MANAGERIAL AND DECISION ECONOMICS, VOL. 16, 525–535 (1995)

The 'Hong Kong' Solution to the Overfishing Problem: A Study of the Cultured Fish Industry in Hong Kong

Lawrence W. C. Lai

Department of Surveying, University of Hong Kong

and

Ben T. Yu

Department of Economics, California State University, Northridge, CA, USA

It has long been recognized that open access to ocean resources will lead to overfishing.[1] Cheung (1970), Johnson and Libecap (1982), Johnson (1990) and Dupont (1990) have studied contractual remedies to mitigate the inefficiencies of overfishing. The prevalence of wild harvest of fish can shape the political economy in working out a solution to overfishing.[2] If the dissipation of rent is due to excessive efforts along numerous dimensions of fishing, a natural tendency is to curb the input dimensions of the fishermen. Less direct methods may include the assignment of territorial rights, the reliance of local fishing unions, as well as instigating anti-new entrant sentiments.[3] Understandably, negotiation and enforcement of these remedies involve considerably high costs, and international fishing agreements are notoriously difficult to implement.

Interestingly, in the case of Hong Kong, the tragedy of commons has not been resolved by designing cooperative solutions in terms of input restrictions among fishermen or any type of territorial rights. In fact, methods of transforming marine fish into a private property by means akin to commercial riparian or fresh water fish culture in private lakes, artificial ponds or paddy fields have long existed in China.[4] The Hong Kong government in 1982 reinforced this tradition by setting aside some designated coastal water areas for the private raising of fish. Twenty-four Marine Fish Culture Zones (MFCZ) were gazetted on 9 July 1982 under section 5 of the Marine Fish Culture Ordinance of Hong Kong. The granting of these zones has led to a drastic increase in the output of fish supplied to the area. This occurred in spite of the increasing threat of water pollution, sometimes destroying large quantities of fish in a few hours.[5] This paper studies the reasons behind the success of the industry, its relationship with water pollution, and suggests a framework to evaluate the outlook of the cultured industry in Hong Kong.

THE EMERGENCE OF THE CULTURED FISH INDUSTRY

Private mariculture using rafts first appeared in Hong Kong waters in the late 1960s. It originated when some fishermen found that their practice of keeping some captured live fish in cages for private consumption could be adapted for commercial purpose. The success of the pioneers led to extensive imitation and many fishermen ceased operating their in- or offshore fishing vessels and switched to coastal fish culture. However, the initial efforts of fish culturists were rather amateurish — mostly by retired fishermen, private households, etc.

The expansion and the gathering of fish culturists infringed the Crown's marine rights and can be regarded as a form of squatting.[6] Squatters' rights are defended by their own efforts. Disputes among culturists and infiltration of un-

CCC 0143–6570/95/050525–11

derground societies occasionally erupted into violence. Cultural activities also came into direct conflict with public activities, i.e. coastal development projects (reclamation, dredging, dumping of marine spoil, extraction of sand) and the use of coastal resources for purposes such as recreation, fairways and typhoon shelters (see Wu, 1985). It was under the pressure of these competing interests that the government in 1980 passed the Marine Fish Culture Ordinance. In May 1982 a survey was carried out. This identified 1789 culturists operating 2745 culture rafts scattered in 50 areas and occupying 25 hectares of coastal water. Non-transferable culture licenses were then granted under the Ordinance to the surveyed culturists. This marked the beginning of the MFCZ in Hong Kong.

Under the Marine Fish Culture Ordinance, any person can obtain the rights to utilize an MFCZ by paying an annual license fee. The fee varies according to the culture area occupied, but not according to the MFCZ location. Subsequent applications for fish culture rights since the initial allocation have been processed on a first come, first served basis. There were no regulations stipulating the cultivation method and species of fish reared. The common practice is to capture fry from the coastal waters or buy them in the open market.[7]

A MFCZ licence can be renewed annually, but is not transferable. If a zone becomes too crowded the government will try to reduce congestion by not allocating licenses given up by the farmers who abandoned the business. The allocation scheme is not what economists would consider to be the 'first-best' solution, and can be a topic of separate inquiry.[8] However, even with a 'second-best' solution, i.e. one that entails only an exclusive right to operate but not to transfer, the effects have been notably significant.

Table 1 shows the coastal cultured fish production in Hong Kong by weight and by districts from 1979 to 1989. It is interesting to note that prior to the Marine Fish Culture Ordinance in 1980, annual production of cultured fish was only a few hundred metric tons.[9] In about six years since 1982, annual production rose to over 3000 metric tons. In fact, in the first four years after MFCZ from 1983 to 1987, the increase in annual production of cultured fish averaged about 31.8%.

Table 2 compares the total catch of coastal captured and cultured fish by weight and by district from 1979 to 1984. Again, in sharp contrast to the gradual reduction in captured fish due to overfishing, cultured fish increased drastically. Between 1979 and 1984, captured fish in the North District fell by 10%, but cultured fish increased by 157%. Likewise, in the same period, captured fish fell by 24% to 35% in the Tai Po District, but cultured fish increased by 254%.

FACTORS CONDUCIVE TO THE DEVELOPMENT OF AQUACULTURE

Commercial captive rearing of wild species is not a new idea.[10] Indeed, the private raising of low enforcement cost species such as salmon, catfish, seabass, trout, shrimp and oyster, etc. can be found in may places. However, aquaculture in Western countries has not been widely practiced.[11] Citing the study of Brown (1983), Johnson (1990, fn. 5, p. 131) noted: 'Even in Japan, an early leader in aquaculture, the wild harvest accounts for about 90% of total fish production. In the case of Hong Kong, however, there are reasons to believe that the situation may be more conducive to the development of aquaculture.

Consumer Demand

The most important aspect that contributed to the success of the cultured fish industry in Hong Kong is its seafood market. There is a high demand among the local population for live seafood. Live seafood is to be contrasted with fresh seafood which are dead but unfrozen before they are sold. Johnson (1990) assumed that captive rearing outputs are perfect substitutes for wild harvest outputs. This assumption allegedly may cause an 'output response' from the wild harvest sector, leading to too low a price for the aquaculture sector to survive (see also Anderson, 1985; Johnson, 1990).

This situation does not seem to exist in Hong Kong. The premium that consumers are willing to pay for live seafood can sustain the growth of the aquaculture sector, which has the comparative advantages of keeping fish alive close to shore, shortening the time between when the fish dies and when it is consumed. A large part of the consumer market is seafood restaurants. They obtain their live seafood from captured as well as cultured suppliers. The transported live fish are

Table 1. Output of Coastal Cultured Fish by Weight by District 1979–89

Year	North District	Tai Po District	Sai Kung District	Islands District	All Districts
Output (metric tonnes)					
1979	58	57	407	198	720
1980	104	75	396	185	760
1981	119	111	417	315	962
1982	132	182	484	355	1155
1983	112	151	403	294	960
1984	149	202	538	394	1283
1985	185	250	666	488	1589
1986	400	428	779	491	2098
1987	483	653	1011	723	2870
1988	604	790	1063	824	3281
1989	525	719	993	782	3019
Annual output % change					
1979–80	79	32	−3	−7	6
1980–81	14	48	5	70	27
1981–2	13	64	16	13	20
Average 1979–82	44	73	6	26	20
1982–3	−16	−17	−17	−17	−17
1983–4	33	34	33	34	34
1984–5	24	24	24	24	24
1985–6	116	71	17	1	32
1986–7	21	53	30	47	37
1987–8	25	21	5	14	14
1988–9	−13	−9	−7	−5	−8
Average 1983–9	61	63	24	28	36
Output as % of all districts					
1979	8	8	57	27	100
1980	14	10	52	24	100
1981	12	12	43	33	100
1982	11	16	42	31	100
1983	11	16	42	31	100
1984	11	16	42	31	100
1985	11	16	42	31	100
1986	19	20	37	24	100
1987	17	23	35	25	100
1988	18	24	33	25	100
1989	17	24	33	26	100

Source: Agriculture and Fisheries Department, Hong Kong Government, 1990.

kept in tanks for display outside and inside the restaurants. Customers supposedly can 'inspect' the fish before it is cooked.

The practice of choosing your own fish and ordering it to be cooked on the spot existed long before cultured fish became a widespread phenomenon, but the number of seafood restaurant per capita was nowhere as large as it is now. Undoubtedly, keeping large quantities of fish alive in cages in ocean water and the changes initiated by the Marine Fish Culture Ordinance has greatly increased this practice.[12]

The market of fish in Hong Kong is also known for its variety. In seafood restaurants, the names of different species and their prices are handwritten in Chinese on erasable red plastic boards, scattered over the walls of the dining area, creating a sense of excitement and helping to wet the appetite.[13] A dish of fish in an ordinary seafood restaurant in Hong Kong can sometimes command a price of over US$100!

To illustrate the price premium consumers are willing to pay for live seafood, Table 3 gives an example of the variety and the average price of species displayed at twelve seafood restaurants in November 1992. Red grouper, a very popular

Table 2. Physical Output of Coastal Captured and Cultured Fish by Weight (metric tonnes) by District 1979–84

Year	North District (Sha Tau Kok and Mirs Bay)				Tai Po District (Tolo Harbour and Tolo Channel)					
	Captured		Cultured		Captured				Cultured	
	Metic tonnes	% annual change	Metric tonnes	% annual change	Metric tonnes	% annual change	Metric tonnes	% annual change	Metric tonnes	% annual change
1979	1312		58		935		1034		57	
1980	998	−24	104	−79	902	−4	962	−7	75	−32
1981	852	−15	119	+14	787	−13	828	−14	111	+48
1982	975	−14	134	+13	773	−2	801	−3	182	+64
1983	978	0	112	−16	586	−24	880	+10	151	−17
1984	1179	+21	149	+33	606	+3	786	−11	202	+34
1979–84		−10		+157		−35		−24		+254

Sources: (1) Coastal captured fish—Richards (1985).
(2) Coastal cultured fish—Agriculture and Fisheries Department, Hong Kong Government, 1990.

dish, has an average price of $15.45/tael (about US$21.13/1b) and Pacific grouper, an expensive dish, an average price of HK$33.3/tael (about US$45.54/lb)[14].

Another feature of the fish market is the variety of names given to sub-species. For example, for groupers, the names can be superseded by a sub-species label such as red, green, yellow, brown-dotted, tiger, laterally banded, coral, melon-seed, coin, etc. Red grouper can also be listed with or without an extra sub-species label with 'ocean' on it, differentiating the fish from those that are privately raised. For certain species, such as the Pacific grouper (recognized by a tapering head, milky body with brown dots) which has an average price double that of the red grouper, no sub-species labelling of 'ocean' is needed since they are caught offshore and have not yet been able to be cultured.[15] While some of the labelling could be purely an advertising gimmick, the labelling also reflects how detailed the varieties of fish within a given species have been graded. For example, a dotted grouper can be differentiated into types called 'East' and 'West'. East dotted grouper normally has a higher price than West.

Economic theory suggests that the higher the price of a resource, the more detailed will be its measurement and grading. The high premium for seafood in Hong Kong has provided strong incentives for the private breeding, grading and transaction of fish. In other words, it is unlikely that entry of cultured fish into the market will lead to a response from wild harvest to flood the market as other areas in the West have experienced.

Technology

Floating cages are ideal for the private breeding of fish in Asia. For one thing, they are excellent for the sizes (small and medium) usually on a fish dish (which include head and tail) in a Chinese meal. Captured fish are caught in all sizes; a large fish has to be cut up into portions, decreasing the aesthetic presentation of the dish.[16]

In some ways, floating cages also can nourish fish better than their natural habitat. Apart from protecting the fish from natural predators like seagulls, jellyfish, octopus, dolphins and sharks, they can also be towed to havens during typhoons and natural disasters. Chinese folklore has two philosophers debating the 'happiness' of a fish swimming in a pond. From a scientific perspective, this is a moot point.

The more important characteristics of floating cages from the production standpoint is they they provide flexibility in expansion and contraction of fish stocks while, at the same time, reducing the transaction costs of breeding and marketing. Because floating cages can be tied together in groups, walkways and guardhouses can be built on top of them. It is not uncommon for fish culturists to keep dogs and watchmen on the premises, reducing the cost of protecting a fish farm from theft and robbery. Prior to 1983, these floating cages were illegal and their use was limited; but after 1983, technology led to full usage.

The technology of floating cages has also reduced the transaction costs of selling one cage business to another, since the capital value of the

Table 3. Seafood Market 1992 Survey from a Sample of 12 Restaurants

Fish name	Average price (per tael)
Red grouper	15.45
Green grouper	9.55
Yellow grouper	8.05
Dotted grouper	15.38
Red-spotted grouper	25
Leopard grouper	18
Brown-spotted grouper	13.5
Coral grouper	18
Tiger grouper	18
Pacific grouper	33.3
Yellow-finned seabream	7
Gold-lined seabream	3.
White seabream	4.5
Black seabream	6.83
Red pargo	8
Banded red snapper	9
Mangrove snapper	7.83
Red snapper	5.67
Russell's snapper	5.5
Sea perch	5
Black-tipped rudder fish ('black drayon')	12.25
Sweetlip	7
Lentjan	4
Moray eel	2
Wrasse ('giant labrid')	26.5
Green wrasse	17.14
Yellow wrasse	15
Rainbow wrasse	15
Toothed wrasse	15
Sea bass	3.5
Stone fish	14
Pearl-spotted-spine foot	9
Flag fish	80
Yellow dragon	13
Sole	28

fish in a cage can be more easily identified once buyers have information on the species, number and sizes of fish. Similarly, long-term contracts between the fish culturists and wholesale buyers of fish or seafood restaurants can be more easily structured because the fish culturists are less mobile than fishermen of captured fish.

Input Markets

In Hong Kong fish fry can be found locally or imported from abroad. The fry of red groupers and sea perch come mainly from China, green groupers from Thailand and the Philippines. Hong Kong is able to supply its own seabream fry and even export red pargo fry to Japan. The fry of Russell's snappers and mangrove snappers come from Taiwan and Thailand, and those of black-tipped rudder fish from Taiwan.

The market for fry is very active and dealers can make good profits by being 'fry-speculators'. The fry are measured in inches. The fry of red groupers in 1988 was HK$7.00 each for fry 2–3 inches in length and HK$12.00 each for sizes of 4–6 inches. These prices fell to HK$5.00 and HK$7.00, respectively, in 1989. The prices of fry of different lengths are affected by supply and demand as well as by the growth rates of the fry, very much like the futures market operates. For example, even though red groupers fell in price

between 1988 and 1989, green groupers remained the same at HK$14 for fry 2–3 inches in length, but fry of 4–6 inches increased from HK$18 to HK$20.

Transportation

The population density in Hong Kong and its close proximity to the fish culture zones have also contributed to the success of the cultured fish industry in the area. When fish reach their optimal size to be harvested, they are sent to local piers for delivery (mainly Tin Ha Wan or the Fish Marketing Organization (FMO) Piers). Storage areas for live fish 'in transit' are also available. Apart from Tin Ha Wan, Lam Ma Island has now been used as an active life fish depot as well as a popular reception area for importing marine fish from elsewhere.[17] Land transportation is provided by lorries, and within half a day, live fish can be delivered to any seafood restaurant in the city.

PROBLEMS

Apart from possible improvements in the MFCZ allocation system, the biggest problem facing the aquaculture industry in Hong Kong may be water pollution. Wu (1988, p. 4) pointed out that Victoria Harbour received sewage from 3.6 million people and industrial waste waters from 275 hectares of industrial land through 19 sewage outfalls and 77 stormwater drains. The problem is likely to be compounded when industrial development in south China, especially the Pearl River Delta, continues. Aquaculture will be affected by as well as influencing water pollution in the area (see Wu, 1988; Lam *et al.*, 1989; Lam, 1990). Regulating waste discharge is the most straightforward remedy to the problem. However, the geography of Hong Kong, i.e. its close proximity to the Pearl River, the influences of the ocean currents, the gradient of the ocean floor cumulatively made it 'difficult to differentiate pollution effects from natural perturbations' (Wu, 1988, p. 1). In addition, there is always a danger of over-regulation.

Before considering how the problem may be confronted, one might want first to evaluate how serious the problem has been in the past. Although there have been technical data indicating that water quality in Hong Kong has deteriorated since 1973, whether the effects have been significant enough to affect fish output is still unclear. While there was evidence that fish production decreased significantly from 1979 to 1984,[18] it is not clear how much of that can be attributable to water pollution.

Figure 1 suggests some clues on why the effect of water pollution can be exaggerated. The graph

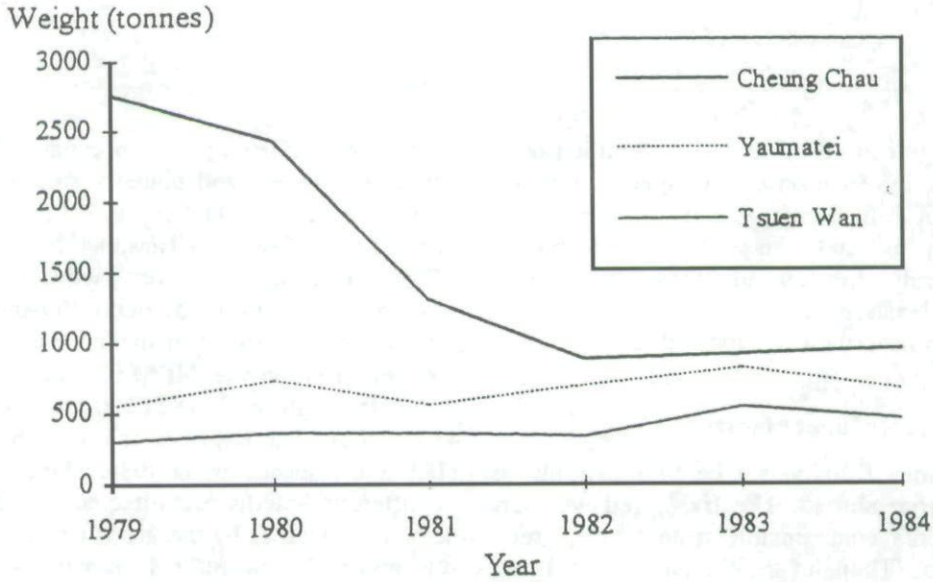

Figure 1. Fish production in Yau Ma Tai, Tsuen Wan and Cheung Chau, 1979–84. (Source: Richards, 1985.)

plots the quantities of fish caught in three different areas of Hong Kong during this time period. The two heavily polluted areas, Yaumatei and Tsuen Wan, did not experience significant changes in the output of fish during this period. Paradoxically, the large reduction occurred in Cheung Chau, an offshore area where it is much less polluted.

There is no doubt that in specific instances, fish stocks have been destroyed by water pollution. Wu estimated that the total value of fish destroyed by red tides, algal blooms, coastal development, oil spillages and toxic discharges amounted to US$1.51 million between 1976 and 1986 (see Wu, 1988, Table 12). That amounts to US$151 000 a year, a trivial figure compared with the cost of regulation. Indeed, the overall picture is indicated by Fig. 1 has suggested that the problem in the fishing industry during this period was overfishing and not pollution. Environmental concerns therefore cannot be raised solely on the grounds of the increasing chemical substance in the sea water.

OUTLOOK: AN EVOLUTIONARY APPROACH

We suggest that the outlook for cultured fish must be evaluated in terms not only of the quantity dimension but also of a quality dimension. Starting in the early years of the aquaculture industry, fish culturists noticed some quality difference between captured and cultured fish. Although some fish culturists believed that cultured fish can be more tasty,[19] cultured fish prices historically have always been lower than those of captured fish.

Table 4 provides some information on the price differentials between captured and cultured fish prior to 1983, ranging from 66.2% to 86.5% (cultured fish price as a percentage of captured fish price). The data are in aggregate form, and may not correspond to the price differential for individual species. Nevertheless, the table can be used as a starting point of enquiry.

To interpret the price differential between captured and cultured fish, Fig. 2 depicts the supply and demand of captured and cultured fish, treating them as two separate markets with high cross-elasticity but not perfect substitutes. Assuming that demand stays constant, the supply curve of the captured fish market would shift to the left due to overfishing, but the supply of the cultured market would shift to the right due to an increase in the private breeding of fish. Indeed, as Table 2 has already indicated, the difference in output response in the two markets has been quite significant.

Regarding the price differentials, one should expect the cultured fish price as a percentage of the captured fish price to fall over time. This implication should be quite robust even if one takes growing demand and water pollution into consideration. Growing demand would shift the demand in both sectors, raising the overall price of fish, but the *price differentials* would still be larger due to the supply respones. Likewise, if water pollution can influence the taste of fish, the demand for the cultured fish should shift down relative to the demand for captured fish, again, yielding a prediction that the *price differentials* should be increasingly larger over time.[20]

Although the quantity response implied by the theory has strong empirical support, confirmation cannot be made with respect to the change in the price differentials. Using recent information provided by the Agriculture and Fisheries Department of Hong Kong, Table 5 surveys the price of

Table 4. Estimated Price of Captured and Cultured Fish 1974–9

	1974	1975	1976	1977	1978	1979
Price of captured fish (per ton)	3737	3323	3693	4366	4727	5899
Price of cultured fish (per ton)	2554	2200	2976	3558	5088	4396
Price of cultured fish over captured fish (%)	68.3	66.2	80.6	81.5	86.5	74.5

Source: Richards (1980).

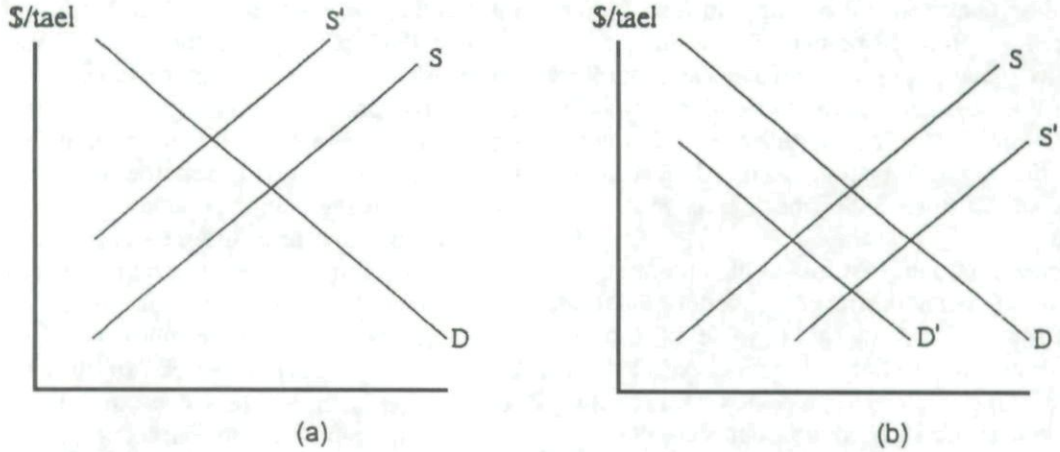

Figure 2. Cultured and captured fish markets.

cultured fish as a percentage of captured fish over 13 species by month between January 1988 and July 1992. There is no clear pattern of increasing or decreasing price differentials over time. In fact, the price differentials for certain species seem surprisingly low. For example, sea perch, red snapper, red pargo and gold-lined seabream have their cultured prices as a percentage of their respective captured price over 90% and seem *increasing* for most of the years reported. Looking at the 1992 figures, the average percentages of these 13 species appears, if anything, *higher* (meaning that the price differentials are *lowered*) than those suggested in Table 4, which are pre-1983 prices. Granted that these are heuristic arguments, as Tables 4 and 5 are not really comparable, the speculation is that there should be more to the theory.

We suggest that the outlook for cultured fish should be evaluated from an evolutionary per-

Table 5. Price Differentials Increase or Decrease over Time

Finfish species	Jan.–Dec. 1988		Jan.–Dec. 1989		Jan.–Dec. 1990		Jan.–Dec. 1991		Jan.–Jun. 1992		Jan .1988–Jun. 1992	
	Average cultured price as % of captured	Variance	Average cultured price as % of captured	Variance	Average cultured price as % of captured	Varance	Average cultured price as % of captured	Variance	Average cultured price as % of captured	Variance	Average cultured price as % of captured	Variance
Red gouper	78	0.008	70	0.019	46	0.002	62	0.005	67	0.007	64	0.020
Balck-tipped rudder fish	78	0.005	77	0.002	67	0.001	71	0.001	73	0.000	72	0.004
Green grouper	85	0.003	81	0.002	73	0.001	76	0.003	83	0.001	79	0.004
Yellow-finned seabream	87	0.001	86	0.000	84	0.001	82	0.000	82	0.001	84	0.001
White seabream	86	0.001	85	0.000	85	0.000	83	0.001	88	0.002	85	0.001
Yellow grouper	90	0.001	87	0.001	87	0.002	87	0.001	89	0.000	88	0.001
Black seabream	86	0.001	87	0.001	85	0.000	85	0.001	87	0.001	86	0.001
Mangrove snapper	82	0.002	82	0.004	74	0.002	78	0.002	80	0.001	79	0.003
Russell's snapper	82	0.002	81	0.001	80	0.003	79	0.002	79	0.003	80	0.002
Sea perch	92	0.002	95	0.001	94	0.001	94	0.002	96	0.001	94	0.001
Red snapper	89	0.006	90	0.002	92	0.002	98	0.002	95	0.002	93	0.004
Red pargo	82	0.003	87	0.003	93	0.001	94	0.002	93	0.001	90	0.004
Gold-lined seabream	92	0.003	90	0.001	94	0.003	98	0.001	96	0.002	94	0.003

spective,[21] involving changes not only in terms of quantity but also in quality as defined by consumer sovereignty. The interaction between development activities in Hong Kong and south China and the cultured fish industry may not be deterministic but, rather, interactive and evolutionary, producing positive as well as negative results. For example, tilapia was first introduced to Hong Kong from the USA and Singapore back in 1946 (*Hong Kong Fisheries Journal*, 1954). Originally intended to be raised as a pond fish,[22] it has survived in sea water and in fact seemed to do well in nullahs and itches next to reclamation areas. It has also been found to survive in *kei wei*, brackish water pond fishing by embankment. The species' characteristics are expected to be changing over time.

Another interesting example is the pearl-spotted-spine-foot fish. Although large specimens are usually found in deep seas, the smaller types can be found close to the shore, very often close to a sewage outlet. The seemingly 'uncomfortable' habitat of the fish has resulted in its nickname of 'mouse grouper'. In contrast to what one might think, the mouse grouper can be delicious. The price of a mouse grouper in a seafood restaurant costs about HK$9.00/tael (US$12.3/lb), comparable to seabream or even some groupers. Larger pearl-spotted-spine-foot fish found in deep water have less value because their flesh tends to be tougher.

Yet another indication of the evolutionary process in the development of the cultured fish industry is the distribution of total production across different areas in Hong Kong. As Table 1 indicates, there was a gradual shift in the percentage of production away from the Sai Kung District to the North District and the Tai Po District from 1979 to 1989. In light of the fact that the North District and the Tai Po District are more highly populated and contain industries, this shift may be a response to low transportation costs rather than to water quality. In fact, if water quality becomes a major factor in breeding fish, one should expect cultured fish zones to be concentrated in less industrial areas (e.g. the Sai Kung District). Thus, the observed shift in the proportion of fish production from the Sai Kung District to the North and Tai Po Districts is also likely to change the general characteristics of the cultured fish as industrial pollution in those areas is higher.

From a technical point of view, the evolutionary adjustment of cultured fish can be expected from the early stages of a culture cycle. For example, different water zones are suitable for different sizes of fish fry. Due to waves and clean water (lacking micro-organisms as nutrients), the zones at Tap Mu, Kau Lau Wan and Sham Wan are suitable for larger fry. On the other hand, the protected and algae-rich water at Yue Shu Au is ideal for very small fry. There is specific information about where, how, and what type of fish can be bred in different areas of Hong Kong; information expected to be ever changing, responding to development activities in the areas.

CONCLUSIONS AND SUGGESTIONS

Although the cultured fish industry in Hong Kong has enjoyed great success, urban development and water pollution will continue to plague the industry. Our study provides several suggestions:

(1) The efficiency of a cultured fish farm should not be evaluated solely on the quantity dimension requiring the marginal product of breeding fish to equal the marginal cost. Although eliminating inefficiency due to average product equalling marginal cost for common property has been the conventional emphasis of aquaculture (see Agnello and Donnelley, 1975, 1976a,b), efficiency may need to be evaluated on the basis that the whole marginal product curve would shift to the right. The MFCZ license, in this context, derives its value *not* solely on the basis of an increase in quantity of fish but on the reward of experimenting with different species and fish fry in an everchanging environment. In this context, it is justifiable for a MFCZ license fee to be levied only on the basis of the cultured area occupied and not according to location. Likewise, prohibiting the transfer of licenses (coupled with a good administrative criterion of selecting fish culturists with potential for experimentation) can increase output more than the situation where licenses are freely transferable. This paradoxical prediction bears a similarity to that suggested by Furubotn (1988,

p. 173) who argued that for certain types of codetermined firms, not allowing workers to sell the control and income rights can actually allow the firms to operate more efficiently.

(2) From a legal perspective, aquaculture turns a common property (fish) into private property. In terms of quantity, the damage of fish culturist suffers from water pollution in terms of destruction of fish stocks can be a basis for legal action. With fast economic and industrial growth in the area, we expect complaints to the government and industry from fish culturists to increase in the future. Because liability for water pollution would be difficult to implement in Hong Kong, some forms of direct regulation is inevitable. Presumably, emission charges accumulated from factories can be used for a 'pollution disaster fund' to compensate for the loss of fish. The implications of establishing this fund, however, need to be studied.

(3) Water polllution can also affect the quality of fish marketed. Here, direct regulation may not be desirable. The effects of water pollution on cultured fish, if captured in terms of a lowering of fish price, has not raised alarm in the fish culture industry of Hong Kong. As pointed out earlier, the cultured fish price can be as high as 98% of that of captured fish. In addition, if there is an evolutionary adjustment process in the quality as well as the quantity of cultured fish, the cultured fish price as a percentage of the captured fish price is expected to *increase*, not decrease, over time. In the limiting case, one might want to argue that the marginal cost of pollution can be lowered due to fish culturists' willingness to experiment. This, however, is merely a conjecture, and is mentioned as a possible area of future investigation.

Acknowledgements

Much of the work on this paper was done while the second author was a visiting Professor in November and December 1992 with the Department of Surveying at The University of Hong Kong. The authors wish to thank the personnel working at the Fish Marketing Organization and the Environmental Protection Department in Hong Kong for supplying several public sources of information for this study. The views expressed in this paper do not reflect the positions of the FMO, EPD and the universities. The comments of the editor, the referee, and the research assistance of C. K. Cheung are gratefully acknowledged.

NOTES

1. Classic citations supporting this proposition are Gordon (1954) and Scott (1955).
2. For example, Johnson and Libecap (1982) pointed out that fishermen union contracts have been considered to have violated the Sherman Anti-trust Act in the USA. The political economy of captive rearing versus wild harvest has been further studied in Johnson (1990).
3. Johnson and Libecap (1982) and Johnson (1990) discuss some of these methods.
4. Artificial hatching of fish allegedly began in China as early as 2000 BC (see Lin 1940).
5. The most serious form of water contamination in Hong Kong is caused by red tides (algal bloom via a process known as eutrophication.) During a red tide, the oxygen content in the ocean is drastically reduced and the whole stock of fish can be destroyed in a few hours.
6. A squatter is a person who occupies land without lawful authority or without consent in a 'derelict boat or by the foreshore or in a typhoon shelter'. (Hong Kong Government, *Town Planning Glossary*, p. 56).
7. The market for fish fry has partially contributed to the success of the cultured fish industry. This will be elaborated in the next section.
8. Direct grant of marine rights to the squatters saves the costs in using the Marine Police to enforce or to evict illegal culture activities and the resulting confrontation cost between the fish farmers and the government. Subsequent policy of allocation is by waiting. In 1989, there were about one thousand outstanding MFCZ applications (see *Sing Tao Daily News*, 27 August 1989, p. 34).
9. In the year when the survey was taken in 1982, annual production rose to 1155 metric tons. Expecting the regard of a MFCZ license, respondents to a survey have the incentive to exaggerate the size of their yields. A more realistic guess on the annual production of cultured fish prior to the MFCZ cannot be more than 1000 metric tons.
10. Smith *et al.* (1983) and Bell (1986) have made similar suggestions.
11. The economic and political problems of captive rearing industries and aquaculture have been studies in Brown (1983), Anderson (1985) and Johnson (1990).
12. Prior to 1982, the use of floating cages, net impoundment or embankment of bays without Crown permission were all illegal. As will be discussed in the next section, floating cages are a very effective low-enforcement-cost technique in the private breeding of fish.
13. A small restaurant that seats 80–100 people can offer 10 species on a given day. Most of the prices are quoted per tael (42.5 g or 1.5 oz.) but some are quoted by the whole fish, probably reflecting different suppliers' pricing methods.

14. The sample was taken from low- to medium-priced restaurants. Ten of the 12 restaurants sampled carried red grouper, but only three carried Pacific grouper (1 tael = 1.5 oz. approx.). Exchange rate is US$1 = HK$7.8.
15. Notice also the wrasse can be superseded by 'green', 'yellow', 'rainbow', 'toothed', etc.
16. In this respect, the Hong Kong situation also differs from that in Japan in that sashimi, raw fish for consumption, only needs to be fresh but *not* alive.
17. It is also interesting to note that very down-to-earth seafood restaurants have clustered around these live fish depots. Typically, a family with friends in groups of 6–10 people would go to these restaurants for a meal exclusively of seafood.
18. Fish production decreased by 35%, 24% and 10% in Tolo Harbor, Tolo Channel, and Mirs Bay respectively. The percentage reduction can be extrapolated from Table 2 in Wu (1988).
19. A news article in the 1970s reported: 'According to the fish culturists in the Taipo and Sai Tau Ko areas, among the seabream species, red pargo has the highest growth rate. It is 'fatter' than the natural ones, shorter but with thicker meat. It also tastes better than the natural ones' (*Hong Kong Fisheries Newsletter*, **4**, No. 2, p. 2).
20. The possibility that water pollution can reduce the supply of cultured fish has been discounted earlier in this paper. Certainly, the observed increase in the output of cultured fish over the years is inconsistent with this speculation.
21. The idea of an evolutionary approach to development and environment has been suggested in Common and Perrings (1992), Turner (1993) and Fu (1993).
22. The original 100 tilapia fry imported from Singapore in 1948 did not survive a cold spell in 1949. Different specimens have also been experimented on by the Fisheries Research Unit at the Department of Agriculture, Fisheries, and Forestry during the early years.

REFERENCES

R. J. Agnello and L. P. Donnelley (1975). Property rights and efficiency in the U.S. oyster industry. *J. Law & Econ.*, **18**, October.

R. J. Agnello and L. P. Donnelley (1976a). Externalities and property rights in the fisheries. *Land Economics*, **52**, November.

R. J. Agnello and L. P. Donnelley (1976b). Prices and property rights in the fisheries. *Southern Economic Journal*, **42**, October.

J. L. Anderson (1985). Market interactions between aquaculture and the common-property commercial fishery. *Marine Res. Econ.*, **2**, 1–24.

F. W. Bell (1986). Mitigating the tragedy of the commons. *South. Econ. J.*, **52**, 653–64.

P. Berck and J. M. Perloff (1985). The commons as a natural barrier to entry: why there are so few fish farms. *Amer. J. Agr. Econ.*, **67**, 360–63.

N. S. Cheung (1970). The structure of a contract and the theory of a non-exclusive resource. *J Law & Econ.*, **13**.

R. Coase (1960). The problem of social cost. *J. Law & Econ.*, October.

M. Common and C. Perrings (1992). Towards an ecological economics and sustainability. *Ecological Economics*, **6**, 7–34.

D. P. Dupont (1990). Rent dissipation in restricted access fisheries. *Journal of Environmental Economics and Management*, **19**, 26–44.

T. T. Fu, D. Shaw and T. Yu (1993). A property rights and contractual approach to sustainable development. Manuscript, October.

E. G. Furubotn (1988). Codetermination and modern theory of the firm: a property-rights analysis. *Journal of Business*, **61**, No. 2, March.

H. S. Gordon (1954). The economic theory of a common property resource: the fishery. *Journal of Political Economy*, **62**, 124–42, April.

Hong Kong University Fisheries Journal (1954). No. 1, December, 63–5.

Hong Kong Sing Tao Daily News (1989). 27 August, 34.

R. N. Johnson (1990). Commercial wild species rearing: competing groups and regulation. *Journal of Environmental Economics and Management*, **19**, 127–42.

R. N. Johnson and G. Libecap (1982). Contracting problems and regulation: the case of the fishery. *American Economic Review*, **72** (5), 1005–22, December.

C. W. Y. Lam (1990). Pollution effects of marine fish culture in Hong Kong. *Asian Marine Biology*, **7**, 1–7.

C. W. Y. Lam, P. H. Lui and M. F. Fong (1989). *Marine Water Quality in Hong Kong*, June.

S. Y. Lin (1940). Fish culture in ponds in the New Territories of Hong Kong. *Journal of the Hong Kong Fisheries Research Station*, **1**, No. 1, February, 161–92.

J. Richards (1980). The status of fisheries in Hong Kong waters. Unpublished manuscript, Hong Kong Agriculture and Fisheries Department.

J. Richards (1985). Fisheries production in Hong Kong waters. Internal report MRRD/WP/7/85, Agriculture and Fisheries Department, Hong Kong Government.

A. Scott (1955). The fishery: the objectives of sole ownership. *Journal of Political Economy*, **63**, April, 116–24.

R. J. Smith, J. Goldstein and R. K. Davies (1983). Economic incentives as a conservation strategy for nongame and endangered species of wildlife. In *Transactions of the Forty-Eighth North American Wildlife and Natural Resources Conference* (edited by K. Sablom) Washington, DC: Wildlife Management Institute.

R. K. Turner (1993). *Sustainable Environmental Economics and Management: Principles and Practices*, London and New York: Belhaven Press.

S. S. Wu (1985). Marine fish culture in Hong Kong: problems and some possible solutions. *Fish Farming International*, **12**, 12–13.

S. S. Wu (1988). Marine pollution in Hong Kong: a review. *Asian Marine Biology*, **5**, 1–23.