunal Hearing 1988, p. 220). In that report the Waitangi Tribunal put it this way:

"It is the fundamental right of all aboriginal people, following the settlement of their country to retain what they wish of their properties and industries, to be encouraged to develop them as they should desire, and not to be dispossessed or restricted in the full enjoyment of them without a beneficial agreement."

Aquaculture provides one area of endeavour in which the Government and the Maori can look to work together to mutual benefit, in a form of partnership.

Many of the traditional Maori tribal bases are located in rural coastal places, close to prime aquaculture areas such as harbours, bays, inlets, estuaries, lakes, and rivers. In times past, most of these places were traditional Maori fisheries or fishing places over which the local iwi (tribes), hapu (sub-tribes), and whanau (family groups) exercised control.

Manukau Harbour was a Maori fishery for the Waikato sub-tribes (Waitangi Tribunal Hearing 1985, p. 112). Lake Taupo was a traditional Maori fishery for the Tuwharetoa people. The Wanganui River was a traditional Maori fishery for the Whanganui hapu. The Kaipara was one big traditional fishing area for the Ngatiwhatua. The rivers and streams, bays and inlets and, indeed, the greater part of the coastal waters in the far north, were the fisheries properties of the

Muriwhenua iwi, hapu, and whanau (Waitangi Tribunal Hearing 1988). The Ngaitahu people currently have a claim before the Waitangi Tribunal in respect of ownership of, and control over, the inland and offshore fisheries and fishing places around the greater part of the South Island.

The Waitangi Tribunal did not support the claim of the Manukau tribes to ownership of Manukau Harbour, but suggested they should have a share, as kaitiaki or guardians, in the control of it (Waitangi Tribunal Hearing 1985, pp. 103–108).

The Crown, in the 1920s, recognised Tuwharetoa ownership of Lake Taupo and, in an agreement with that tribe as embodied in the Maori Land Amendment and Maori Land Claims Adjustment Act 1926, took over that ownership in exchange for a sharing of the fishing revenues generated by the lake trout fishery with the tribe. This put in place a form of Crown-Maori partnership.

The Waitangi Tribunal, in its findings on the Muriwhenua fishing rights claim, found that their fisheries meant the business or activity in fishing and included the places of fishing, the methods used, and the right to fish (Waitangi Tribunal Hearing 1988, p. 217); also the full authority over these things and over the produce of fishing (Waitangi Tribunal Hearing 1988, p. 218); also to the complex relationship between Maori and their ancestral lands and waters involving the whole of the land, waters, sky, animals, plants, and the cosmos itself, into one holistic body encompassing both living and non-living elements (Waitangi Tribunal Hearing 1988, p. 180).

The Government is currently endeavouring to come to terms with the meaning of all of this, and it is possible that some form of partnership could emerge in respect of ownership and control of the nation's fisheries resources and resource areas. The partners, of course, would be the Crown and the Maori, with the common reference point being the Treaty of Waitangi.

As stated earlier, the country's harbours, bays, and freshwater areas were all Maori resource areas, whether in the narrow sense of fish and fisheries, or in encompassing the wider physical dimensions of water, land, and sky and the metaphysical dimensions which have already been mentioned. In the Maori world, all of these things are inseparable, and it was the Maori view of things that the Treaty guaranteed to recognise and protect.

Therefore, in my view, the Manukau tribes were perfectly justified in maintaining that the Manukau Harbour was theirs and that the Treaty promised that that ownership would prevail for as long as they so wished. Their harbour was never given away, or sold, or abandoned as far as they knew, although Pakeha see the matter differently. At the least, Pakeha needed to negotiate the right to use the harbour and its resources, but this was never done. The best the Waitangi Tribunal could suggest in its 1985 report was that the Manukau tribes be given a share in the control of their harbour.

The Waitangi Tribunal has on its books Maori Treaty claims to proprietary rights to most of New Zealand's inland and coastal waterways. Most tribes will be arguing for a share in the control of those waterways. If the Manukau and Muriwhenua outcomes are any indication, many of the upcoming claims will be sustainable, at least under current law.

Maori aquaculture aspirations require positive support from the Government. They need to be able to plan aquaculture developments in their areas, within guidelines which suit their particular requirements. There is a need for local control over resource areas, with the ability to exclude undesirable outside user groups in particular cases. There is a need for a wider interpretation of current fisheries law to allow for foreshore leasing, and even leasing of part or all of particular harbours, bays, and inlets, for aquaculture purposes.

These concessions and others would allow for harvesting, reseeding, and further harvesting on a rotational basis of productive natural shellfish beds (cockles, tuatua, toheroa, dredge oysters), the seeding of prime sandy bays with scallop spat for eventual harvesting and reseeding, for rotational harvesting of seaweed from leased coastal stretches, for paua seeding and harvesting along leased stretches of coastline, for extensive, low-cost farming of oysters, scallops, and other shellfish in particular bays, inlets, and harbours, and so forth.

Finally, Maori tribes require both finance and expertise to get them going. The reality is that aquaculture is at an early stage of development in New Zealand, and Maori tribes have neither the finance nor necessary expertise to develop aquaculture facilities and take one or other of the new aquaculture species through trial farming to the point of commercial viability.

Maori groups even struggle to culture established species (e.g., oysters in the far north and mussels at Great Barrier and Hokianga) being hampered by poor management and inadequate finance. There is a certain critical mass of both those components which must be available to Maori groups before widespread Maori involvement in aquaculture will become a reality.

There has always been Maori interest in the field of aquaculture. This interest has generally received little support. I have cases in my files of Maori groups waiting 7 or 8 years for marine farming licences. Management advice and support available to them through agencies such as the Department of Maori Affairs have generally been inadequate. Financial packages made available from time to time for Maori initiatives are generally too small and short term. Maori business performance has, therefore, been poor. This has engendered a great deal of negativeness about Maori projects within the bureaucracy and elsewhere in society. It's a vicious circle with little chance of positive outcomes.

The circle needs to be broken. Probably, the only recourse now for Maori groups is to Treaty rights, with the aim of sharing the control of their traditional resource areas with the Crown. This is probably the only way they will get to pursue their aspirations in aquaculture, in their own way, in their own areas.

Kia ora tatou katoa.

References

Best, E. 1929: "Fishing Methods and Devices of the Maori". Government Printer, Wellington. 264 p.

Habib, G. 1987: Korekore piri ki Tangaroa. Maori involvement in the fishing industry. Report to the Maori Economic Development Commission and the Department of Maori Affairs, Wellington. 286 p.

McHugh, P.G. 1984: Aboriginal title in New Zealand courts. 2. *Canterbury Law Review 233.*

Waitangi Tribunal Hearing 1985: Manukau claim. Paper Wai 8. Nganeko Minhinnick and others (Ngati Te Ata and Tainui re Manukau Harbour).

Waitangi Tribunal Hearing 1988: Muriwhenua claim. Paper Wai 22. Hon. Matiu Rata and others (Ngati Kuri and others re Muriwhenua lands and fisheries).

Discussion

Q. You mentioned a number of areas in which Maori are interested. Do you know of any firm proposals and how they are being financed?

A. There is nothing concrete at the moment and most of the tribes are virtually bankrupt. The future probably depends on the outcome of arguments about the Treaty of Waitangi. Once there is the mechanism for developing projects, Maori groups are just as capable as any.

Q. Money or quota from the Government is a form of subsidy. It could put the recipients at a commercial advantage, whereby they could make money where under the same circumstances no-one else could. This is the current situation in the meat industry; what are your comments?

A. I don't see quota or finance to Maori tribes as any form of subsidy, but as reparation for shortcomings under the Treaty of Waitangi. Maori people are hardly in an advantageous position in the fishing industry. They have no boats, factories, expertise, or money and it would take any Maori group many years to even become equal with the established operators. There must be a solid and ongoing injection of expertise and finance into Maori communities to give them the opportunity to develop viable projects. It will still be many years before such projects become highly productive.

Maori traditional fishing: a perspective

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R.D.Te Kao
Kaitaia

E nga Rangatira o nga hou e wha tena koutou. Tena koutou io tatau mate tuatini. Mai i te Rerenga-Wairau ki te Waipounamu whiti atu ki Whare Kauri. Ko mihia ko tangihia ratou no reira nga mate haere. Kaati kia ratou.

I want to start by restating the simple questions raised by the Treaty of Waitangi, the rights mutually agreed between the Maori and the Crown in 1840, and the obligations involved. There is not the slightest doubt that Article 1 transferred sovereignty from the Maori people to the Queen of England. There is also not the slightest doubt that Article 2 provided that in exchange for sovereignty a guarantee was written into the Treaty protecting the full, exclusive, and undisturbed possession of the lands, forests, fisheries, and the possessions of the Maori signatories. Article 3 conveyed the rights and privileges of British subjects to Maori people.

In 1974 I had the privilege of introducing into the New Zealand Parliament a bill which would enable this country to deal with its Treaty obligations and responsibilities. The passing of the Waitangi Tribunal Act in 1975 heralded a major turning point for the Treaty of Waitangi. The purpose of this enactment was to provide the lawful means of honouring the Treaty terms. It also provided the means by which Maori people could achieve redress under New Zealand's judicial system, and thus deal with longstanding grievances by judicial means instead of political patronage. For too long the wrongs to Maori people and their interests have been dealt with by political means instead of lawful means. No other citizen in this country would tolerate such a position: no other citizen would accept constantly having to go cap in hand to Government over matters which should be part of their lawful rights.

The Maori people will not accept or tolerate that situation either.

For the past 700 years my forebears fished the Far North regions. This was not a simple beach or shellfish collecting operation; it was an extensive and major industry extending to areas some 50 miles out, and involved every member of the tribe. Yet by 1988 we have been reduced to one solitary fishing licence to fish over the same region — a nation and fishing people legislated and regulated out of existence.

Between 1869 and 1986 over 94 major fisheries petitions or submissions were presented to the New Zealand Parliament or governments by the Maori people in attempts to gain recognition for their rights and interests. These rights were the foundation of the Treaty of Waitangi. None was successful. During that time Parliament enacted over 59 fisheries statues and regulations which had the effect of not only removing very basic rights in fishing, but eroded the Treaty as though it did not exist. First it was land. When fish became a valued commodity, the Treaty and the guaranteed rights of Maori people were, and continue to be, treated with callous indifference.

Even now over 33 enactments are in force which have a direct bearing on the rights, such as they are, of Maori people in fishing. Only one clause in the Fisheries Act, Section 88(2), expressed the Maori fisheries right, and even that is under threat. It should be remembered that Section 88(2) of the Fisheries Act is the only legal expression of Article 2 of the Treaty of Waitangi in existence.

Our society as a whole has always interpreted rights to mean only individual rights. It has ignored collective or communal rights as practised by Maori or Polynesian societies. Maori rights, including possessions and properties, were communal. That, too, is part of the Treaty agreement.

Past Governments have welshed on such matters, and so have denied Maori people rights to which they were entitled, and which were inviolate under the Treaty.

Let me return to the implications of the Treaty on fisheries. No claim made by any Maori in the terms of the Treaty has interfered with, or affected, any personal right, and nor should it. These matters are between the Crown and the Maori. Although the Crown readily acknowledges that the Treaty does afford Maori people the right to fisheries or to go fishing, it has taken little or no action. To date, the opposite has been true. While individual fishermen have enjoyed the support of common law in fishing matters, Maori as a kin-group have been deprived. The failure to fulfil the Treaty obligation in fisheries has seen the wholesale removal of the Maori from a traditional industry and economic base.

Communal ownership has been a part of the Maori fisheries legacy, and that concept has not quite disappeared. We have as much right as other citizens to own and do what we believe is relevant.

On the matter of claims arising from the Treaty, public examination, criticism, and scrutiny are appropriate. Some of the criticisms of late, however, are far wide of the mark and are simply mischievous. Lack of knowledge of the Treaty of Waitangi is no excuse; on that alone, a great deal of learning is needed.

We must enlighten everyone as to the value of the Treaty. It is the foundation of New Zealand society as we know it. It is good for New Zealand. Government must pay attention to it.

For many years the Treaty was known only north of the Bombay Hills and as an event which appeared on television on 6 February each year, coupled with the protest movement. That perception must be replaced with a commitment to achieve its objectives and desires, one which establishes a bicultural partnership from one nation and two people.

Our forebears signed because it would bring great scope to their lives: reason would replace conflict. They traded their trigger-finger for a finger grasping a quill as expressing and symbolising a commitment to reason. This commitment gave rise to our bicultural partnership.

There are those who say that the Treaty has no relevance today. They say that such an agreement signed 149 years ago should be regarded as a thing of the past. This would be tantamount to telling Americans that their Bill of Rights, based on the agreements of their forebears, was not worth the paper it was written on. Or, like telling every Englishman that the Magna Carta was not only worthless, but that our Bill of Rights was not influenced by this important event.

It would be idle to pretend that the Treaty agreement did not mean or do what it says. Let us be absolutely clear that the Treaty of Waitangi is not only relevant, but is the very basis and foundation of our nation. It not only guarantees the rights of Maori people, but also imposes obligations and responsibilities. The Treaty is a living principle. New Zealand will be the greater because of it.

I want to now take up the matter of the fishing issues of more recent times and the effects on Maori people. The Government, on behalf of the Crown, in introducing a new fisheries policy created a new constitutional concept. The introduction of the quota system, designed to conserve our fish stocks, is in breach of Article 2 of the Treaty of Waitangi. By establishing fishing quotas which can be bought and sold, the Crown has created a property right. Both the Courts and the Waitangi Tribunal have expressed that, and have regarded the action as illegal.

We accept the principle underlying the quota system, that of conservation. We do not accept, however, that the "right to fish" may be traded or sold for ever.

The Crown needs to be reminded that there are Treaty obligations governing fisheries. The Crown is required to uphold them and not take matters into its own hands. (It is like selling our lands. Government must be told bluntly that the sale of New Zealand lands to overseas ownership is in breach of the Crown's obligations. We cannot, as a nation, afford to sell our legacy of land to overseas interests, nor should we expect to have some foreign moneylender bankroll our shortfalls or shortcomings.)

To return to the matter of fishing quotas; the proposals now being negotiated with Government should see the Maori people become part of the fishing industry again. A gradual transfer of fishing quotas, say from 1 October next, at the rate of say 2.5% would also ensure that the Treaty terms are fulfilled. A recent National Maori Fisheries Hui in Wellington endorsed the principle of the partnership by recommending that 50% of all New Zealand fisheries be gifted to the Queen. It follows that steps must be taken to restore the other 50% to the Maori as soon as practicable and in the terms of the Treaty. That may take some years, but it must be done. I would expect that current negotiations will lead to a new fisheries arrangement that will include effective conservation measures. Our hope is that this arrangement will begin this coming season.

It may take some years before Maori people's fishing interests are fully satisfied in terms of the Treaty. This should be achieved under the quota system on a "willing seller and purchaser" basis.

We do not accept that compulsion be used to settle any Treaty claims, nor do we see it as necessary. We do not believe that the grievances the Maori have endured can be remedied by the imposition of another grievance.

The non-commercial fisheries are of considerable importance to the Maori people. Our current negotiations include the need to protect the areas that support them. We also regard the commercial exploitation of such areas as a breach of the Treaty. We do, however, totally support the expansion of marine farming of species such as oysters and mussels. There have been some exciting and encouraging developments in this area.

The issue of the Treaty includes the recognition that the Crown does have sovereignty over the whole of New Zealand. However, we contend that we own all the fisheries, though 50% has been gifted to the Queen, subject to an agreed settlement overall. The Government should acquire quotas to enable Maori to collectively become an integral part of fisheries. We believe that this should begin from the foreshore and extend to the boundaries of the 200 mile exclusive economic zone.

We also believe that the future management of fisheries has to be based on the Treaty. It is not possible to effect a realistic change for Maori fisheries without a major change being undertaken. Any new management regime could include recreational, industry, Crown, and Maori representation. The partnership must be shared.

We must encourage that commitment. The implications of the Treaty are important not only to you and the industry, but to us all. I know of no reason why anyone should be alarmed by any claim.

It is the responsibility of the Crown to act for the public interest and good. There is need for balance and reasoned settlement. The Government has clung tenaciously to its task, although it could have aborted the Treaty negotiations. It at least deserves credit for that, and it is to be commended for providing the first real opportunity for New Zealand to deal with the Treaty of Waitangi and the issues it raises.

Some years ago I hosted the Canadian Minister of Indian Affairs. His visit in 1973 was to study Treaty issues and to see what we were doing in this field. After his visit he returned to Canada and introduced some far-reaching measures to deal with their treaty responsibilities. They have made some progressive strides. We need to do so as well.

We do not expect that this generation should foot the bill for the Treaty omissions. What we should expect, however, is that this generation initiate the moves that make it possible for every generation hereafter to fulfil their Treaty commitments, for they must surely be beneficiaries as well.

The blueprint for our society was drawn up in 1840. Those principles apply to this time. They are more than capable of being honoured: they are capable of application.

Justice must be done. We wish to see it done, and it is high time our Government remedied the differences and fulfilled the Treaty expectations.

Discussion

Comment. The New Zealand aquaculture industry is not the same as the New Zealand fishing industry. The attitudes and practices needed for success are quite different. Protection of the coastal environment is the responsibility of all New Zealanders.

A. At Parengarenga Harbour the landowners (the Crown, two major incorporations, and a trust) have agreed to retire 3–5 chains [60–100 m] of the land surrounding the harbour to protect the water quality. This could be applied elsewhere and perhaps we should look to Government to provide financial assistance to farmers and others to retire suitable properties to ensure clean water for marine farming.

Q. In its discussions with Government, your working party has stated that the Crown has consistently failed to recognise the Treaty of Waitangi. How do we decide who are the real owners of the resources of this country? As a Maori representing the Maori people, do you follow Maori traditions and customs in your discussions with the Pakeha?

A. I believe we are talking about a philosophical, rather than a racial, matter. There is a feeling that most Maori people have become total strangers and economically deprived in their own land. We must increase our economic and social abilities to not only compete, but also to contribute to the common good. It has always been the view of Maori people that property rights, such as fishing, belong collectively and communally to a people rather than to individuals. We should ensure that Maori concepts are embodied in our laws and that Maori beliefs form part of New Zealand's practices and policies.

Q. About 20–30% of Maori people are not represented on your working party. I believe that representation is restricted to tribes with cases before the Waitangi Tribunal. Is this so, and what will you do about it?

A. The Government decided the membership of the working party. It was drawn mainly from those who had applications and proceedings before the courts. We shared the concern of many about the composition of the working party and, in consequence, arranged a National Hui on Fisheries for our people; 146 representatives from all over New Zealand took part. The hui authorised the four of us to act for Maoridom. I regard it as a privilege to serve Maori interests.

Making a good business plan

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Introduction

A high proportion of new businesses fail because they have not adequately addressed the issues that can go wrong within the first year of setting up. The best way of ensuring that the issues are covered is to write down a business plan. Your banker will expect to see a well thought out business plan before finance can be considered. He will not be willing to put the bank's money at risk unless he has the confidence that your business will survive and be profitable.

Why small businesses fail

Providing finance to small businesses is fraught with risk. Accounts are usually unaudited, and data given to financiers are often suspect in accuracy and may be based only on figments of imagination. Experience has shown that there is often a rather cavalier attitude shown by businessmen in providing financial information to their accountants and in documents sent on to banks for loan decisions. Quality information is needed to protect the business operator and the financier from incorrect, unwise, or simply bad borrowing.

In New Zealand, 60–70% of new businesses fail within the first 4 years. Bad management is the cause of business failure 99% of the time. The manager must be able to assess his own capability, the market he is going to operate in, the impact of the economic environment on his business, and the limitations of his business.

Borrowing too much is the prime reason for business failure. When interest rates go up, the business becomes highly exposed. Many people go into business thinking they can pick up the basic rules as they go along. The high failure rate of new businesses is witness that you can't.

Who are you?

The critical factor in the success of a business venture is the manager. You must be able to demonstrate to the financier that you personally can make the venture succeed. He will be looking for evidence of good character, experience in the technical areas of the business, managerial ability, and financial performance to date (how you have managed your money in the past, paid back debts, honoured commitments). He will also need a corporate structure (whether company, partnership, or sole trader and a detailed flow chart of the structure of the body); a list of names and addresses of the general manager, partners, shareholders, and directors; and full details of the borrowers key advisers, such as accountants and solicitors. These will be checked; full disclosure will avoid any embarrassment later.

Why do you need the money?

You must describe the business you are proposing to undertake. You have to think of the customers you are going to try to satisfy for it's what you sell that counts and meeting the wants of customers. You will need to put yourself in the customer's shoes and ask, "What is it that I want?"

The location of the business is critical to your purpose, your customers, and the facilities needed. There must be room for expansion and access to transport. What are your operating policies? Who will do what in the business, and what outside help will you need (technical advice, financial advice, legal advice)?

The industry within the particular environment in which the borrower operates is a critical aspect considered by lenders, as is the particular market in which the borrower will be selling his products. You will need to show that there is a market need for your product and that the product can be sold at a profit.

The marketing plan

Your business won't succeed unless there exists a genuine business opportunity. The marketing plan ensures that you have done your market research thoroughly. The aim is to gather market-based information in a systematic way. Beware of interpreting your research to fit your own ideas; be objective. You must know your target market; the size of the market; the nature and identity of competitors, their strengths and weaknesses; the political climate and likelihood of change; technological changes, and the union and industrial climate.

What will be your sales policy, how will you promote your product, and how will you package and sell the product?

Even if you are not selling to the final customer, it's important that you can answer the above fundamental questions. It's simply not good enough to take the word of an intermediary.

How will you pay it back?

Financial skills are an essential part of management; finances are not something that can be left to the accountant. To determine the amount of money you need, the first step is to convert your plan into a budget; from this is developed the cash flow forecast. These two statements are tools that are used and revised regularly and whenever there is a major change in the environment. When things change, you go back and revise the budget and the cycle begins again.

The cash flow statement is one of the most important things you write as a manager. It shows how much money you need, when you need it, and when you will be able to pay it back. From this the financier will determine the funding he will provide, the financial instrument that is best suited to the business, and the method and timing of payments.

Financiers are increasingly becoming cash flow lenders. They do not want to resort to realising on security to recover advances because it brings bad publicity, ill feeling, and is above all costly and time consuming to both borrower and lender. Thus the business must be able to demonstrate the ability to repay both interest and principal.

Financial statements

In reviewing your financial statements the financier will undertake an orthodox analysis, but because the accounts are not likely to be audited he will take particular notice of trading income and the percentage of gross profit to sales; trends in opening and closing stocks; sufficient salaries to support the employment levels; current assets in relation to debtors (an aged debtors list enables the checking of debtors) and stocks (a current stocks list helps overcome the practice of overstating stock amounts); and working capital and quick assets ratios to determine the ability of management to provide the funds for day to day use.

What security can you offer for finance?

In today's environment it is a mistake to think that company formation provides limited liability. Financiers will almost always require personal guarantees to cover risk. Cash deposits and freehold security are the prime assets sought for security. Third party guarantees backed up with security are an acceptable alternative. In unaudited balance sheets, financiers will set little store on bad and doubtful debts showing as a current asset.

Aquaculture risk and protection

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Every organisation faces risks, which may be commercial, natural disasters, or liability exposures. Non-trading (or pure) risk, can impact on the cash flow of a trading entity, affect its profitability, or even threaten its very survival. Management must, therefore, find the best method or combination of methods of treating risk.

Pure risk may be defined as "the chance of loss with no corresponding chance of a gain". The loss could be a loss of property, an income and expense loss, a liability loss, or any combination of these.

It is not unusual to attempt to protect oneself against risk by purchasing insurance, that is, to transfer as many risks as possible to a professional risk carrier. This often proves the least effective, if not the most expensive, option unless it is purchased correctly and for the correct reason.

It is essential to formulate insurance philosophies with the following points in mind.

- There are certain risks which are not insurable.
- There are types of risks which professional insurers are willing to assume only in return for disproportionately high premium levels.
- There are certain types of risks which are more economically retained by an organisation even though they could be transferred to the insurance market at reasonable premium levels.

Losses which stem from risk can be financial, physical, consequential, or personal. The probable frequency or severity of potential losses can be reduced. Sometimes risks can be transferred to organisations other than traditional insurers, whilst there are some types of risk which should, if possible, be avoided completely.

Effects of loss

Few people consider controlling the unforeseen exposures to risk or analysing their "chance of loss". One needs to adopt a "what if" philosophy and pose a series of hypothetical scenarios. First, the effect of loss needs to be analysed. What if each facility, site, person, or even market were lost? How long would the recovery take? What outside expertise would be needed? Who could assist? And above all, what will be the monetary cost?

The second key question is: What measures are available to control exposures to loss? In other words, would expenditure on back-up systems reduce the need to insure against the effect of loss? For example, there are two ways to protect a motor cycle: one is to purchase a padlock, and the second is to buy an insurance policy. Within the aquaculture industry, loss control mechanisms and contingency planning need careful consideration and appraisal. Risk may, for example, be reduced by installing water or oxygen level alarms, or having inspections more frequently. Here are some other self-examination questions.

- If access to a farm or hatchery were lost, are sufficient feed and veterinary supplies on hand to last a reasonable period?
- If the feed stock mill burnt down, is an alternative supplier arranged?
- Should disease break out, is there an established quarantine facility?
- Are the operations spread geographically, or could one accident impact on your total operation?
- Could records or data be kept in several places? Alternatively, management expertise, which may lie with one person, could be imparted to others.
- Should alternative power or water supplies be installed?
- If water became polluted, how could the existing water be aerated and recycled?

Production flow charts can often help to identify crucial points of loss exposure. When superimposed on a loss control chart, the analysis becomes complete.

The third step in risk planning is to establish how one should fund losses, once they occur. As already stated, this may well be to purchase an insurance contract, but this should be left until all other avenues of risk management and loss control have been fully explored. Before risk is understood, and its likely effect planned for, a risk consultant should be engaged. It is his task to identify risk, analyse loss exposure effect, investigate loss control techniques, and implement loss funding systems.

Risk identification

Risk identification embraces all facets of exposure. Physical loss includes fire or earthquake damage, environmental impairment, losses in transit, malicious damage, windstorm or tidal wave, theft or poaching, breakdown or damage to plant, landslip or subsidence, agricultural run-off or aerial spray drift, and mortality by diseases or Government enforced slaughter.

"Consequential" losses include delayed start up or commissioning date, loss of feed supplier's premises, increased costs to maintain production, prevention of access to facilities, and loss of profit from mortalities.

Liability losses include libel and slander, damage to third party property, and pollution of environment or water supplies.

Finally, personnel loss includes death of partners, or key-knowledge personnel, repatriation costs for overseas consultants, and injury to, or sickness of, employees.

Changes to the Earthquake and War Damage Act outlined in the 1988 Budget also require analysis relative to individual risks. The changes are to be implemented from 1 April 1989, and can be summarised as follows.

The Earthquake and War Damage Commission will charge premiums according to type of structure, construction, site, soil type and foundations, age, and location. There will be differential premiums in the future instead of the single premium rating as at present. The worst rated risk will obviously be an unreinforced concrete raceway near a fault line, and the best one of fully reinforced concrete in an area of lesser earthquake activity.

Self insurance will be allowed. This means that deductible levels which are commercially acceptable will in future be available as part of the insurance programme. Earthquake insurance may be bought from the reformed Earthquake and War Damage Commission or from private insurance companies operating in New Zealand or elsewhere.

Advantages to the buyer of cover are freedom of choice (everyone will be able to choose which insurer they wish to deal with) and simplification: the announced changes will make it possible to combine various types of insurance under a single sum insured. (The requirement to supply annual property valuations and monthly stock declarations may be removed entirely or altered to improve efficiency. No longer will there be the same possibility of a gap between indemnity and replacement insurance.)

There are also disadvantages. Because the "user pays" principle will apply, premium costs will probably increase for those considered to have a higher than average risk factor. Government aims to reduce its contingent liability as insurer of last resort by reducing the amount of call on the Earthquake and War Damage Fund and by creating a competitive atmosphere. Reinsurance cover for an additional $1 billion will be sought, but earthquake insurance is an unattractive catastrophic risk to insurers. There is, therefore, a finite capacity to insure. No-one can gauge precisely what the market capacity will be, but there is insufficient capacity to handle the maximum possible loss in a key location (e.g., central New Zealand, which has been assessed at a minimum of $20 billion). Earthquake protection will, therefore, remain a problem for both the insurance and the aquaculture industries.

At present many crucial items of plant are excluded from cover under the Earthquake and War Damage Act 1944. These items include pipes and reticulation systems; cables and lines; drains, channels, dams, retaining walls, reservoirs, water tanks, and raceways; wharves, roads, watercraft, and sea cages; loss of profits and consequential losses. The opportunity now exists to revise insurance covers by purchasing full earthquake protection before the expected rush on existing market capacities.

Loss funding

Internal funding (self-insurance) of all losses is seldom justified. Small losses can be treated as a working expense; any attempt to fund them from insurance policies would prove expensive. Internal funding is viable only if one or more of the following apply: no vulnerability for borrowed funds, loss severity and frequency can be contained, diversification of activity will allow a business to carry a loss or series of losses, and the risk of loss and its effect is so small as to be insignificant.

If these factors are not present, then the exposure to loss should be transferred to another party, usually a specialised insurer. Insurance thus becomes a line of contingent credit.

The insurance of aquacultural risks is as specialised as the aquaculture industry itself. Until recently, local insurers shunned the specialised covers required. The only policy wordings available related to United Kingdom and Scandinavian operations. Excesses were high and insurance was being bought uneconomically and, more often than not, at excessive prices. A reluctance to insure led to policies not being renewed: most aquaculturists now have no cover for a catastrophe.

Marsh and McLennan Ltd. has organised a consortium of local insurers to pool their individual insuring capacities to create an insurance facility available to the local industry. Where the sum insured is greater than can be accommodated by the consortium, a secondary policy will be used. This policy (arranged overseas with Lloyds and others) can prove most cost effective as it is purchased purely to protect against catastrophe for sums in excess of the level of the "consortium" cover. By combining the consortium cover and the "top-up" insurance, an averaged down premium and cost effective protection programme will be achieved.

Insurance brokers

Limited cover only is available to cover live species. Because premiums are influenced by an insurer's perception and understanding of the risk, clear advantage can be gained by having specialised assistance in the buying of cover. This is the role of an insurance broker.

Regrettably, few insurers understand your industry. They are cautious when quoting premiums, which are generally higher than warranted. The role of the professional insurance buyer again becomes obvious.

To minimise insurance overheads, one should periodically reconsider existing protection programmes. Ask yourself if you are paying too high a premium and whether risk can be contained by extending existing control mechanisms. Again, the broker can assist.

And so to market

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There is probably some significance in the fact that I am the last speaker in one of the last sessions on the last day of this conference — often this is how the question of international marketing is dealt with in many industries.

To give me a measure of the marketing drive within this industry, I referred back to the report from the 1979 aquaculture conference and was indeed very hard pushed to find anything meaningful relating to marketing. I was, therefore, led to conclude that your industry in the past has been production driven.

Your industry is not alone in this. The Market Development Board (MDB) was formed 2 years ago to provide some export marketing perspective to various industries. You may be aware that the Board has a small team of executives recruited from the private sector. We have a lump of Government cash available to invest in worthwhile marketing ventures. Our target is the foreign exchange that can thus be earned for New Zealand.

In selecting the industries and programmes that we support, our guiding principles tend to be as follows.

- The future of exports is in marketing, not in trading and in differentiated products being targeted at increasingly affluent populations.
- Innovation is the essential key to successful overseas marketing.
- There is a need for New Zealand exporters to share the costs of non-proprietary information and co-operative activities.

You will be aware that the MDB has already provided a sizable 3 year grant ($250,000 each year for 3 years) to jointly fund, with the New Zealand industry, the U.S. seafood promotion. The keys to our involvement were that: the industry agreed that there needed to be greater co-operation and co-ordinated effort in the development of overseas markets; the programme involved all varieties of New Zealand seafood, including aquaculture products; a target market had been clearly identified; a formal plan had been prepared and agreed by all parties; the industry has made a long term commitment to this plan (at least 3 years); a facilitator has been employed; and the plan has a good chance of success and is likely to generate significant foreign exchange earnings for New Zealand.

Late in 1986 the MDB undertook extensive consumer research in the U.S., Canada, and Japan to find out what consumers knew about New Zealand and things New Zealand. This enabled us to develop a positioning statement, an advertising line if you like, for all New Zealand food products that will unify and add value to the whole range of New Zealand products in major overseas markets. For seafood, this positioning statement has evolved as being "New Zealand Seafood — the Best Naturally". The purpose of this statement is to get consumers past the "so what" barrier. Seafood from New Zealand — so what, who cares?

As a result of this programme the seafood industry is now participating in the Board's Dallas Promotional Programme which begins later this month [September], runs for 12 months, and involves the major export sectors of the New Zealand food industry. Essentially, this is the first ever outing of a "New Zealand Inc." approach to marketing in a major overseas market.

Getting back to the "so what", what does all this mean to the aquaculture sector?

New Zealand seafood is now in a spotlight, the industry is co-operating in a very exciting plan for the next 2 years in the U.S., and all sectors of this industry, aquaculture included, stand to benefit greatly. Add to this the financial assistance and marketing guidance available to any exporter through the Individual Exporter Programme (IEP) that the MDB administers for Government, and I say that opportunities await anyone wanting to help themselves or be helped.

The IEP is a simple form of Government financial assistance available to any exporter. Since its birth a year ago we have recruited nearly 1500 clients. If you are looking for a good business plan, then the IEP is an excellent place to start. It covers preparation of a business plan, the necessary market research, market visits, consultants, trade fairs, and promotional and advertising costs.

In 1987, New Zealand's total fish exports (156 000 t) were worth $676 million, of which $241 million came from the U.S. Aquaculture products contributed about $30 million.

The U.S. imports more than US$4 billion worth in total. Our share of total U.S. imports, therefore, is about 3%, which hardly makes us a major player. The total U.S. market, including imports, is 1.9 million tonnes, of which New Zealand accounts for 0.7%.

For aquaculture products, I understand that per capita consumption in the U.S. is expected to increase from 0.62 kg a head in 1985 to 0.88 kg by 1990, a 50% increase in 5 years which would give aquaculture 10% of the total U.S. fish market. This market is too big for the New Zealand industry to cope with, so let's focus closer.

At present, the U.S. fish market is 60% retail, 40% catering. By 1995 the split is expected to be 50/50 which means a 1.5% increase per annum in retail sales, but a 7% increase per annum in catering sales. Obviously, the catering market is very important for aquaculture products; for example, between 70 and 80% of shellfish currently ends up in the catering market.

Within the catering market in 1985 there were 625 000 outlets with a combined turnover of US$158 billion. Food purchases totalled US$73 billion, of which US$3.7 billion was fish. Within this sector there were 119 000 restaurants and 100 000 fast food outlets with a combined turnover of US$96 billion. Food purchases were US$34 billion, of which US$2.3 billion was fish. These restaurants and fast food outlets combined account for two-thirds of the U.S. catering market for fish. The six top restaurant chains in the U.S. have 2500 outlets which consume 7700 t of fish per annum.

By now I should have proved that markets exist within the U.S. alone for New Zealand's total production of aquaculture products, existing and new species, even if this were to be increased tenfold. However, before you all get too excited and rush off and plough all your money into new R & D and additional production and processing, think more about the needs of the market.

First, find your market, not only how big it is and where it is, but what it needs. New Zealand companies individually are very small, and it seems to me that if an aquaculture species is to be successfully marketed overseas, then the whole of the New Zealand producing sector should be unified in its marketing efforts. Even then, such a marketing group would still be a niche marketer. The trick is to find the best niche markets and concentrate efforts on them.

The greatest challenge to any exporter is to get close to the market and find out exactly what the customer needs. More than ever, the customer has control and is exercising that control more aggressively. When a customer buys he will not only want price, he will want quality, consistency, reliability of service, and he may also have unique needs in terms of packaging, size, seasonality, and promotional support. If you can't provide these, others can and will. I am reminded of a famous quote from a recent study of customers in Europe conducted for the N.Z. Apple and Pear Marketing Board, "We really don't need New Zealand apples, but we do need the New Zealand Apple and Pear Board". Wouldn't it be nice if that also applied to New Zealand fish products?

Finally, I issue an invitation to any group within your industry, be it a marketing group for green-lip mussels, salmon, or oysters, or some other new species. Our door is always open, we can help, we would like to help.

General discussion on Session 8

Comment. We need an aquaculture organisation along the lines of the Game Industry Board. The only way to improve the product is to have one goal for everyone, and that goal is to maximise the return to the producer.

A. In any group, the key to success is commitment to, and an understanding of, the needs of the group, be they quality standards or the promotion of New Zealand. However, commercial reality is individual exploitation of markets. The U.S. Seafood Promotion would have been more successful had there been an umbrella organisation rather than individual efforts by the various producers. You can't bulldoze groups into existence — they have to come from the needs of the industry.

Q. MAF have the power to slaughter salmon stocks without compensation. Is it possible to insure against that?

A. The wording of New Zealand policies follows that current in Britain. Up to now, nobody has objected to it. Slaughter for humanitarian, veterinary, or officially authorised (including governmental) reasons is not covered.

Comment. We usually have cover against disease and intentional slaughtering is usually because of disease. We would be better off to let the fish die and collect the insurance.

Q. In assessing risks do you have a formal model in which probabilities can be put on various risks or is it a subjective process?

A. No two insurance propositions are the same. We use a searching questionnaire to help develop individually tailored insurance policies.

Comment. The level and sophistication of risk analysis is directly related to the dollar value of the project. With high value projects, very detailed sensitivity analyses of cash flow projections are made.

The potential for marron farming in New Zealand

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Introduction

Marron (*Cherax tenuimanus*) is endemic to the rivers and streams of south-western Western Australia. It is a member of the Parastacidae family of freshwater crayfish and is reported to be the third largest species in the world; specimens over 2 kg have been recorded, but over 1 kg is uncommon.

Government sponsored research into marron culture began in 1967 at the Western Australian Fisheries Research Station at Pemberton. Commercial interest was generated by publications in the mid 1970s giving encouraging production figures which indicated that marron had market potential, and in 1976 marron were declared a "farm fish". Since then about 40 licences have been approved for marron farms, although several have since expired. Most farms are small, part-time operations, and only half a dozen could be said to be of commercial size. Many of the larger operations also incorporate tourism.

Attributes of marron

Marron have several attributes for aquaculture, including excellent flavour (which many people say is superior to rock lobster); large size; relatively disease-free status; ease of breeding and transport; non-burrowing habit; high meat yield (the tail and claw meat can account for 50–60% of total body weight); high market price (A$25–35 per kg in Australia and up to $40 per kg overseas for live adults).

Commercial interest in marron over the past decade has prompted their introduction into other parts of Australia, and the export of live marron to over 20 countries including New Zealand, mainland China, Singapore, South Africa, the U.S., and some European countries.

Critical factors

Despite the short time (just over 10 years) that marron farming has been undertaken, a number of major developments have occurred in the industry. In addition to a greater understanding of some aspects of the life history and biology, culture and hatchery techniques have been fine-tuned in the areas of predator-control, stocking densities, water management, and brood stock manipulation.

In Australia, the following are regarded as necessary for a successful marron farming operation.

- A site with a mild climate allowing water temperatures to remain between 15 and 30 °C
- Plenty of clean water and flat land free of pesticides and herbicides
- A pond water salinity less than 4 parts per thousand
- Readily drainable purpose-built ponds with hard clay bottoms (0.5 to 1 ha is ideal)
- A stocking density between 5 and 10 juveniles per square metre
- Fencing and netting to exclude predators, poachers, and competitor species
- Provision of pelletised food
- Provision of hides and refuges to provide protection from cannibalism, especially during moulting
- Maintenance of oxygen levels above 6–7 ppm through use of mechanical aerators such as water wheels and aspirators
- Turbid water to reduce predation and algal blooms
- Water depth between 1 and 1.5 m
- Water with a pH of 7–8 (slightly alkaline)
- A hatchery to supply juveniles
- Harvesting by draining the ponds.

Under these conditions marron should reach 60–70 g within a year and 100–200 g within 2 years, although growth rates vary greatly between individuals and stocking densities. Stocking at 5-10 juveniles per square metre should give a harvest of 3–6 marketable marron after 12 months. Annual production rates for ponds established and managed in this way should be between 2000 and 3000 $kg.ha^{-1}$.

In the past 12 months two new multi-million dollar companies have been formed in Australia; this shows that marron farming is no longer a cottage industry.

Pests, parasites, and other problems

Since 1981, marron have been imported into Queensland where the greatest developments outside Western Australia have taken place. Over a dozen farms were established with lots of hype and misinformation in the press about growth rates and expected production figures. Unfortunately, the marron did not live up to its new reputation, and a number of mass mortalities occurred; the presence of residual pesticides in the soil and water, high water temperatures, and low oxygen levels, as well as lack of experience of growers were the main reasons for the deaths.

Although marron are quite easy to keep, there are some problems with their culture, including the need for strict maintenance of water quality (particularly temperature, dissolved oxygen, and salinity), and cannibalism (especially with juveniles and recently moulted animals). The lack of proven pelletised feed may contribute to cannibalism.

The need for fences and netting to keep out predators (such as birds, eels, and water rats) and competitors (like tadpoles and aquatic insects) drastically increases the capital cost of marron farming.

Our company

Koru Aquaculture Ltd. (K.A.L.) is a privately owned aquaculture company concerned solely with the production of marron. We have an 8.4 ha property at Warkworth, with 19 purpose built ponds stocked with 30 000 marron which have now been in quarantine for about 16 months. Once a fish farming licence has been granted, K.A.L. plans to build a further 200 pond grow-out facility at Warkworth along with a fully equipped hatchery able to produce up to 3 000 000 juveniles each year. With ever-increasing world demand for crayfish, the opportunity is also there for other farmers to become involved in the industry; K.A.L. would undertake to supply initial brood stock and buy back all marketable size marron.

Benefits to New Zealand

New Zealand needs another primary industry that uses our land and water resources. We see many benefits to New Zealand in the following areas.

Export revenue. We have had marron at Warkworth for 16 months and estimate a possible $44 million in export revenue over the next 6 years. This is based on all production being exported as better prices are paid overseas.

Employment. K.A.L. will employ 20 staff upon receiving a licence and expansion would begin soon after. Another 20 people would be employed part-time during harvesting. Spin-off employment would also occur in service industries, e.g., transport, packaging, and research.

Diversification. K.A.L. see marron farming as a means of making existing agricultural and horticultural farms with financial problems profitable.

Maoridom. We currently have five Maori Trust boards interested in marron farming. Once we have received our fish farming licence they will become involved in the venture. Some areas have been allocated for them.

Economics. On a turnover per hectare per year basis, marron farming compares very favourably with established land uses: marron $72,000, kiwifruit $31,500, dairying $1,784, beef $1,590, sheep $357.

Marketing. We have business contacts here and in the U.S. and Japan who wish to handle our marketing arrangements. We have had many letters from overseas wholesalers because of the articles about our Warkworth site which have appeared in international aquaculture and seafood magazines.

With the declining consumption of red meat throughout the world, the increase in spending power per capita of the Asian people (who are large fish eaters), the abundance of good quality water, and the favourable climate here in New Zealand, we believe we have the right formula to make marron farming very lucrative, and at the same time relieve pressure on the native stocks of koura and saltwater rock lobster.

We at Koru Aquaculture Ltd. believe in the future of aquaculture and hope that marron be allowed to play its part.

Discussion

Q. How do you dispose of water from the quarantine farm?

A. There is a storage dam, also under quarantine, alongside the complex. Water passes through a seepage drain, where all the silt settles out, into the dam. The water is oxygenated during this process and eventually is returned to the farm.

Q. How do you derive your figure of $44 million for exports?

A. It is based on production estimates for the next 6 years, a price of NZ$30 per kilogram, and allows for expansion and the involvement of other people.

Culture of *Macrobrachium rosenbergii* (giant Malaysian freshwater prawn) at Wairakei, New Zealand

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Why grow prawns?

We have gone into prawn farming because there is keen demand for prawns in New Zealand. All New Zealand prawns are imported frozen, and last year this country imported 80 000 kg.

The demand for prawns is increasing worldwide and aquaculture is moving to meet that demand. We aim to supply chilled and live prawns to the top hotels and restaurants in New Zealand, and there may be potential for export.

Why *Macrobrachium*?

The sea around New Zealand is too cold for year round survival and growth of the commonly cultivated marine prawns, which have a complicated juvenile life history with a requirement for specialised live foods. *Macrobrachium* has a high market price, a simple life history, is tolerant of a wide range of environmental variables, grows rapidly (marketable prawns can be harvested within 6 months of hatching), and has no known disease problems.

Why grow prawns at Wairakei?

There is an abundance of waste heat from the geothermal field and a supply of very pure fresh water from Lake Taupo in the nearby Waikato River. Wairakei has a central location for markets, transport routes, and tourism. Eventually we hope to promote our prawn farm as a tourist destination (including a restaurant serving, as you can guess, prawns cooked in various ways).

Within a year we have built a 4000 ft^2 (370 m^2) hatchery with associated laboratory, administration, workshop, food storage, and preparation areas. We have a settling pond and five, 1 acre (0.4 ha) ponds ready to be stocked with prawns. All piping and plumbing works are completed and the system is fully operational. Brood stock have been imported from Malaysia and have been bred repeatedly. There is a crop in one pond ready for harvest and production of post larvae is now continuous.

A venture of this size inevitably means hassles. All things we have done ourselves have been under budget. The real headaches begin when we need performance from outside agencies and consultants. In future I would tie up any works to be done on a stringent contract basis. I have found consultants prepared to charge heavily for their services, although they have little experience in the problems of aquaculture. In addition, they are not prepared to take any responsibility for poor quality work. Engineers, in particular, seem never to have heard of the KISS rule.

Aquaculture also attracts a lot of self-styled "consultants". They value their services highly and would like to attach themselves to your project. The worst are those who say "I know exactly what you want". It has been my experience that specialists and highly qualified "scientific" types are not much use on the fish farm. Fish farmers have to be practical "hands on" people.

We are fooling ourselves if we think that New Zealand can develop a viable aquaculture industry with the present bureaucracy and red tape. We need a complete change in attitude from local and national Government. Let me tell you about some of the hassles I have had.

Take MAF, the Ministry promoting aquaculture. First, we had to have the regulations changed to allow fish farming in the Rotorua-Taupo wildlife conservancy. It took 6 months to get consent from the Wildlife Service, but then well over a year for MAF to change the regulations. When we finally appealed to the Minister's office it took less than 3 h to make the change.

MAF is also responsible for our quarantine status. Tropical fish come from exactly the same area as our prawns and are released to the public after 6 weeks quarantine. Our prawns were certified disease free by the exporter. Repeated tests by MAF showed no bacterial or virus infections, yet 10 months later they were still in quarantine. All this time we have had to pay for regular visits (including travel costs from Hamilton and Rotorua).

When we brought the prawns into the country, MAF quarantine officers and customs couldn't get their act together. Our prawns sat on the tarmac in the hot sun for over 2 h after unloading and we couldn't touch them. This contributed to the death of many valuable brood stock animals.

But MAF does not stand alone. The Waikato Valley Authority took over 6 months to grant a water right. Although our nutrient loading on the river is less than the average milking shed, in the end we had to pay for a tribunal hearing at a cost of thousands of dollars. Just recently we received a bill for over $7,000 as the first annual charge for our water right. This is despite the fact that we actually help the river ecology by taking heat loading off it.

The Tourist and Publicity Department administers the Wairakei Tourist Park, within which is our farm. Our site covers 30 acres (12 ha) and has always been just a wilderness of gorse and blackberry, yet Tourist and Publicity values it at a $10,000 per year rental. This corresponds to a take of $1.3 million off the other 400 acres (1618 ha) of the Wairakei Tourist Park, and I doubt if they make that. In contrast, Electricorp have seen the potential of our project and have been very helpful throughout.

Those are some examples of our hassles with red tape, but within the same organisations are people who have been very helpful. Identifying these people early on and working through them is the key to making progress within the bureaucratic system, so I would like to thank people like Mike Hine, Michelle de la Cour, Bob McDowall, and Len Tong and his enthusiastic staff from Mahanga Bay. Finally, without the support from our backers, Salmond Smith Biolab, we wouldn't have any prawns at all.

To conclude, when setting up an aquaculture venture in New Zealand the developer must consider the following.

The rules and regulations are vastly overcomplicated and will cost you dearly in cash and time.

Market research is essential.

Have a healthy contingency sum for start-up.

Realise that labour and seed are going to cost you plenty.

Recognise that a pilot study is very necessary, and allow a big learning curve.

Don't overestimate your first yields.

Allow for processing losses.

Don't let engineers overdesign for you.

Appendix: Are biologists of any use to aquaculturists?

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Jeff Knewstubb has said that fish farmers have to be practical, "hands on" people, so what use is an expensive boffin in a white coat?

First, the boffin has more resources than you. A workaday biologist (such as I) has not only a background of scientific problem solving and back-up laboratory facilities, but also access to the latest world literature on aquacultural developments, and access, often at a personal level, to various experts scattered around the country.

Second, employing me on a part time basis on his prawn farm may have cost Jeff a lot under user pays, but I think that it was worth it because I could accelerate his progress by identifying and overcoming key biological problems. He simply cannot afford trial and error learning at this stage.

Third, you may say that for an animal like *Macrobrachium* everything has already been done and published by other scientists around the world. This is true, but a biologist can read those impenetrable scientific reports and quickly translate things like micrometres, ppm, and numbers per millilitre into "mash it through this mesh, take *x* teaspoons, wheelbarrowloads, or the number in this cup", for the practical fish farmer. Mind you, to be of much use a biologist also has to be a hands on person (there have been times when Jeff wished I wasn't quite so much of a hands on person).

I became involved with Aquatech at the importation and quarantine phase, and later was asked to help with larval rearing. This was a challenge because the hatchery system uses closed cycle, brackish water recirculation, and relies on biological filtration to maintain water quality. Add to this high stocking density, high feeding rates, high water temperatures, and the fact that it is a long way to go from Taupo for any new sea water.

The larval phase lasts for a month before the larvae metamorphose into postlarvae and can be acclimatised to fresh water. For that month you walk a tightrope between maintaining high water quality while keeping feed and growth rates up.

There was also the task of developing an acceptable artificial food for these marine, pelagic larvae. Food had to be a complete diet of the correct size and readily prepared. This was done and, of course, remains something that Jeff has paid for and can sell in turn.

Cannibalism was a problem with such high density culture, particularly as the prawns underwent the major moult from larvae to postlarvae. At this stage the environment in the hatchery tanks had to be modified to allow for changed behaviour of the prawns. In between times I have been found work such as mass brine shrimp culture, pump maintenance, heat exchanger cleaning, and even washing the glassware.

Prawn farming must have a future in New Zealand with our abundant natural resources. Aquatech Developments now has the expertise, facilities, and brood stock to supply freshwater prawns not only to ourselves, but to others who may be interested in working in with us.

Discussion

Q. Did the geothermal water cause fouling problems in the heat exchangers?

A. Initially, yes, there were extensive build-ups of silica, but we've overcome the problem.

Comment. You were critical of quarantine certification procedures, but I believe the receiving country is obliged to make its own separate checks. Many years ago MAF imported grass carp and were assured by overseas government agencies that they were completely disease free. Yet we found at least six parasitic species on them when they arrived.

Rock lobster farming in New Zealand: problems and possibilities

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Introduction

The high demand for, and value of, New Zealand rock lobsters have created intense interest in the possibility of rock lobster farming. Because of biological stress in the commercial fishery, aquaculture is the only way to significantly increase the country's yield of rock lobsters. Cultured animals could fetch higher prices than those from the wild: there is the potential for better continuity of supply of particular sized, especially small, rock lobster, and greater uniformity of product (including fewer animals with damage such as missing limbs). The production of juveniles for restocking is also possible.

This paper addresses some of the biological issues concerning the farming of the red rock lobster, *Jasus edwardsii*, in New Zealand. Legal issues are only briefly touched on, as are technical, engineering, economic, and marketing matters.

Rock or spiny lobsters (Family Palinuridae) are generally tolerant, hardy, and gregarious animals, yet no species anywhere is commercially cultivated. They are characterised by a long, complex larval development. New Zealand has three species, the only important commercial one being the red rock lobster, *J. edwardsii*. This species has been studied for many years and there is a large biological literature (Breen and McKoy 1988, Booth in press a). Clawed or true lobsters (Family Homaridae) occur only in the Northern Hemisphere and differ most noticeably in having pincers and in having a much shorter and less complex larval development period. This simpler development has led to successful laboratory culture (Van Olst *et al.* 1980, D'Abramo and Conklin 1985), but not to commercial production.

There is high demand for live, wild-caught rock lobsters in Japan, other southeast Asian countries, and Europe. *J. edwardsii* is supplied to some of these markets at and above the minimum legal size, which is equivalent to about 400 g total weight. It is held in especially high regard on the Japanese live market (Hollings 1988); a cold water species with excellent flavour and texture, *J. edwardsii* resembles in shape and colour the Japanese lobster and has a good reputation for survival out of water. A large and valuable market also exists in Japan for live, undamaged animals of a smaller size (about 200 g), particularly for various ceremonies, such as weddings, and in the restaurant trade. This market is generally undersupplied because the minimum legal size in most wild fisheries means that animals are harvested at a much greater weight.

Farming of rock lobsters in New Zealand could be based on culture from eggs to a marketable size, or on on-growing recently settled, wild-caught animals. Both approaches will be considered in this paper. Legislative changes would be required to allow the holding of egg-bearing females as well as undersized animals. Production could be particularly aimed at times of peak demand (mid year and end of year festivals) and undersupply (March-May) in the Japanese live market.

Breeding and early life history

Depending on the part of the country, female *J. edwardsii* begin breeding at 3–8 years of age. They breed once a year, every year, during winter and spring, with fecundity up to 500 000 eggs depending on the size of lobster. The species appears to breed readily in captivity. After 3–5 months under the female's tail, the egg hatches into the short-lived naupliosoma larva, about 2 mm in length. This is followed by the phyllosoma larva, a flat, transparent, and leaf-like stage which lasts for several months (Lesser 1978). After about 15 moults and at about 50 mm in length, the phyllosoma metamorphoses into the puerulus stage and settles mainly in shallow areas. This stage is of much shorter duration (probably a few weeks) and resembles the juvenile in shape, but is almost transparent. Early-stage phyllosomas and pueruli occur inshore of the continental shelf edge; mid- and late-stage phyllosomas occur almost exclusively beyond the shelf edge and to distances several hundred kilometres offshore. The total length of the planktonic phase for *J. edwardsii* may be as short as 6 months or as long as 23 months (Booth 1979). It is the length and complexity of this larval development which has posed the greatest hurdle to rock lobster aquaculture.

Juvenile growth in the wild

Juveniles studied in warm (Gisborne) and cool (Stewart Island) waters reached 38 and 33 mm carapace length (CL) (about 25 g) respectively 1 year after settlement (McKoy and Esterman 1981, Annala and Bycroft 1985). At the end of the second year they were 58 and 50 mm CL (95 and 65 g), and 75 and 68 mm CL (200 and 160 g) at the end of the third year.

Phyllosoma culture

The most successful of the several attempts to cultivate phyllosomas in New Zealand was that of Lesser (1974), who cultured small numbers of *J. edwardsii* to the fourth stage. Until recently, attempts at rock lobster culture overseas have also generally had limited sucess (*see* Tamm 1980, Van Olst *et al.* 1980). The most notable recent achievements have been in Japan where several species, including *Jasus* spp., have now been cultured to the final phyllosoma stage or to settlement (Kittaka 1988, Kittaka *et al.* 1988). Healthy larvae resulted from interbreedings between *J. edwardsii* from New Zealand and *J. novaehollandiae* from southeastern Australia (which according to recent MAFFish work is the same species) with metamorphosis to the puerulus stage in 319 days. *J. edwardsii* was also grown to the final phyllosoma stage, and large numbers of late-stage larvae of this species are currently in culture. Larvae in all these experiments were grown in filtered water in a recirculated system to which cultured microalgae were added. The phyllosomas were fed *Artemia* nauplii and adults in the early stages, and then *Mytilus* gonad. Highest mortality occurred in the early phyllosoma stages.

Achieving routine phyllosoma culture with reasonable survival will require a lot more research. Little is known of specific food requirements. Although the recent Japanese work suggests that late-stage phyllosoma larvae are surprisingly hardy, disease diagnosis and control will be a continuous problem. Care is essential in the choice of containment and plumbing; certain metals, plastics, and chemicals are toxic to some rock lobster larvae and small juveniles (Serfling and Ford 1975). Little is known of the tolerance of phyllosomas to other factors such as poor water quality, or changes in salinity and temperature. Optimal stocking and feeding rates need to be determined; the shape and large size of late-stage phyllosomas will restrict culture densities if entanglement of appendages is to be avoided. Once these and similar problems have been addressed for *J. edwardsii*, it should be feasible to grow phyllosomas to the puerulus stage in 6–9 months, the minimum time taken in the wild.

Capture of puerulus stage

Pueruli and small juveniles are abundant along many New Zealand coastlines. Studies using specially designed collectors have shown that highest settlement occurs along the east coast of the North Island south of Matakaoa Point (Booth 1984a). Up to 100 pueruli settle in the crevices of each collector per month during the main settlement season. Larger collectors, including types similar to those used to catch pueruli of other palinurids, could be used to obtain animals for commercial on-growing. It may also be possible to attract pueruli using sound; there is evidence that vibrations from the New Plymouth power station attract pueruli (Booth in press b). Large scale collections of pueruli are therefore possible.

The greatest obstacle to these collections is the biological stress in the *J. edwardsii* fishery. It may be inadvisable to allow the large scale removal of pueruli unless it can be shown that their survival rates in nature are low, and therefore their removal would have little effect on the wild fishery. I know of no techniques to demonstrate this, but I am convinced that in places such as Gisborne Harbour, where high numbers of pueruli are caught on the collectors, only a small proportion of the pueruli survive and breed or contribute to the fishery. Their removal from such areas for on-growing in captivity should, therefore, result in increased survival. However, removal in big numbers of larger, older juveniles would adversely affect the fishery (Booth 1984b).

Return to the sea of some animals, particularly females, after culture to a larger size is often seen as a solution to this problem. However, it is our experience that animals in captivity quickly adapt to confinement to the point that they would not survive in the wild. For example, small juveniles readily leave shelter during daylight to feed; if returned to the sea, these animals would be at greatly increased risk of predation.

Ultimately it is likely that any large scale aquaculture of rock lobster will be dependent on a supply of cultured juveniles rather than wild-caught animals. This should guarantee a regular and predictable supply that will be politically and ecologically more acceptable.

Culture of juveniles

A major advantage of rock lobsters over clawed lobsters is that they are gregarious animals, and cannabalism is much less of a problem. Rock lobsters show little aggression, even under conditions of high density, so the on-growing of juveniles is relatively straightforward. Although little is yet known of the requirements for good growth and survival of juvenile *J. edwardsii*, growth to 200 g can probably be achieved within 2 years of settlement under appropriate culture conditions. Growth rates of rock lobsters in the laboratory have generally exceeded those in the wild when conditions have been as near as possible to optimal (e.g., Chittleborough 1974).

Kensler (1967) grew early juvenile *J. edwardsii* for up to 12 months and considered them to be particularly sensitive to water quality. More recently, MAFFish has co-ordinated a number of studies aimed at optimising growth and survival of early juvenile *J. edwardsii*. Tom Hollings (N.Z. Fishing Industry Board) found that growth at 18 °C was 25–100% greater than at ambient (10–18 °C) or 22 °C. However, survival at ambient was slightly better than at 18 °C and much better than at 22 °C (Hollings 1988). The growth result seems at odds with most other lobster species studied where, up to a threshhold, temperatures considerably higher than ambient resulted in fastest growth (e.g., *Panulirus cygnus* and *P. interruptus*; Chittleborough 1974, Serfling and Ford 1975, Phillips *et al.* 1977).

Bryan Quigley at Victoria University found that although *J. edwardsii* pueruli will feed, they can successfully moult to the juvenile without feeding (Quigley 1988). Those that did feed grew more at the moult. Nick Rayns found during studies still in progress at the University of Otago that the food which produced best growth in small juveniles was fresh meat from the cockle *Chione (Austrovenus) stutchburyi* and the mussel *Perna canaliculus*. Chicken, mutton, and frozen *Artemia* resulted in less growth. Hollings (1988) and Kensler (1967) also reported fresh mussels to be a suitable food. In nature, *J. edwardsii* eat a wide range of foods, but prefer other crustacea and molluscs (McKoy and Wilson 1980). Specific nutritional requirements and food conversion ratios need investigation, but high levels of generally more expensive, protein-based food will probably be necessary for cultivation of *J. edwardsii*. The general paling in colour (and reduced market acceptability) often seen in laboratory-held animals can be overcome with dietary additions. Ultimately an artificial diet will probably be necessary because of its dependability and convenience. This could be based on what appears to be the complete diet already developed for clawed lobsters (Provenzano 1985). Feeding of animals to excess, with removal of uneaten material, will be required at least once a day for best growth. Marketable detritivores, such as shrimps, might be used to remove uneaten material.

Rayns has not been able to detect any significant differences in growth and survival of early juvenile *J. edwardsii* with various culture density, but found density-dependent growth and survival in 3 year olds. All animals were provided with adequate food and cover. Tony Brett of Victoria University has begun a study on the effect of various light cycles on growth and survival of small juvenile *J. edwardsii*. He hopes to modify behaviour and promote feeding and growth by providing more than one day-night cycle every 24 hours.

Several other factors affecting growth and survival of juveniles in culture need investigation. The specific tolerance of *J. edwardsii* to reduced water quality (build-up of ammonia and other metabolites, and changes in pH), and reduced levels of oxygen and water flow is unknown. Quality and quantity of refuges are important; e.g., animals held in PVC tanks often have difficulty moulting because surfaces give no grip. Chittleborough (1975) found detectable differences in growth rates of animals with shelter compared with those deprived of it. The behaviour of juveniles, such as their level of gregariousness, may change during growth (Phillips *et al.* 1977) and necessitate changes in shelter design. Provision of vertical mesh surfaces, rather than just tank floors, may suit the animals and at the same time lead to better use of tank space. The tolerance of *J. edwardsii* juveniles to reduced salinity is unknown; the effects of elevated water temperature should be further investigated. Rayns's study of the downstream effects of one animal's moult on the moulting of others may lead to husbandry changes during culture. Growth and survival can be optimised by appropriately combining these and other factors.

Other means of promoting growth, including the use of moulting hormones, might be addressed. Eyestalk ablation increases moulting frequency in some decapods, although often with unwanted side effects such as poor survival. Nick Rayns observed increased growth in ablated *J. edwardsii*, but surprisingly this has mainly been the result of a larger moult increment. How acceptable an animal without eyes will be to consumers is unknown. The long generation time in rock lobsters means slow genetic selection for desirable characteristics such as fast growth and disease resistance.

Reduction of stress throughout culture is important. For example, bright lights, unnecessary movement and handling (particularly during moulting), and contaminants such as detergents in sublethal concentrations should be avoided. Once stressed, animals are more susceptible to disease which can spread rapidly in dense cultures.

Disease

Although rock lobsters are generally hardy and robust, and the impression is that at least the juveniles and adults of *J. edwardsii* in the wild are relatively free from disease, infection at all stages of culture will need to be addressed (*see* Stewart 1980, Provenzano 1985). For clawed lobsters, the larval stage appears to be the most critical period in terms of microbiological diseases (D'Abramo and Conklin 1985). Disease may explain the particularly high mortality seen amongst early-stage *J. edwardsii* phyllosomas. Nematode infestation and associated water quality problems recently caused high mortality of pueruli and early juveniles at Victoria University (T. Brett, pers. comm.). Shell disease, the result of chitin-reducing bacteria or fungi, has been observed in a few of Rayns's animals. It has been predicted that outbreaks of *Gaffkemia* could occur in New Zealand animals held in conditions of stress. This bacterial infection of the haemolymph has been responsible for mass mortalities of clawed lobsters in the Northern Hemisphere, can exist in a free-living stage, and appears to be widespread (Stewart 1980). Correct diagnosis and appropriate treatment need to be applied to any disease outbreak in New Zealand, and then preventative measures taken. The impact of abiotic disease factors such as chemical pollutants needs to be recognised.

Commercial production of *Jasus edwardsii*

Farming of rock lobster in New Zealand might consist of three elements. The first is controlled breeding and egg production by control of light and temperature. The reproductive cycle of female *J. edwardsii* transported to the Northern Hemisphere soon became 6 months out of phase with that in New Zealand. The second element would be larval production and rearing to the puerulus or early juvenile stage. I envisage the need for only one or two such "hatcheries" for the whole country. The third element would be the on-growing of juveniles to a marketable size.

New Zealand is well placed for juvenile on-growing in that it has an abundant supply of good quality, sheltered water. Various scales of operation can be envisaged. At one extreme are the large scale, highly automated on-growing facilities of the sort proposed for lobsters (Van Olst *et al.* 1980); at the other extreme, small scale production in shore enclosures with natural tidal flooding or in floating cages. Polyculture might be considered; e.g., rock lobsters grown in conjunction with *Gracilaria* and other seaweed farming, or mussel, oyster, and salmon farming. If elevated temperatures are required for best growth, thermal effluent or solar heat could be used. Thermal effluent could come from power stations, or from geothermal areas with the heat harnessed through heat exchangers.

Transport of live rock lobsters

Rock lobsters can be transported at any stage of development, giving flexibility to farming ventures. Fertilised eggs attached to the female survive for many hours in damp conditions out of water; transport of eggs in sea water in oxygen filled bags is probably also possible. Mid- and late-stage phyllosoma larvae of *J. edwardsii* in water have been airfreighted internationally, although with high mortality; this mortality can probably be reduced with practice. Pueruli and early juveniles survive at least 24 h in oxygenated sea water, or if transit times are less than 2 h, they can be transported out of water providing temperatures are kept low and the animals kept damp. Techniques for live transport out of water for larger animals are well developed, with several hundred tonnes of *J. edwardsii* exported annually to Japan.

Future of rock lobster farming in New Zealand

What then is the future for rock lobster farming in New Zealand? There is still no commercial production of clawed lobsters in the Northern Hemisphere, despite their much shorter and simpler larval development. In the most studied rock lobster species, *Panulirus cygnus*, the economics look marginal at best (Phillips 1985); this must temper our optimism for the success of *J. edwardsii* culture in the immediate future. However, factors in favour of profitable farming of rock lobsters are their gregariousness at most stages of development, and their higher value per unit weight live on the Japanese market. The highly significant breakthrough with the culture of *Jasus* larvae in Japan makes rock lobster culture that much closer. If large-scale production of *J. edwardsii* pueruli in 6–9 months can be achieved, and if these animals can be grown to 200 g in 2 years, I think we may then have the basis for an economically viable industry. The next steps will to be to evaluate fully the economics of large scale production and to develop the necessary production technology. I believe that it is now no longer a matter of "if" rock lobsters can be cultured commercially, but of "when".

Acknowledgments

My thanks to Paul Breen (MAFFish) and Tom Hollings (N.Z. Fishing Industry Board) for their helpful reviews of the manuscript, and to Nick Rayns (University of Otago) for use of his unpublished results.

References

Annala, J.H. and Bycroft, B.L. 1985: Growth rate of juvenile rock lobsters (*Jasus edwardsii*) at Stewart Island, New Zealand. *N.Z. Journal of Marine and Freshwater Research 19*: 445–455.

Booth, J.D. 1979: Settlement of the rock lobster, *Jasus edwardsii* (Decapoda: Palinuridae), at Castlepoint, New Zealand. *N.Z. Journal of Marine and Freshwater Research 13*: 395–406.

Booth, J. 1984a: Rock lobster fishery causes concern. *Catch 11(2)*: 12, 21–23.

Booth, J. 1984b: Interest in ongrowing rock lobsters. *Catch 11(9)*: 9–10.

Booth, J.D. (in press a): History of biological research into the rock lobsters of New Zealand. *CSIRO Circular.*

Booth, J.D. (in press b): Occurrence of the puerulus stage of the rock lobster *Jasus edwardsii* at the New Plymouth Power Station, New Zealand. *N.Z. Journal of Marine and Freshwater Research.*

Breen, P.A. and McKoy, J.L. 1988: An annotated bibliography of the red rock lobster, *Jasus edwardsii* (Hutton) in New Zealand. *N.Z. Fisheries Occasional Publication No. 3.* 43 p.

Chittleborough, R.G. 1974: Review of prospects for rearing rock lobsters. *Australian Fisheries 33 (4)*: 4–8.

Chittleborough, R.G. 1975: Environmental factors affecting growth and survival of juvenile western rock lobsters *Panulirus longipes* (Milne-Edwards). *Australian Journal of Marine and Freshwater Research 26*: 177–196.

D'Abramo, L.R. and Conklin, D.E. 1985: Lobster aquaculture. *In* Huner, J.V. and Brown, E.E. (Eds.), "Crustacean and Mollusk Aquaculture in the United States", pp. 159–201. AVI Publishing Company Inc., Westport, Connecticut.

Hollings, T. 1988: Aquaculture of the NZ rock lobster. Unpublished report to the N.Z. Fishing Industry Board, Wellington, New Zealand.

Kensler, C.B. 1967: Notes on laboratory rearing of juvenile spiny lobsters, *Jasus edwardsii* (Hutton) (Crustacea: Decapoda: Palinuridae). *N.Z. Journal of Marine and Freshwater Research 1*: 71–75.

Kittaka, J. 1988: Culture of the palinurid *Jasus lalandii* from egg stage to puerulus. *Nippon Suisan Gakkaishi 54*: 87–93.
Kittaka, J., Iwai, M., and Yoshimura, M. 1988: Culture of a hybrid of spiny lobster genus *Jasus* from egg stage to puerulus. *Nippon Suisan Gakkaishi 54*: 413–417.
Lesser, J.H.R. 1974: Identification of early larvae of New Zealand spiny and shovel-nosed lobsters (Decapoda, Palinuridae and Scyllaridae). *Crustaceana 27*: 259–277.
Lesser, J.H.R. 1978: Phyllosoma larvae of *Jasus edwardsii* (Hutton) (Crustacea: Decapoda: Palinuridae) and their distribution off the east coast of the North Island, New Zealand. *N.Z. Journal of Marine and Freshwater Research 12*: 357–370.
McKoy, J.L. and Esterman, D.B. 1981: Growth of rock lobsters (*Jasus edwardsii*) in the Gisborne region, New Zealand. *N.Z. Journal of Marine and Freshwater Research 15*: 121–136.
McKoy, J. and Wilson, C. 1980: Rock lobster feeding behaviour studied. *Catch 7(7)*: 23–24.
Phillips, B.F. 1985: Aquaculture potential for rock lobsters in Australia. *Australian Fisheries 44(6)*: 2–7.
Phillips, B.F., Campbell, N.A., and Rea, W.A. 1977: Laboratory growth of early juveniles of the western rock lobster *Panulirus longipes cygnus*. *Marine Biology 39*: 31–39.
Provenzano, A.J. 1985: Commercial culture of decapod crustaceans. *In* Provenzano, A.J. (Ed.), "The Biology of Crustacea, Vol. 10, Economic Aspects: Fisheries and Culture", pp. 269–314. Academic Press, New York.
Quigley, B. 1988: Behavioural and morphological aspects of feeding in the puerulus stage of the red rock lobster *Jasus edwardsii*. Unpublished BSc (Hons) project, Victoria University of Wellington, Wellington.
Serfling, S.A. and Ford, R.F. 1975: Laboratory culture of juvenile stages of the California spiny lobster *Panulirus interruptus* (Randall) at elevated temperatures. *Aquaculture 6*: 377–387.
Stewart, J.E. 1980: Diseases. *In* Cobb, J.S. and Phillips B.F. (Eds.), "The Biology and Management of Lobsters, Vol. 1, Physiology and Behaviour", pp. 301–342. Academic Press, New York.
Tamm, G.R. 1980: Spiny lobster culture: an alternative to natural stock assessment. *Fisheries 5(4)*: 59–62.
Van Olst, J.C., Carlberg, J.M., and Hughes, J.T. 1980: Aquaculture. *In* Cobb, J.S. and Phillips B.F. (Eds.), "The Biology and Management of Lobsters, Vol. 2, Ecology and Management", pp. 333–384. Academic Press, New York.

Discussion

Q. What funding do you need for R & D, and where will it come from?

A. We have $20,000 to undertake phyllosoma culture trials to complement current Japanese work. A Japanese team is coming early next year to do combined research with us and we need $20,000 to have animals in culture for when they arrive. If the initial work shows promise, I think we need about $1 million to set up a pilot culture trial. We have no Government funding for it.

Comment. In Perth, similar trials with the western rock lobster look very promising.

A. CSIRO sought $10 million in joint-venture capital. They expected 25% from the Federal Government and the rest from industry and proposed a 5 year pilot trial. I'm not envisaging anything on quite that scale, but I think we should be proceeding on similar lines.

Q. Could you expand on the use of artificial feeds?

A. Bivalves are the best feed. An artificial diet might have green-lipped mussels as a major component, pelletised with an appropriate binder. We could learn a lot from Californian work on feed for the North American lobster.

Q. You said that salable animals would be about 200 g. That's below the legal limit. Will sale of undersized animals be allowed? It's a question that applies to other species, too.

A. I believe that this is not an insurmountable problem, but I can't comment further than that.

Comment. The minimum legal size issue held up the Western Australian marron farming industry. Now the government has dropped the limits on farmed animals and there is a new interest in the industry. Something similar is happening in Queensland with barramundi.

A. I think if we can show that the industry is worth millions of dollars a year there will be little trouble changing the regulations.

Comment. We already have an example in salmon. The minimum size limits don't apply to farmed fish, so there should be no problem with lobsters.

Current and future trends in crustacean aquaculture

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We have heard some exciting things at this conference concerning the potential in New Zealand for several kinds of crustacean aquaculture, including projects already underway. I would like to present a more general review and then offer some thoughts on options for New Zealand, which I hope will provoke some discussion or even controversy.

When we mention "crustacean aquaculture", most of us assume immediately that we mean decapod aquaculture or perhaps even more specifically, shrimp (or prawn) aquaculture. There are very good reasons for these assumptions, and most of my remarks today will be aimed at this major part of crustacean aquaculture.

A few years ago I attempted a general review of the status of commercial crustacean culture (Provenzano 1985), and while much of the biological information summarised remains valid, the rapid pace of economic and technological development in this field now requires almost continuous re-evaluation. For New Zealand, there are special considerations.

For all intents and purposes, crustacean aquaculture began centuries ago in Southeast Asia and in western South America as a by-product of fish culture efforts. The technology consisted of stocking tidal ponds or lagoons with wild plankton and fish fry at empirically determined seasons and lunar phases, then waiting for the young to grow without further attention. The harvested crop consisted of a mix of species, including predator fishes and a few shrimp.

This general approach has been used right up to modern times and continues in some areas today. It survives because the cost of such extensive culture is modest and, despite low yields, it is economically feasible. More intensive monoculture of prawns had to await the advent of new technologies which include hatchery production of seed, improved methods of water quality management, and other scientific advances. However, technology alone does not make success. Enormous growth in demand for the product during the last few decades, coupled with the problems of intensively pursued fisheries, has given economic impetus to shrimp farming development and is largely responsible for its success.

World shrimp fishery landings have been fairly stable at about 1 600 000 t since 1977. Farmed production on the other hand has been rising, and now approximates more than 300 000 t. In 1980 farmed shrimp constituted only 1.2% of the world supply, but by 1987 it had risen to 20%. There is nothing on the horizon to suggest a change in this trend during the next decade. Major producers of farmed shrimp in 1987 include: China, which doubled its production from 43 000 t in 1986 to 85 000 t in 1987 and by 1990 is expected to produce more than 100 000 t (Hjul 1988); Taiwan, 70 000 t, up from 60 000 t the previous year (Chauvin 1988); Indonesia, 50 000 t; and Ecuador, which raised 41 000 t (Leslie 1988, Rosenberry 1988).

Shrimp or prawn farming, for all its current dominance on the world aquaculture scene, is not the only commercial crustacean culture. Lobsters have been the target of much aquaculture research, and enough has been learned to give some basis for optimism that commercial culture may be feasible in the very near future. There are several dominant problems in lobster culture, and these vary somewhat according to the type of lobster. For example, the northern clawed lobsters, which have a relatively short larval life, can be easily reared to metamorphosis in hatcheries, and enough is known of their reproductive biology to permit scheduled maturation and hatching and at least a theoretical production plan. However, the relatively slow growth (2 years even at optimum temperatures) coupled with the cannibalism problem and relatively modest market price for this item in many markets suggests to many investors that shrimp will give a faster, safer, and better return. Indeed, in the time it takes to grow a 500 g lobster, four to six crops of shrimp can be produced, and at lower cost. Of course the geographical location of would-be investors is important in such considerations. If one lives in a cold climate where prawns will not grow, but lobsters are found in nearby waters, one will naturally tend to lean towards the local species.

The tropical lobsters present a different problem. Here the hatchery technology on which self-contained business wants to rely appears not to exist. The larvae generally are long lived and have resisted large scale rearing attempts. As we have heard from Dr Booth [previous paper], the Japanese have recently had success in rearing *Jasus edwardsii*, the New Zealand species, from egg to metamorphosis. This is most exciting news and gives renewed hope for commercial lobster culture. The growout phase for some species appears to be very promising, with growth to market size being reached in significantly less time than that required for field populations. Opportunity exists, therefore, for growout efforts based on wild-caught seed. It is known that for some species, including the Caribbean *Panulirus argus* and a Western Australian rock lobster, certain recruitment areas collect more seed than the available habitat can support. The major problem here is likely to be political rather than biological. How does one convince the fishing community or government that removal of seed from the wild, even in the form of highly vulnerable postlarvae, will not reduce future harvests for the fishermen? Perhaps the answer lies in a collaborative arrangement in which a percentage of juveniles would be released into the sea in exchange for the right to keep some to market size. This principle has been applied elsewhere, such as in marine turtle culture. Whether it makes ecological and economic sense to release partially grown juveniles to the predators and other hazards of the natural environment is another question.

Freshwater crayfish, cousins to the lobsters, have perhaps the best short term potential for commercial success in the group. These animals present all the advantages of lobsters, including good prices, without the major disadvantages. There is no sea water to worry about, no hatchery difficulty, detrital based natural food chains allow many options for cost effective feeding, and generation time is relatively short. In the U.S., crayfish culture has reached a very large scale (tens of millions of pounds weight per annum). In Europe, the extraordinary value of crayfish has driven the production of hatchery seed to levels beyond the imagination of most American "crawfish" farmers.

We are familiar with the boom in crayfish farming in Australia, and we have heard about the efforts to introduce marron farming to New Zealand. The local koura, or freshwater crayfish, has been examined as a possible aquaculture candidate. Previous reports have not been overwhelmingly optimistic, but there may be factors not yet examined. We know that the performance of a species in the wild is nearly always vastly improved under optimum culture conditions. The time required for growth of wild stocks to commercial size can often be reduced by half, given adequate temperature and feed. Moreover, it may not be necessary to rear such species to maximum size for commercial success. Even the koura might be marketable at small sizes as a very valuable softshelled product: more about that later.

Crabs are seldom given serious consideration as aquaculture candidates in most western countries, primarily because of historically low prices, abundant supplies, and the predatory and cannibalistic habits of most commercial crabs which make them expensive to feed and rear. Nevertheless, in some parts of Asia, where crabs are highly valued, culture has been practised and hatcheries have been developed to support such culture, both for seeding the environment and for growout to harvest size. China, Japan, and Australia have all developed large scale crab hatcheries. Wear (1980) pointed out the possibility of culture of the New Zealand swimming crab, *Ovalipes catharus*. In the intervening years, sufficient progress has been made in hatchery technology and other aspects of crustacean culture to warrant growout trials, based initially on captured juveniles as Wear suggested.

In North Carolina, on the east coast of the U.S., consideration is being given to a similar approach to aquaculture of the American swimming crab, *Callinectes sapidus*. On the Atlantic and Gulf coasts of the U.S. (and in some other countries) a form of short term culture for production of softshelled crabs converts a low value product (small, hardshelled crabs) into one worth 5–10 times as much. The process is a simple one, consisting of holding pre-moult crabs in shallow trays with flowing water, careful sorting to keep crabs of similar moult phase together, and then the removal within hours of the soft, recently moulted individuals for freezing or shipment live. Since the shell is softer than tissue paper, the whole animal is eaten — there is no waste. This production of softshelled crabs is worth millions of dollars annually. Historically, the supply of crabs for moulting has come from harvest of wild crabs near market size which are then held through a single moult. Because of high demand and the seasonally inadequate supply of peeler crabs, the rearing of small juveniles to peeler size using aquaculture methods is now being considered. Because the technology for softshell production is quite simple, it can be applied to other crustaceans. During the last 3 or 4 years, annual production of softshelled crayfish in the U.S. has developed from almost zero to more than 100 000 pounds (over 45 t) and is expected to reach at least a million pounds (453 t) very quickly.

Johnson (1980) discussed the possibilities of commercial culture of the native New Zealand crayfish (koura) and pointed out some concerns. At that time it was considered that growout might require a rather long time, perhaps 2 to 4 years. With today's knowledge of culture methods for crayfish generally, it may be possible to shorten that time significantly. Moreover, softshelled crayfish do not have to grow as large as hardshells to be acceptable in the market place since almost 100% of the softshelled animal is consumable. An export market for this product may also develop. The Japanese have recently bought the largest American softshelled crab and softshelled crayfish companies. Their demand for these products has driven up prices and, for softshelled crayfish at least, their demand alone currently exceeds the supply.

There are other possibilities. We have a tendency to be blinded by the perception that only commercial production on a scale of millions of pounds or dollars is worth talking about. There are always opportunities available for small scale culture activities, even with crustaceans. Perhaps some of these potentials are insufficient to excite government agencies, and perhaps some of them are inappropriate for New Zealand, but I would like to mention a couple of examples to illustrate the point because even small enterprises help to diversify the economy and strengthen the aquaculture industry.

Our discussions during this conference have been restricted largely to consideration of food species. After all, we all know the incredible growth in demand for seafood and the inability of the natural environment to yield ever-increasing quantities of aquatic protein, but let us not forget that it is economics which drive all enterprise. Put another way, we are growing not fish, but dollars, and if the dollars aren't there, neither will be the production. In general, any organism grown for food will bring a lower price in the marketplace than the same or related organism grown for any other use. How much do we pay for an edible bird such as a chicken and how much for an ornamental bird such as a canary? Similarly, for fish or crustaceans, the most expensive lobster or shrimp does not begin to compare in price with the least expensive of ornamental species. We are talking here about the spread from perhaps $5 per pound (2.2 kg) to hundreds of dollars per pound. Of course, the markets are different, and most ornamental species are not sold by the pound, but do not underestimate the potential. The world market for marine and freshwater ornamentals is of the order of hundreds of millions of dollars annually. Of the crustaceans, most are marine species and all are currently collected from the natural environment, as are nearly 100% of all marine ornamental fish. Although it is possible to harvest safely on a sustained basis from natural habitats, a number of countries have already banned or restricted the collection of ornamental species from their waters. In future, we should expect many marine ornamental species to be farmed just as freshwater ornamental fish, birds, and even reptiles are now being farmed. Does New Zealand have appropriate native species with ornamental potential? You don't know and neither do I. It should be looked at.

Here is one more example of an unconventional market for unconventional crustaceans. In the U.S., industrial and other dischargers of effluent are required to demonstrate the safety of the effluent through prescribed bioassay tests with approved species. One such species is a tiny mysid crustacean weighing perhaps as much as a milligram. For testing, such organisms must be cultured and a number of small companies have entered this market in which they can demand US$0.35–0.50 each for these and similar bioassay organisms. You figure out the value by weight. Can you think of any other legal product which comes within two orders of magnitude of this? Perhaps, because of your relatively small population and generally unspoiled environment, such problems and the corresponding opportunities will not exist in New Zealand for some time. My point is, opportunity lies all around us if we but look for the demand or have the imagination to create it.

The title of this paper concerns trends in crustacean culture, and I have diverged somewhat from that topic. What can we expect in the near future? There are at least three major trends which are evident today in crustacean culture. These are technological, geographical, and biological. They are tied to each other and to economic changes in markets and production procedures.

The geographical distribution of crustacean culture is a function of the nature of the dominant species of choice. Today that is the shrimps and prawns, of which almost all the economically important ones are tropical or subtropical. Probably there will always be some culture of prawns in temperate zones, if only seasonally, or in closed systems close to markets. For the foreseeable future, however, major production will remain dependent on those features of tropical latitudes which permit year-round production with subsidy from nature in the form of sunlight and warmth. The Taiwanese and others have shown the extremely high production levels which are possible under intensive culture conditions; annual average yields are 11 $t.ha^{-1}$ (Fast *et al.* 1988). Although hundreds of new prawn farms are being constructed annually, a large part of the increase in world production in the near future will come from the application of more intensive methods and better pond management on existing farms. Still, some exciting new developments point the way to even more promising potentials. Tank culture is now feasible on a commercial scale and can yield extremely large crops. Visitors to Hawaii during the World Aquaculture Society meeting last January might have seen the round ponds which have produced prawn harvests equal to, or higher than, the best Taiwanese operations. A completely artificial tank farm for prawns, consisting of covered raceways and occupying several hectares, has been built and operated in Hawaii. A major crop loss occurred and has been attributed to a virus which attacks the particular prawn species originally stocked in the facility, but after decontamination, a resistant species will be used to resume the extraordinary production already achieved.

Nutritional research for crustacean species has lagged somewhat behind that for fishes, perhaps because so many of the dominant species in culture today are able to use detritus-based food webs. As culture becomes more intensive, complete feeds are required, and with them come production levels up to 10 times higher than can be supported by natural ecological food webs.

Looking further ahead, there are several biological advances which may contribute to substantially higher yields once management and systems have approached their maximum effectiveness. We can expect to see trials of hybridisation. (Artificial fertilisation and interspecific hybridisation have already been achieved for lobsters, freshwater prawns, and penaeid shrimp.) As many crustaceans demonstrate sexual dimorphism and differential growth of the sexes, it may be possible to select the sex of choice for growout, as is already done for some fish species. Polyploidy and hormone transfers by genetic engineering are potential tools for the improvement of growth. These have not yet been tried with crustaceans, to the best of my knowledge. None of these tools will make up for bad management.

What crustacean cultures are most promising for New Zealand? We should consider first the country's location and resources. The temperate climate means large scale productions are going to be for temperate tolerant species. This does not mean that the extensive geothermal resources cannot be used for tropical species, or that covered tank farms are not feasible here, only that large scale pond type culture operations will require temperate species. Second, we should consider the internal versus external market potentials. Past experience and limited population suggest that there will not be vast local markets, but surely there is room for the development of some domestic consumption, even if it is aimed largely at the tourist trade. We will have to think in terms of the export potential for large scale operations: what advantages will New Zealand have in world markets? Can the exports carry the symbolic flag of New Zealand identity, or will they be lost among many competing items? Barbara Hayden (1988) reviewed potential aquaculture species for New Zealand. The number of native crustacean species listed was small indeed; surely these ought to receive first consideration. Can the koura and the paddle crab be developed into softshelled products? The unique nature of these species and product forms may give them market advantage.

The rock lobster can be looked at in a different light these days. If foreign markets are willing to pay as much as $2.00 per postlarva, and something like $36/kg for full sized animals, perhaps culture of wild-caught or hatchery-reared juveniles to subadult size for that market will be more cost effective than the more conventional approach of rearing to sizes required for legal regulation of the fishery.

We have heard of the efforts to bring some exotic species of crustaceans to New Zealand, notably the freshwater prawn and the marron. Both would seem to have great potential for commercial development. It should be possible to consider exotic species which have the potential of great contribution and limited liability in terms of native fauna.

Another possibility is offshore or foreign joint ventures. This could allow aquaculture of species not suited for the homeland, and would constitute a valuable market for intellectual property, offshore use, not necessarily the permanent export of high level technical expertise. Joint ownership would assure the return of economic benefits to the country.

Most trends in crustacean culture are going to be market driven. New Zealand must be able to recognise opportunity as it presents itself, and must create opportunity where it doesn't exist.

References

Chauvin, W. 1988: Aquaculture News. *Shrimp Notes (New Orleans, Louisiana) 12(2)*: 3.

Fast, A.W., Shang, Y.C., Liao, I.C., and Rogers, G. 1988: Description and economic analysis of intensive marine shrimp culture in Taiwan and simulated technology transfer to Hawaii. *Aquaculture Digest 13(5)*: 9.

Hayden, B.J. 1988: Evaluation of species with potential for aquaculture in New Zealand. 48 p. (Draft report held in Fisheries Research Centre library, Wellington.)

Hjul, P. (Ed.) 1988: Shrimp farm boom: harvest could top one million tons. *Fish Farming International 15(3)*: 1.

Johnson, W.S. 1980: Eel and koura farming. *In* Dinamani, P. and Hickman, R.W. (Comps.), Proceedings of the Aquaculture Conference, pp. 65–72. *Fisheries Research Division Occasional Publication No. 27.*

Leslie, M. 1988: Back to Ecuador. *Aquaculture Digest 13(3)*: 6.

Provenzano, A.J. 1985: Commercial culture of decapod crustaceans. *In* Provenzano, A.J. (Ed.), "The Biology of Crustacea, Vol. 10. Economic Aspects: Fisheries and Culture", pp. 269–314. Academic Press, New York.

Rosenberry, R. 1988: Ecuador: the year of the hatchery. *Aquaculture Digest 13(7)*: 1–3.

Wear, R.G. 1980: Crustacean culture — its prospects in New Zealand. *In* Dinamani, P. and Hickman, R.W. (Comps.), Proceedings of the Aquaculture Conference, pp. 23–27. *Fisheries Research Division Occasional Publication No. 27.*

Discussion

Comment. You mentioned the possibility of taking puerulus or early juveniles of *Panulirus argus* from the sea, on-growing them, and then returning a proportion of them to the wild to ensure the continuation of the commercial fishery. We have thought of this, too, although we find the animals quickly adapt to culture conditions and will come out into the open to feed during the day. If returned to the wild, their chances of survival would be minimal.

A. I agree; there is little sense in returning such animals to the wild, but if it is politically necessary to do this to establish farming, then I can see the rationale.

Q. Some Southeast Asian countries are producing very high yields of tropical prawns from small but intensive operations. Do you have any comments on the relative merits of the various hatchery systems?

A. The most reliable hatchery system is the one that gives you the most control. In New Zealand you have unpredictable weather, phytoplankton blooms, and so on, and you have to develop a reliable system that will deliver the product you want when you want it.

Q. Are there any markets for softshell, freshwater crayfish?

A. When I talk of crayfish, I mean the freshwater varieties, not the marine animal. In the U.S. softshell crayfish have been available only for the last 3 years. Most people have never heard of them, the market is unexplored, and we can sell every one produced at about US$40/kg to the restaurant trade. They are going to be a very valuable product. Your koura is well suited.

Q. Are there opportunities for a softshell prawn?

A. Yes. Apart from the Asians and the French, most people eat only the tails. The flavour of softshell prawn head is superb and you get 40% more per animal. The idea has enormous potential.

Q. Can a western country with high labour costs, such as New Zealand, compete in prawn production and marketing with tropical Third World countries which have cheap labour and more suitable environmental conditions?

A. The tropical countries have a greater potential and your profit margins may not be as high as theirs, but if you can achieve an adequate return on your investment, why not do it.

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It is my privilege to close this national aquaculture conference, although as the person who started all this perhaps I should be the one to finish.

First and foremost I want to say "thank you" to a few people. Two years ago I thought it was time we had a second aquaculture conference. I called Peter Redfearn in and asked him if he would act as the main organiser. As amiable as always, Peter said "Yes", not realising, I think, the magnitude of the task. He soon had the ball rolling, but quickly had to deal with the hassles of postponing the conference until this year, but he took that in his stride.

This year the real work began. Peter has done a marvellous job and I want to thank him sincerely for his contribution to the success of the past 3 days. But he was not alone, and my thanks also go to Mike Beardsell and John Schellevis for their part and I would like you all to show your appreciation of their efforts.

My thanks also go to John McKoy and senior staff in MAFFish for their support, and especially to my staff in the Aquaculture Section; they have had to do a lot of running around preparing posters and acting as scribes and general dogsbodies. Also to Alan Blacklock who has seen that your slides are presented without mishap.

I wish to thank our overseas speakers, David O'Sullivan, Eric Edwards, and Anthony Provenzano, for their contributions and for making themselves readily available to you at all times, and also all the speakers who have presented papers and posters. Also to the CCM staff, our organisers, whose unobtrusive presence has helped to make the conference run so smoothly.

Finally, I want to thank you for coming, for participating and contributing and sharing with us your thoughts and ideas. In his welcome and opening address John McKoy said that his goal for the conference was to see us all working together positively. I believe that has been achieved; we have been talking to each other, made contacts, and I am sure many will follow these up to further the development of their own particular interest or venture. It is certainly our aim in MAFFish to continue to work with all aspects of the industry to further the development of aquaculture.

John had three objectives for us: to break down the barriers that may exist, to discuss the issues, and to look at prospects for the future. We have gone a long way to breaking down any barriers by just being here and communicating. My role now is to highlight the issues.

The image

Let us start with the clean image we were given by Barbara Hayden. Are our waters that clean and are they clean because of good luck or good management?

We should not be complacent. We do have raw sewage discharges into our waters, and there have been suggestions here of ways of speeding up the solving of this problem. We have TBT problems and they must be addressed rapidly. As Eric Edwards said, we must not make the same mistakes as they did in the U.K. We must watch out for some of the nasties such as dinoflagellates and MAFFish is setting up legislation for the control of disease which will enable us to act quickly if something happens. We must be vigilant, and everyone has to do their bit.

Conservation

Conservation has been one of the big issues of this conference. As an industry you certainly are doing your bit as far as conservation is concerned. I do not think I have met anyone connected with this industry, farmer, scientist, or technical expert who is not concerned about the value of his environment. No farmer wants to pollute his own waters, and there was a plea for more realism from the Department of Conservation and the Ministry for the Environment. But the evidence from DOC on licensing showed that they were approving marine farming ventures, and I believe that you all have to keep communicating and work together to see that aquaculture keeps up its image and is able to expand. In this respect MAFFish will be taking the lead role, and your support for this will have to be made very visible.

Industry voice

Talking to individuals and feeling the pulse of the conference, it seems to me that the time has come for the formation of an aquaculture association. Your separate associations have done well so far, but there are now issues on which, collectively, you would have a much greater impact.

I was asked if I could think of anyone suitable to pull you together to get an association up and running on the same lines as the Shellfish Association that Eric Edwards directs in the U.K. I couldn't, but you should start thinking along those lines yourselves, and perhaps discuss the idea at your next in-house meetings.

The time has come for a united voice, to sell yourselves to the public and the politicians as Barb Hayden said. You must fight to maintain what you have achieved, put forward your case so that you can exist alongside all the other users of our waters. The words integrity, respect, high profile, public relations, quality, and professionalism were all mentioned here and as one association you will be able to put forward that sort of image. The potential for marketing your products has been highlighted and Eric Edwards illustrated the promotional side of his industry. Added value applies as much to the products of aquaculture as it does to the meat industry.

MAFFish

I hope too that we in MAFFish have put forward a similar image. I hope we have been able to show you that we are not just a bunch of scientists indulging in research, but a group of people who have aquaculture development as a priority and endeavour to make our work apply to your situations. I gave examples in my introductory talk and more came up at the conference, such as the excellent work done on the effects of salmon farms on the environment. We do communicate, but no system is infallible and if you have been missed out, then I apologise.

We are here to help you and I think you all much appreciated the talks yesterday by Neil Martin and his staff which showed the very positive attitudes being displayed by Ministry staff. The "one-stop shop" concept will play a vital role in fostering the development of aquaculture. We hope that we can establish an aquaculture magazine through which we can all communicate and convey information and ideas.

The Maori issue

I believe we can all work together, no matter how long we have been here. However, I am pleased we made time available to air this issue and hear Matiu Rata and George Habib put their case. Two major points were made. The Maori want to be involved in, and wish to promote, aquaculture and they will not interfere with anyone's rights.

Resources

We certainly have the people and the expertise in New Zealand — that is obvious from the past few days. We have very suitable species and we are in a position to explore new ones. For example, there was debate on the red seaweed *Gracilaria* and its suitability, and research has shown that perhaps we do, or can, match overseas quality. We have raw materials, and many waste materials waiting to be used, but there was a plea to source new materials for fish feed. The industry needs your support as dependence on overseas supply may be costly in the long run.

Exotic imports

There have been problems in the past and I am sure there will be more in the future, but we have a wealth of experience which can be tapped to make full and thorough investigation of any proposal. As a scientist I have integrity and concern, and I will make sure that any proposal with which I am involved will proceed with due care and consideration and it will be based on facts and evidence and not on emotion.

Prospects

The prospects for aquaculture are far reaching and exciting. We heard about the salmonids and the projections for that industry. Larger cages are being designed and tested and will likely be used in more exposed waters where any pollution problems would be negated. The possibility of trout farming was again aired; sea cage farming of this valuable species would be ideal in New Zealand waters. Salmon farming is already a cash flow industry, and is in a position to diversify into other complementary aquaculture ventures. In Chile they are planning to suspend barrels containing abalone from the floats around the salmon cages.

Other fish species were mentioned as likely candidates for culture. Freshwater perch was given support. The perennial snapper was brought up again, but it was interesting to hear Ned Pankhurst put snapper at the bottom of the list of species suitable for cultivation. Other species, such as the dolphinfish, may prove to be the best farmed marine fish. Dos O'Sullivan talked of the very fast growth rates being obtained in Western Australia.

Crustacean culture has enormous potential, as shown by the four speakers in that session. Tony Provenzano talked of the opportunities that exist for the production of softshelled products from a variety of species. The recent breakthrough in rock lobster rearing and the willingness of industry to fund the preliminary investigations in New Zealand show that there are exciting prospects with just one of our indigenous species. However, it was obvious that imported species do have an important and growing role in aquaculture.

The molluscan species have dominated the aquaculture industry for many years, but their growth and potential is still high. New technologies, research information, and better markets will ensure further developments, and the emergence of new candidate species, such as paua, will bring diversity.

Aquaculture also embraces reseeding and enhancement, and Dave Schiel illustrated the effect enhancement has had on the Japanese scallop fishery. He outlined the current enhancement programmes on scallops and paua in New Zealand and both species have shown great potential.

Overall, prospects for aquaculture in New Zealand are very high and just looking at a magazine such as *Fish Farming International* one can see that exciting prospects are ahead.

And what about the future prospects in a general sense?

This conference is the penultimate step in a plan that started some years ago with the setting up of a Strategic Planning for Aquaculture (SPA) Group. Its task was to prepare reports on five species which were being cultured or proposed for culture. As Neil Martin said, the group has some of the best brains we have to look at the problems and prospects. However, we also knew that we had to consult with as many people as possible about the future.

One issue about the future that I wish to highlight is funding. The past 2 years have, as we all know, been a difficult time. For research and development it has been particularly difficult, with budget cuts hitting all science departments. The Minister, Colin Moyle, reminded us yet again that there is little money in the coffers and we all have to pull the belt in a bit tighter. Unfortunately for us, planning for the future in aquaculture research has become difficult.

Any industry, whether it be agriculture, horticulture, or aquaculture is dependent on knowledge and that has been highlighted at this conference. Research plays a vital role in any development, and my introductory talk emphasised the link between scientific research and the development of commercial aquaculture industries.

There are many examples from around the world where little pieces of research by a scientist beavering away in some small laboratory eventually prove to be very valuable to an industry. This is also true in aquaculture, and one excellent example is the work done on salmon over the years before culture of that species was even thought of. Reference to this work was made earlier this year in *Fish Farming International* by Dr Ron Roberts, the world famous director of the Institute of Aquaculture at Stirling University in Scotland. I would like to quote from the article, in which he sounds off about the amount of money being spent on defence in the U.K.

"You may wonder what this sort of bitter diatribe has to do with international fish culture.

Well, two things are important in relation to this.

Firstly, aquaculture cannot just depend on salmon. There are many other technologies that need to be developed, and a great many more inputs that will be needed to complete "the blue revolution". But that won't be coming from British science the way things are going.

The idea, or excuse, for this is that where government funds are cut industry will pay. We find industry does try, but frankly it is difficult to see why individual companies should pay for research needed to help the whole industry.

Also — and this is the *second* feature of the problem — is much more worrying. These ideas are spreading to other economies. In the U.S., research in government laboratories is being greatly reduced, in Australia it is rumoured that half the universities may be closed.

In Japan — ah now that is different. There the investment in basic research and in strategic industrial research is to double. Universities are being expanded. Fish culture research and the supporting development strategies are given high priority. Do they know something we do not? Or are the Japanese people proving once again that they can think more strategically, in relation to long term economic advantage than the West?"

Now Dr Roberts comments on an issue, "user pays", that has received some publicity in this country. In fact, we have the Beattie report that addresses the policies being imposed on the scientific community in New Zealand.

The report does not object to the user pays principle, and neither do I when it can be applied to a specific target. There are many positive effects of user pays; but there are also negative effects. The Beattie report lists and comments on several. I just want to mention one that affects the work in my section.

It concerns me that I and my staff are well trained and experienced scientists and technicians. We are damn good at our job of doing research and development, but we are being taken away from what we do best. Lately, to maintain the level of research in aquaculture, we have had to run the equivalent of a research funding cake stall. We have been very successful at raising money and John Schellevis gave examples of our enterprise.

But, we do less and less research. To quote from the Beattie report, "Fund raising is time consuming and detracts from efficiency. Scientists should aim to excel in research not in commercial activities".

As I said, I do not object to user pays. I am not asking for more money. What I would like, though, is some consistency. Stop changing the rules so that we can plan. We need long term planning in finance so we can put some effort into long term strategic research, work that has some risk but may one day prove beneficial. No one industry or individual is going to pay for that type of research. It is quality research and in the long term could have greater value.

We have shown that we are as good as the rest of the world, if not better, and it would be nice to keep it that way — particularly in aquaculture which definitely has a future in this country and is worthy of support. I will add that your support, too, is required and, as I stated in my introductory talk, industry has made some very positive steps in supporting research and development.

We all know that wild species are under stress, everywhere, and FAO predict that by the year 2000 aquaculture will supply 20% of total fisheries production. It has been repeated several times at this conference that aquaculture will expand in New Zealand and we all have very positive attitudes to ensure that it does. There is, therefore, a lot of work to be done.

On that note, I officially close AQUANZ '88.

Poster paper

Cultivation of the African sharptooth catfish (*Clarias gariepinus*) in southern Africa

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Clarias gariepinus (synonymous with *C. lazera*), one of the two largest catfish species in Africa, is omnivorous. It can survive under low oxygen levels in muddy water and live for hours out of water owing to the possession of an auxiliary air breathing apparatus, the suprabranchial organ. It can also tolerate high salinities. It has a high fecundity; mature 1 year old females (about 1 kg) can produce 60 000–70 000 eggs in one breeding season. Spawning is in spring and summer.

The sharptooth catfish is widely accepted as food amongst rural populations in southern Africa. When processed, it fetches high prices and has been identified as one of the most promising potential aquaculture species in southern Africa.

As the eggs become adhesive on contact with water, a dry fertilisation process is used after gentle stripping. Fresh or cryopreserved semen can both be used successfully to fertilise the eggs.

To hatch the eggs with a minimum of mechanical handling, and without the need to remove their inherent adhesiveness, they are transferred on to screens in hatching trays straight after fertilisation. There they are evenly and rapidly dispersed under water into layers 1–3 deep before they become adhesive. Recirculating water is then passed over the eggs attached to the screens until hatching takes place. The larvae leave the system with the recirculating water to accumulate in rearing tanks.

The best larval growth over the first 15 feeding days is obtained from feeding with zooplankton (rotifers, cladocerans, and *Artemia* nauplii). Later, dried formulated feed can be substituted for, or used in combination with, live feed.

Cannibalism occurs in nearly all the developmental stages of *C. gariepinus*, both under natural conditions and in captivity. Availability of live food and uniformity of size of larvae and juveniles appear to be major factors inhibiting cannibalism.

There is little published information on the pond production of *C. gariepinus* in southern Africa. Fish stocked at a density of 5875 fish per hectare of water fed macerated chicken offal yielded 2.12 t over a production period of 75 days. In another production investigation, red and normal (black) varieties were stocked together in ponds at a density of 15 000 fish per hectare. They were fed a mixture of minced trash fish, bakery floor sweepings, and an 18% protein formulated pelleted diet and yielded 7.641 t of fish per hectare over a growth period of 100 days. The red strain had a slightly superior growth to that of the normal variety.

Clarias gariepinus stocked in equal numbers in polyculture with the European common carp (*C. carpio*) at a total density of 11 045 fish per hectare in final effluent maturation ponds and fed an 18% protein formulated chicken broiler pellet yielded 4.55 t of fish per hectare over a production period of 100 days.

Clarias gariepinus has high resistance to diseases, good growth rate in captivity, and the ability to grow under extremely high stocking densities as a result of its ability to gulp air. It is an ideal candidate for aquaculture. Although it may take time to penetrate the sophisticated market for fish in South Africa, where an abundance of seafish is still available, it has already captured a small portion of it. There are already a number of small scale commercial catfish farms in operation in the warmer parts of the country.

Poster paper

Growth and feed intake of turbot (*Scophthalmus maximus* L.) on a silage-based feed

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Introduction

The price of fish feeds can be reduced by cutting the storage costs of their perishable components. Adding acid to fish offal or trash fish is a cheap means of preservation. The liquid obtained (silage) need not be frozen and may be mixed with other components to form an artificial feed.

This study compared the nutritional performance of a silage-based feed for turbot with a control feed containing no silage.

Materials and methods

Fish: 96 turbot juveniles (mean liveweight 5.89 g, s.d. 2.52 g)

Feeds:

Composition (% wet weight)

	Control	Silage
Fresh whiting (g)	44.0	–
Whiting silage (g)	–	44.0
Herring meal (g)	49.3	48.5
Oil, vitamins, minerals and binder (g)	6.7	7.5

Proximate composition (% wet weight)

	Control	Silage
Moisture	38.0	38.0
Crude protein	42.0	40.0
Lipid	8.0	8.0
Carbohydrate	3.0	5.0
Ash	9.0	9.0
Gross energy ($kcal.g^{-1}$)	3.2	3.1

Treatments: Control and silage-based feeds were offered twice daily to appetite for 50 days.

Replicates: Eight fish per tank and six tanks per treatment in a randomised block design.

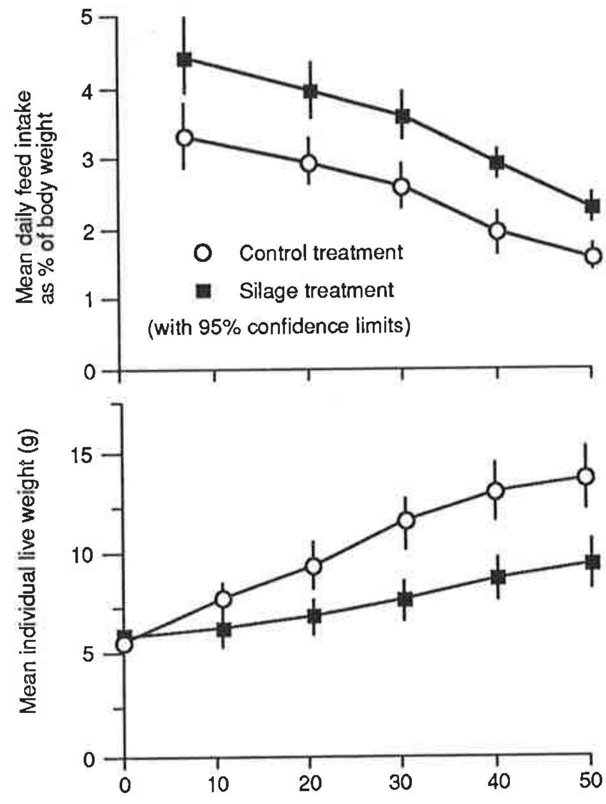
Measurements: Daily group feed intake; individual liveweight gain (each 10 days); and initial and final chemical body composition.

Results

Feed intake was significantly higher ($p < 0.001$) relative to liveweight for silage fed fish.

Liveweight gain was significantly lower ($p < 0.001$) in silage fed fish.

Body composition (moisture, protein, lipid, and ash) was not significantly affected ($p > 0.1$).



Conclusions

The poorer feed conversion efficiency and growth of turbot given this silage-based feed agrees with the findings from trials with other fish species.

Research into the digestibility and availability of nutrients in silage feeds is recommended because of the potential savings from ensiling fish wastes.

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