Evaluation of Species with Potential for Aquaculture in New Zealand

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INTRODUCTION

World fisheries production is rapidly approaching its maximum projected level.[2] New Zealand waters still produce large catches of some fish species but as with all fisheries, their productivity is limited. Attention is focussing increasingly on aquaculture as a means of expanding fisheries through hatchery rearing and enhancement programmes. Aquaculture is by no means new - there are records of aquaculture from as early as 500 B.C.[1] - and over a hundred fish and shellfish species are already cultured throughout the world. But only a few are cultured in New Zealand - salmon, oysters, mussels, and more recently scallops, paua and freshwater prawns.

This paper contains brief notes on a selection of potential candidate species for aquaculture. It has been compiled to illustrate the wide range of marine and freshwater species that could be cultured in New Zealand, some of the factors which need to be considered when evaluating the potential of these, and the diversity of culture methods possible. Species have been selected to give a range of examples of marine and freshwater, exotic and indigenous, fish and shellfish. Inclusion of a species in this paper does not necessarily indicate that MAFFish considers that culture of the species will be successful. The list is not comprehensive as there are a large number of species which could be grown. For instance it does not include the culture of feed species such as brine shrimps and rotifers, but these species should not be overlooked as candidates for aquaculture ventures.

The variety of culture methods available further extends the possibilities of aquaculture. For some species, it is possible to control all stages of the life cycle so they can be reared totally in a hatchery from egg to market size. For others, it may be desirable to provide a controlled environment for only a small part of the life cycle. Examples of this approach include the transfer of wild cockles to intertidal culture racks for a period before harvest so that the animals rid themselves of sand and grit; or the artificial feeding of harvestable kina to improve the texture and colour of the gonads; or simply harvesting a species from the wild and fattening it for market.

Hatchery rearing of juveniles followed by transfer to on-growing tanks, ponds or cages is a technique already used in the paua industry where juveniles reared in the MAFFish hatchery are being on-grown commercially in land-based tanks or in culture barrels on longlines. It is also the technique used in the salmon industry for both sea-cage and pond rearing.

The capture of wild stocks of larvae or juveniles followed by on-growing in the natural environment is the technique successfully used in the mussel and rock oyster industries and requires no artificial feeding or control of the environment (so long as sites are selected with care). But capture of wild stocks may also have potential for the raising of rock lobsters from the puerulus stage, thus avoiding the lengthy period required for larval development.

An aquaculture technique already used in sea ranching of salmon, but now also being evaluated for paua, is hatchery rearing followed by release of juveniles to a natural environment where they either remain e.g. paua, or return later in their life cycle e.g. salmon. In the case of paua, two options appear to be feasible - the release of small settled paua to suitable habitats, or the release of larvae on to suitable surfaces where they can settle naturally.

And finally, aquaculture offers the potential of enhancing existing fisheries either by the release of hatchery reared animals as discussed above, by the capture of wild juveniles and transfer to suitable growing sites as is now occurring in the Tasman Bay scallop fishery, or simply by providing suitable habitats within the natural environment on to which wild larvae can recruit. Again the Tasman Bay scallop programme provides a fine example where good results have been obtained simply by providing settlement surfaces for natural larvae which otherwise do not seem to survive.

So how do we evaluate which species will be the most suitable to culture, and what culture techniques should be employed?

In a treatise on the pond culture of carp in China in 500 B.C., Fan Lee[1] listed the following criteria used to select aquaculture species. High priority was given to species that 'grew rapidly, were tasty, not cannibalistic, were hardy, and inexpensive to culture'. While these criteria still apply today, we must also consider whether adequate seed is available from natural sources and whether there is a good market value for the final product. Is the primary objective to produce large volumes at a moderate price for consumption purposes, or are marginally appropriate but highly priced species to be the target? The former requires intensive juvenile production methods followed by extensive grow-out methods, and the above criteria for evaluation are probably adequate. However, it is more likely to be the latter in New Zealand and greater consideration must be taken of the biological, engineering and financial limitations of culturing large numbers of seed to adult size in a controlled environment.

The following is a list of criteria which should be considered when evaluating species for aquaculture. No attempt has been made to rank the criteria, nor the species on the following pages, as this will depend on individual needs and constraints, e.g. a species considered by an Auckland company to be ideal because it fills a gap in their existing fish processing schedule may be totally unsuitable for a company based in Dunedin where the water is too cold to grow the animal.

SUGGESTED CRITERIA FOR EVALUATING AQUACULTURE SPECIES

Category	
Markets	Is there existing market demand for the product? Will it require extensive marketing campaigns and what does this do to production costs? Many aquaculture ventures fail because they fall into the trap of being production-led because the species is easy to grow instead of being market-led. Is aquaculture of the species increasing elsewhere in the world?

Larval spawning (natural and hatchery)

What do we know about the reproductive behaviour of the species?
Has it been successfully reared in captivity?
Can overseas data on the same or similar species be easily adapted here?
Is natural seed readily available and plentiful?
What about broodstock? If it has to be imported, there may be lengthy and restrictive quarantine measures required.
Knowledge of the reproductive biology, larval (natural and behaviour and adult maturation of a species is hatchery) essential in order to control or manipulate such factors as breeding, environment, nutrition, maturation, and metamorphosis. It also gives us the information necessary to enhance by selective breeding, desirable qualities such as rapid growth rate and adaptability to intensive culture. More importantly, it provides the information necessary to manipulate breeding cycles so that production can take place outside the time constraints of the natural spawning seasons.

Ongrowing Techniques (natural and in culture)

It is essential to understand the habitat requirements of a species in order to develop ideal culture conditions - either for hatchery rearing or for enhancement of wild stocks.
Knowledge of the growth and behaviour of the organism such as the optimal growth conditions, feeding behaviour, feed conversion efficiency, etc. will largely determine the potential for culture and the rearing methods which can be used, e.g. some lobsters are cannibalistic and so need individual growout containers.

Food supply

Many of the species identified as being good candidates for aquaculture may require research into suitable diets for some part of their life-cycle. Species which consume natural phytoplankton such as filter-feeding bivalves and silver carp are ideal as they do not require artificial feeding. Snapper, however, require large quantities of a variety of foods and could benefit from research to enhance their flesh colour when fed in captivity.

Diseases

Aquaculture often requires that animals be kept in much higher densities than in their natural habitats, and to be handled frequently. This added stress is a frequent cause of disease in many cultured species especially finfish. Again, bivalves have a distinct advantage in this respect as they do not often have to be caged, and can be grown at normal densities in their natural habitats. The obverse side to this is that diseased animals cannot be treated unless they are confined, so once infected, losses may be total as occurred in Europe when Bonamia infected oyster

	stocks. Treatment of diseased finfish is possible in ponds or via their feed.
Water quality issues	Some species such as filter-feeding bivalves must be grown in very clean water to ensure the public health safety of the final product even though they may grow faster and fatter in less pristine conditions. Other species such as lobsters produce metabolic by-products which can become toxic to the species if particular care is not taken to maintain good water quality during culture.
Harvest and post-harvest handling	For many species, harvesting technology has already been developed or can be adapted from elsewhere. For others, it needs to be designed to ensure the quality of the product is retained.
Cost effectiveness of each stage	One of the most important criteria to evaluate. Costs of production for some species can be prohibitive.
Status of species	Does current legislation permit farming of the species? Some species would be regarded as pests if they were released into the wild and may therefore have strict quarantine requirements placed on them. If broodstock has to be imported, information will be required on the likely environmental impact of accidental or intentional release of the species. Inclusion of an exotic species in the examples following should not be considered an indication that MAFFish will support the importation of the species. Each import application will be evaluated individually, and anyone contemplating importation of an exotic species are advised to first refer to the "MAFFish Guidelines for the Preparation of an Environmental Impact Assessment for Utilizing Exotic Fauna for Aquaculture." July 1988.

For simplicity, references have not been included in the tables on the following pages. For more detailed information on these and other aquaculture species, readers are referred to the MAFFish aquaculture scientists at Greta Point, Christchurch and Rotorua, or to the aquaculture section at MAFFish head office.

REFERENCES

1. Mann, R. (1984). On the selection of aquaculture species: a case study of marine molluscs. Aquaculture 39: 345-353.

2. Morse, D. E., Chew, K. K., and Mann, R. (1984). In: Prologue to Recent Innovations in Cultivation of Pacific Molluscs. Elsevier, New York. p. ix.

N.Z. SCALLOP

	Pecten novaezealandiae
LARVAE Spawning (Natural)	Abundant seed available to collectors placed in correct inshore areas. Could be used for suspended culture or reseeding beds.
Spawning (Hatchery)	Techniques for brood stock maturation, spawning and larval rearing all need research.
Settling/Rearing (Natural)	Much work has been done and techniques are well established for capture and ongrowing of spat.
Settling/Rearing (Laboratory)	Inadequately understood.
Ongrowing (Natural) Techniques	Considerable work has been done on reseeding of beds in Golden Bay and limited trials in Tasman Bay & Marlborough Sounds. Trial harvests indicate good profitability. Further research required to determine optimum seeding densities, suitability of different substrates, water quality requirements, impact of predators and the effect of trawling & dredging on survival rates.
Ongrowing (Culture) Techniques	Suspended culture in cages and by attachment to ropes has been attempted in NZ but is generally considered too labour intensive to be profitable. Adults generally non-motile unless disturbed so bottom culture in protected areas possible.
Food Supply	No problem in wild. Similar to other bivalves in hatchery.
Disease	No serious problems known but disease is implicated in periodic dramatic fluctuations of natural populations.
Water quality issues	Not as critical for other filter feeders because the gut of the scallop is not eaten.
Harvest & post-harvest handling	Developed. Hand shucked.
Cost effectiveness of each stage	High value animal but only 15-20% of total weight is recoverable meat. High volume operations such as reseeding appear most profitable.
Markets (current)	France, USA. World production is 300-450,000 t./yr greenweight. N.Z. exported 249 tonnes in 1987.
Markets (potential)	High value animal with already established markets. NZ and Australia also consume 5-15,000 tonne/yr greenweight total. Increased NZ production will easily sell in existing markets at standard prices, i.e. as frozen meats. Increased returns will come from added value such as smoking.
Remarks	N.Z. wholesale price is typically $20-25/kg for meat and roe. Legislation changes may be necessary to permit exclusive harvesting rights to areas of seabed before private enhancement enterprises can proceed.
Status	Indigenous. Natural populations commercially fished.

FLAT OYSTERS

	(*Tiostrea lutaria*)
LARVAE Spawning (Natural)	Considerable data.
Spawning (Hatchery)	Information on similar overseas species (*O. edulis*, *O. angasi*, *O. chilensis*). Needs heat pump for work on adult condition however.
Settling/Rearing (Natural)	Considerable data.
Settling/Rearing (Laboratory)	Information on similar species only.
Ongrowing (Natural) Techniques	Well documented.
Ongrowing (Culture) Techniques	Rearing trials in cages on longlines in Port Underwood indicate adequate growth in 2yrs compared with 5yrs in wild. Bottom seeding also possible.
Food Supply	Information available for similar species.
Disease	Several parasites known in wild populations*.
Water quality issues	As for all filter feeders. Foveaux Strait oysters have very high Cadmium levels. Research required to ensure this is not a problem if farmed elsewhere.
Harvest & post-harvest handling	Developed for dredge fishery.
Cost effectiveness of each stage	Not known.
Markets (current)	N.Z. species sell locally for 30-40c each retail. Export price NZ $6.54/kg in 1987.
Markets (potential)	Good. Retail for $3NZ per oyster in U.K. However, need to be able to distinguish wild and cultured oysters since current legislation restricts exports of Foveaux Strait oysters.
Remarks	*Disease in wild population eg Bonamia has highlighted the need for a quarantine facility to study disease organisms, conduct infection experiment, understand epizootosis and the quarantine and observation of exotic species. Potential for enhancement of severely depleted areas and for development of disease (Bonamia) resistant strain.
Status	Indigenous. Natural stocks commercially fished during controlled seasons.

PACIFIC OYSTER

	(*Crassostrea gigas*)
LARVAE Spawning (Natural)	Long spawning season and multiple spawnings.
Spawning (Hatchery)	Developed. Able to supply eyed larvae on demand. This would provide 6 month advantage over wild caught spat.
Settling/Rearing (Natural)	Well documented
Settling/Rearing (Laboratory)	Well documented
Ongrowing (Natural) Techniques	Developed.
Ongrowing (Culture) Techniques	Entire process is developed and well understood.
Food Supply	Developed.
Disease	None known for hatchery reared except Oyster Vella Virus disease in Canada. Good management practices essential to avoid mudworm problems on intertidal farms.
Water quality issues	As for all filter feeders.
Harvest & post-harvest handling	Developed.
Cost effectiveness of each stage	Known for all stages.
Markets (current)	Currently selling all that is produced. Main export market is half shell to Australia but good return from local market also. In shell export price $5.48/kg in 1987.
Markets (potential)	Good. Also big demand for eyed larvae USA potential seasonal market.
Status	Exotic. Introduced accidentally. Has now taken over from *S. glomerata* as the main farmed species of rock oyster.

ROCK OYSTERS

(Saccostrea glomerata)

LARVAE Spawning (Natural)	Considerable data available. Natural supply successful. Once every 3 years (approx.)
Spawning (Hatchery)	Developed but would be improved by work on adult conditioning.
Settling/Rearing (Natural)	Considerable data available.
Settling/Rearing (Laboratory)	No problems.
Ongrowing (Natural) Techniques	Much slower growing than C. gigas which competes with it.
Ongrowing (Culture) Techniques	Developed.
Food Supply	Developed.
Disease	No apparent problem.
Water quality issues	As for all filter feeders including susceptibility to TBT.
Harvest & post-harvest handling	Developed. Remain alive for long period after harvest.
Cost effectiveness of each stage	As for C. gigas except for length of ongrowing period.
Markets (current)	Australia, Asia.
Markets (potential)	Would be competing with C. commercialis (Australian species).
Remarks	Not as much potential as dredge or Pacific oysters. Markets unlikely to distinguish the shucked product from the more easily produced Pacific oyster.
Status	Indigenous. Currently farmed intertidally in northern half of North Island.

PEARL OYSTER

	Pinctada fucata (=martensii) - Japan *P. maxima* - Australia
LARVAE Spawning (Natural)	Data available.
Spawning (Hatchery)	Hatchery spawning of *P. margaretifera* known from small scale experiments.
Settling/Rearing (Natural)	Data available. Requires high salinity 36^{o}/oo, grows best 23-25°C range 15-25°C.
Settling/Rearing (Laboratory)	Small scale experiments.
Ongrowing (Natural) Techniques	Slow growth - inplanting 2-3 years, full grown stages 4-6 years.
Ongrowing (Culture) Techniques	Techniques available. Skill required and labour intensive.
Food Supply	Grows well only in rich productive areas of the sea.
Disease	Several - trematodes mainly.
Water quality issues	Very sensitive to temperature, salinity and pollutants.
Harvest & post-harvest handling	Developed.
Cost effectiveness of each stage	Unknown for artificial culture which is labour intensive.
Markets (current)	
Markets (potential)	W.German/Europe/USA. Apparent decline in world pearl demand over past two decades.
Remarks	Not many suitable sites in N.Z. - Parengarenga Harbour?
Status	Exotic. Not present in N.Z.

BLACK FOOTED PAUA

Haliotis iris

LARVAE Spawning (Natural)	Spawning behaviour understood. Wild stocks depleted because of overfishing and low recruitment.
Spawning (Hatchery)	Developed but more work needed on adult conditioning (Hatchery heat pump needed for control).
Settling/Rearing (Natural)	Initial experimental work complete. Pilot scale outplant expts needed/about to be carried out. Optimum densities for seeding not known.
Settling/Rearing (Laboratory)	Techniques developed. Some refinements possible.
Ongrowing (Natural) Techniques	Apparent lack of 60-90 mm size range in wild populations - cause unknown.
Ongrowing (Culture) Techniques	Barrel culture trials being carried out now. Land-based on-growing currently being tested commercially.
Food Supply	Adequate although some work needed on food for first 4 weeks and for barrel culture. Some research on development of artificial food at Massey - results not known. Information needed on the availability of seaweeds if these are to be major food source.
Disease	No problems in N.Z. to date. Problem in Australia which causes cysts in meat.
Water quality issues	Found on open coasts and requires similar well oxygenated water for culture. No other particular requirements.
Harvest & post-harvest handling	Unknown for hatchery reared paua - considered an industry responsibility. Need for change in law so hatchery-reared paua can be harvested at small size.
Cost effectiveness of each stage	Not known yet. FRC intends to assess this within next 12 months.
Markets (current)	Good in Asia for wild caught paua. (Canned, frozen meats, shell). 1987 export price was NZ $27.42/kg FOB.
Markets (potential)	Possible potential for cocktail size paua and live exports. World catches declining due to overfishing. Therefore good potential for enhancing local fishery if current research successful.
Status	Indigenous. Natural populations commercially fished for meat and shell. Hatchery reared animals now being raised also.

QUEEN PAUA

Haliotis australis

LARVAE Spawning (Natural)	Not known.
Spawning (Hatchery)	Control of adult spawning condition requires research. Techniques same as for other species.
Settling/Rearing (Natural)	Unknown.
Settling/Rearing (Laboratory)	Techniques similar to *H. iris* but more research required to determine optimum survival/growth.
Ongrowing (Natural) Techniques	Faster growth than virginea. May also be faster than *H. iris* to harvestable size.
Ongrowing (Culture) Techniques	Unknown.
Food Supply	Similar to *H. iris*. Respond well to *Lessonia* and *Undaria*.
Disease	Unknown.
Water quality issues	Unknown.
Harvest & post-harvest handling	Unknown.
Cost effectiveness of each stage	Unknown.
Markets (current)	Small quantities harvested for Asian markets.
Markets (potential)	Unknown. A light coloured species with the ability to grow to harvestable size within 3 years likely to have good potential.
Status	Indigenous. Natural populations commercially fished.

WHITE FOOTED PAUA

Haliotis virginea

LARVAE Spawning (Natural)	Not known.
Spawning (Hatchery)	No problem to spawn in hatchery.
Settling/Rearing (Natural)	Not known.
Settling/Rearing (Laboratory)	Techniques developed but some refinement possible.
Ongrowing (Natural) Techniques	Very slow. Possibly 4-5 years.
Ongrowing (Culture) Techniques	Unknown as yet. Barrel culture being tried.
Food Supply	Adequate, but potential for improvement.
Disease	No problems known.
Water quality issues	As H. iris
Harvest & post-harvest handling	Not developed as none harvested yet.
Cost effectiveness of each stage	Unknown. Grow-out time probably too long to be commercially viable.
Markets (current)	None.
Markets (potential)	Unknown. Strong demand for white-footed species on traditional abalone markets. Useful for polyculture with other Haliotis species e.g. in barrel culture, because it feeds on micro-algae and keeps fouling of shells and barrel surfaces to a minimum.
Status	Indigenous. Natural populations not fished.

CALIFORNIAN RED ABALONE

Haliotis rufescens

LARVAE Spawning (Natural)	No natural populations in N.Z. Information is available on Californian species.
Spawning (Hatchery)	Similar to *H. iris*. Easy to control. Techniques developed.
Settling/Rearing (Natural)	Work done to date eg in Chile, California, Ireland has been poor and has led to many failures.
Settling/Rearing (Laboratory)	Techniques developed.
Ongrowing (Natural) Techniques	Not very successful in overseas trials to date.
Ongrowing (Culture) Techniques	Reasonably good although some doubt about cost effectiveness.
Food Supply	Main food is *Macrocystis*. Availability?
Disease	Susceptible to a hatchery disease - confined to British Columbia.
Water quality issues	None.
Harvest & post-harvest handling	Developed in California. Information is available.
Cost effectiveness of each stage	Unknown.
Markets (current)	Japan - receives higher price than *H. iris*.
Markets (potential)	U.S.A. (NZ $33-43/kg wholesale for farmed greenweight and $104- 112/kg processed into 25g steaks). (Europe $3.30 each for 50-80 mm size). Japan ($23NZ/kg).
Status	Exotic. Not present in New Zealand. Current importation application awaiting approval.

GREEN-LIPPED MUSSEL

Perna canaliculus

LARVAE Spawning (Natural)	Natural spat available but ecological relationships and survival need to be better understood.
Spawning (Hatchery)	Same techniques as for *Mytilus* but conditioning of adults needs work. Requires large scale algae culture.
Settling/Rearing (Natural)	Under study. Information needed on larval behaviour. Also cause of post-settlement mortality.
Settling/Rearing (Laboratory)	Requires work. No control to date.
Ongrowing (Natural) Techniques	Although cannot yet control settlement in wild, it seems adequate. Survival to recruits is the major problem.
Ongrowing (Culture) Techniques	Prior to 3 cm size, prone to heavy fish predation.
Food Supply	No problem for larval culture. Natural food supply at all stages not known - needs work.
Disease	Nothing known of diseases affecting larvae and juveniles. Adults - sporocysts of trematode *Cercaria haswelli*, gregarina spores of genus *Nematipsis*; *Pinnotheres*, *Pseudomyicola lichomolgus* occur.
Water quality issues	Yes - evidence that TBT could be affecting all marine invertebrate larvae. Also *Dinophysis* & DSP. Requires water of high public health quality.
Harvest & post-harvest handling	Developed.
Cost effectiveness of each stage	Known and documented in field but not for hatchery reared.
Markets (current)	Japan/USA/Australia/Pacific/local.
Markets (potential)	Currently unable to supply present demand. 3904 tonnes exported in 1987 earning NZ $15,470,535.
Remarks	Advantage of no paralytic shellfish toxins therefore all year harvest.
Status	Indigenous. Natural populations cultured extensively.