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Status and potential of Australian *Lates calcarifer* culture

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Abstract — ***Lates calcarifer*** *is distributed widely in northern Australia and is important to both commercial and recreational fisheries. Interest in culture of the species is nationwide but most culture activity to date has been in Queensland.*

Queensland Department of Primary Industries commenced research on hatchery production of the species in 1984 and this work is continuing. Hatchery reared fish have been stocked to reservoirs in northern Queensland and have been used in experimental grow-out trials.

Fish weaned onto formulated diets by the age of 25 days were reared to marketable size (> 500 g) in freshwater tanks. Despite suboptimal water temperatures the fish reached market size by the age of twelve months. An overall food conversion ratio of 1.1 :1 was obtained during grow-out. Taste panel analysis showed that the pellet fed fish were of good quality.

Fish stocked to reservoirs grew rapidly demonstrating growth potential of the species under favourable conditions. Mean weights in excess of 450 g were attained by six month old fish and in one reservoir year old fish averaged approximately 2.5 kg. The sensitivity of growth rates to water temperature was demonstrated in both grow-out trials and reservoir stockings.

Fish bred from geographically separated broodstocks exhibited differences in growth rates when stocked to two reservoirs with similar temperature regimes. It is suggested that these differences may be genetically influenced. Electrophoretic studies indicate the presence of a large number of distinct stocks of ***L. calcarifer*** *in Australia, raising a number of important issues for the culture industry.*

Large scale commercial grow-out is presently limited to one company which produced its first sizeable harvest estimated at 20 tonnes in 1988. The fish were reared in saltwater cages on a pellet diet. The company operates its own hatchery and has supplied fingerling fish to other pilot-scale farming operations.

Other commercial grow-out operations in the planning or pilot stages include recirculating freshwater culture systems and culture in geothermally heated freshwater. An angler pay fishing facility is also in operation.

INTRODUCTION

The barramundi, *Lates calcarifer* (Bloch), is one of the most highly regarded sport and table fish in Australia. It inhabits rivers and inshore waters over roughly 8000 km of coastline in Queensland, Northern Territory and Western Australia and is important to commercial and recreational fisheries throughout this range.

Barramundi catch by the commercial sector was about 1000 tonnes (live weight) per annum in the five years to 1983 (Grey 1987). At 1987 prices the return to fishermen would have been around $A 3.5 million per annum.

Estimates of nationwide recreational catch are lacking but angler catches account for about 30 % by weight of barramundi landed in the Northern Territory (Griffin 1989). Data from Australian Bureau of Statistics (1986) suggest that over a one year period 200000 individual anglers fished Queensland barramundi waters, most of them repeatedly. Other species are also sought in these waters but the barramundi catch by these anglers is obviously substantial (about 100 tonnes if 20 % of anglers caught one legal sized fish). Expenditure on barramundi angling probably exceeds the value of the commercial fishery several fold. Direct spending on recreational fishing in the Northern Territory, most of which is directed at barramundi, has been estimated at $A47 million per annum (Cam and Ross, 1986).

Declining catches and significant stock reductions in many areas have prompted increased research effort since the mid 1970's as summarized by Griffin (1987). Increased knowledge of barramundi biology, the desire to conserve wild populations, and the importance of recreational fisheries have directed barramundi culture research into areas not addressed in other countries farming *L. calcarifer.*

The first recorded attempts to culture Australian barramundi were pond trials with wild caught juveniles (Anon, 1955). The ponds were located in south Queensland outside the distribution of barramundi and cool winter temperatures apparently resulted in mortalities. Maclean (1972) considered commercial culture would be feasible if adequate supplies of fry and cheap food were available, and advocated hatchery breeding for conservation as well as farming. Plans for hatchery production were announced in the mid 1970's by a company which sought to stock Lake Argyle, a large reservoir in the north of Western Australia with barramundi in exchange for commercial fishing rights (Anon, 1975, 1976). The scheme did not eventuate however and the next published information came from aquarium rearing of wild caught juveniles (House, 1979).

Interest in barramundi aquaculture intensified in the early 1980's helped by reports from Australian workers of successful hatchery production in Thailand (Barlow, 1981; MacKinnon, 1983). In addition to commercial grow-out there was great interest in hatchery breeding for stocking natural and impounded waters, especially in Queensland where many dams and weirs prevent upstream migration of barramundi causing them to disappear from large areas of former habitat.

HATCHERY PRODUCTION

From 1984 to 1986 the Queensland Department of Primary Industries (Q.D.P.I.) undertook a pilot hatchery project (MacKinnon, 1987a).

Eggs and milt were obtained from ripe wild fish and by hormone induction of freshly captured fish belonging to sexually precocious stocks in the Embley River estuary near Weipa, Far North Queensland. The fish spawned on discrete localized grounds after full moon and new moon as do Southeast Asian *L. calcarifer* but spawning grounds were further upstream than in Southeast Asia reflecting different estuarine salinity regimes.

Fertilized eggs were transported by air to Cairns for transfer to the Northern Fisheries Research Centre. Larvae were hatched and reared in circular fibreglass tanks of 1.2 t capacity, described in detail by Russell et *al.* (1987). Up to 2 weeks from hatching rearing procedures were based on those used in Thailand (Chomdej, 1986). Salinity ranged from 30-34 ppt. and temperature from 26-27.5°C.

Larval development corresponded closely to that of Thai fish as described by Kosutarak and Watanabe (1984), and larval growth rate (mean length approximately 10 mm at 20 days old) equalled the fastest recorded in Thai experiments (Maneewong et *al.*, 1986).

A condition which became manifest at 12 to 14 days of age caused near total mortality in several batches of fish. First symptoms included pale coloration and abnormal swimming behaviour. The only survivors in the first trials of 1984 were a few fish transferred to fresh water soon after the mortalities began. Subsequent research indicates that this condition could result from nutritional deficiencies (Rodgers and Barlow, 1987; Rimmer et *al.*, 1988, Rimmer, 1989), while other recent evidence suggests a virus may have been implicated (L. Owens, pers. comm.).

From about 14 days after hatching, a variety of methods were used to rear the fish through to the juvenile stage. Some larvae were reared further in salt water while others transferred to fresh water at Walkamin Research Station were reared in tanks or earth ponds.

Three batches of fish were placed in separate fertilized 0.1 ha earthen fry ponds. One batch of larvae, all apparently healthy, was stocked at 16 days old (8-10 mm length), and 50 % survived the pond rearing period of 25 days. Growth was rapid and mean length of the fish at harvest was 50 mm. The other two ponds were stocked with 17 day old fish some of which showed symptoms of the nutritional disease mentioned above. Survival to harvest (20 % and 28 %) in these two ponds was lower than in the first pond but growth rate was similar, the mean length being 50 mm on harvesting at 45 days old. These results supported the notion that in Australian conditions pond rearing of advanced larvae might be as cost effective as intensive tank culture through to fingerling stage (MacKinnon, 1983).

Two batches of 15 day old fish were placed in fresh water tanks and fed pond cultured zooplankton and Artemia nauplii. Weaning onto dry formulated diets started at 20 days old and was completed by about

25 days old when the mean length of the fish was 15 mm. Conversion to pellet food at this early stage provided an alternative to the minced fish diet used in Thai hatcheries. Feeding minced fish flesh is labour intensive and carries risks of pathogen introduction, nutritional problems, and pollution of rearing tanks. These problems are minimized by feeding dry pellets.

Investigations to refine freshwater pond rearing techniques for advanced larvae are continuing. It has been found that behaviour of barramundi stocked to ponds at T.L. ì 10 mm makes them susceptible to predation by dragonfly larvae. Survival in freshwater ponds can be increased substantially by delaying stocking until fish are ì 17 mm T.L. Recent pond rearing trials have exhibited survival of over 90 % (C.Barlow, pers. comm). Other continuing Q.D.P.I. hatchery research includes larval nutrition studies (Rimmer, 1989) and induced spawning trials (Garrett and Rasmussen, 1987).

A private company, Sea Hatcheries Ltd., received government funding to investigate hatchery production and grow-out of barramundi during the period 1983-1986. Following this pilot research the company was listed on the stock market in 1986 and in 1987 it relocated from Cairns to a new complex at Mourilyan Harbour about 100 km south. During its early years of operation Sea Hatcheries obtained eggs stripping ripe wild fish and hormone induction of captive fish but recently there have also been natural spawnings of captive fish held in 100 tonne tanks. Larvae are reared in recirculating systems. Early production runs in the new hatchery suffered high mortalities which were attributed to metal toxicities. These problems were apparently overcome however periodic mortalities have continued some of which appear to be similar to mortalities experienced in QDPI hatchery research. Despite these problems Sea Hatcheries produced 220000 fingerlings in the 1987/88 summer and in the current summer it had produced more than 400000 fingerlings (D. Hallam, pers. comm.) before severe mortality problems recurred in the hatchery.

Two smaller private hatcheries have also bred barramundi recently. One of these located near Cairns produced some 2700 fingerlings, obtaining its eggs from ripe wild fish. The other, located near Bundaberg in southern Queensland, reportedly produced in excess of 100000 fingerlings through hormone induction of wild fish, initial rearing in tanks and transfer of larvae to ponds until fingerling size was attained. Seven hatchery permits exist for barramundi production in Queensland (R. Quinn, pers. comm).

Outside Queensland, the Western Australian Department of Fisheries has conducted trials on maturation of tank held fish at Wyndham in the north of that state (Morrissy, 1987) and the Northern Territory Department of Fisheries recently completed a successful nursery trial using larvae supplied by Q.D.P.I. (N. Sammy, pers. comm).

FEEDING TRIALS

Q.D.P.I. pilot hatchery research included several small scale tank trials on the culture of barramundi using dry pelleted feeds. The trials investigated effects of food composition, feeding regimes, salinity and temperature on growth and food conversion (MacKinnon, 1987, MacKinnon et *al.*, 1987 : Tucker et al., 1988, D.J. Russel pers. comm.). Barramundi weaned onto dry formulated feeds as young as 25 days old and grow out in fresh water showed excellent food conversion (FCR 1.1 :1) and reached a mean weight of 566 g at 12 months old. An expert taste panel evaluated pellet fed fish using descriptive criteria similar to those of Tucker et *al.* (1985). The panel rated overall acceptability of the fish at 7.8 on a 9-point hedonic scale, clearly indicating a high quality product suitable for the restaurant trade.

One trial carried out in fresh water compared two diets both of which contained 27 % anchovy meal and approximately 53 % crude protein but with different levels of fat (9.3 % and 12.9 %). Differences in growth rate between the two groups were nonsignificant but significantly better food conversion (FCR 0.93 :1). was obtained with the higher fat diet than with the lower fat diet (FCR 1.01 :1).

Another trial carried out in salt water compared six experimental diets all of which contained approximately 50 % crude protein but which incorporated different proportions (20, 40 or 60 %) of anchovy meal. While the best food conversion (FCR 0.89 :1) was obtained with the diet containing the most fish meal (60 %) and fat (16.9 %), a food containing only 20 % fish meal and 13.4 % fat gave results which were almost as good (FCR 1.04 :1).

The results of these two trials suggested that diets containing > 20 % high quality fish meal, 48-54 % protein, 13 % fat and 10-16 % carbohydrate will produce good growth and food conversion in juvenile barramundi larger than about 10 g.

A trial to investigate the effects of feeding frequency on growth and food conversion was carried out in fresh water tanks. Experimental fish were fed to satiation with a commercial salmon starter formula either once per day or twice per day for 42 days. There was little difference in growth rate between treatments but food conversion was more efficient and food consumption less in fish fed once daily.

On completion of the feeding frequency trial, 30 fishes were retained in freshwater tanks and fed on commercial salmon starter until they were approximately one year old. At the start of this period the fish were 181 days old (mean weight 160 g) and on conclusion 369 days old (mean weight 566 g). Mean water temperature in the trial tanks during this period was 25°C. Over the whole grow-out period average FCR was 1.13 : 1.This suggested that in commercial grow-out conditions in fresh water FCR of about 1.5 :1 could be achieved.

Growth and food conversion of fingerling fish in fresh water and salt water at three different temperatures (22°, 27°, 32°) were also trialled (D.J. Russell com. pers). There was no significant difference in growth rate between fresh water and salt water but marked differences with temperature. Daily growth rate was fastest at 32°C (5.1 %) but the greatest difference was between 27°C (4.5 %) and 22°C (2.2 %). Food conversion was best at 27°C (FCR 1.02 :1). Considering the relatively low temperatures at which the Walkamin feeding trials were carried out, the growth rates compare favourably with those of pellet feeding trials elsewhere (Chou, 1984; Fuchs, 1986) and with growth of fish on a trash fish diet (Sakaras, 1984). Growth at 25°C allowed a complete crop cycle within a year but grow-out time might be considerably reduced at higher temperatures. Effects of temperature on growth are discussed further in subsequent sections.

COMMERCIAL GROW-OUT

Virtually all barramundi grow-out operations at the present time are located in Queensland, the sole exception being a scheme to culture the species in geothermally heated water at Portland in Victoria. This operation lost its initial crop at an early age. In Queensland 13 grow-out operators hold permits endorsed for barramundi production and 8 of these list barramundi as the sole or prime culture species. Not all the endorsed permit holders are presently culturing barramundi (R. Quinn, pers. comm.).

To the present time only one company, Sea Hatcheries, is marketing farmed barramundi in any quantity. The first large harvest of plate sized fish (400-450 g) was made during 1988 and this crop was still being harvested in early February 1989. So far more than 25 tonnes i.e 60000 fish have been harvested. The company states that 180000 fish were transferred from it's hatchery to the grow-out site during the 1987/88 summer indicating a survival over the grow-out period in the order of 35 %. The company is confident that improved cage management will increase survival in future crops (D. Hallam, pers. comm). The cage grow-out section of the companies operations is located in a tidal mangrove creek system 6-8 m deep near Cardwell some 80 km south of the hatchery facility. The cage farm cost $400000 and has been designed to cater for a production level of 300 tonnes per annum. Twelve people are employed in this section of the company's operations. Mean grow-out time to market size (400-500 g) is about 10 months and production cost is around $A5/kg, more than 30 % of which represents feed costs (FCR ≈ 2 :1 and the pellet feed costs the company around $1/kg.).

Several small operators have made trial stockings of barramundi fingerlings purchased from Sea Hatcheries however there are few indications that any of these operations have yet reached a commercial scale. At least one pond grow-out operation is operating as a fishout facility for tourist anglers however this facility in common with several small scale pond culturists has suffered substantial mortalities some of which have been due to protozoan infections and others which are of uncertain causes.

An operation which is currently commencing pilot scale production at Buderim in southern Queensland has converted a former ginger processing factory to raise barramundi in recirculated freshwater tanks heated to 28-30°C. The company plans to produce two crops per year for a total annual production of 80 tonnes. The plant is primarily intended as a tourist venture and it is planned that most of the production will be marketed on site (A. Cockerell, pers. comm.).

RESERVOIR STOCKINGS

Some 14000 barramundi (45 days old, mean length 50 mm) produced by the Q.D.P.I. pilot hatchery project were stocked to Lake Tinaroo (surface area 3300 ha) in late December 1985 (MacKinnon and Cooper, 1987). Extremely rapid growth was exhibited by these fish and by early April 1986 gillnet samples indicated a mean length of 300 mm and mean weight of approximately 390 g. By one year after stocking the fish had reached a mean weight of more than 1.1 kg (despite total cessation of growth during the winter months from June to September) and at three years from stocking the mean weight had increased to 5.2 kg. This growth rate exceeds most growth estimates for *L. calcarifer* in Australia and Papua (Garrett and Russell, 1982; Reynolds and Moore, 1982; Davis and Kirkwood, 1984) and is very much greater than the slow growth rate calculated by Davis (1984) for the parent stock in the Embley River. Only the estimates of Dunstan (1959) exceed the growth rate of the Tinaroo fish. Further stocking of Embley River fish to Lake Tinaroo in 1987 resulted in similar growth rates to the original stocking.

Continuing Q.D.P.I. research has included the stocking of another local storage, Lake Morris, with fish originating from populations in the Cairns area. These fish have exhibited even faster growth rates than the Embley River fish stocked to Lake Tinaroo. Fish stocked to the dam at 2 months old (mean length 58 mm) had reached a mean weight of 5.2 kg (equivalent to 3 years old fish in Lake Tinaroo) at the age of 20 months. Sampling of these fish has been irregular and it remains to be seen whether the difference in growth rates between the two lakes is primarily due to different physico-chemical conditions, genetic differences or a combination of both. At least part of the growth variation probably results from a temperature differential between the lakes (see subsequent section on temperature).

Other stockings of barramundi have been made to the Clare Weir in the Burdekin River system and to the Gunpowder dam near Mt. Isa in northwestern Queensland but no information on the success of these stockings is available.

WATER TEMPERATURE

The latitudinal range of *L. calcarifer* in Australia extends from sub-equatorial conditions at Cape York (10°S) to the southernmost limit of the species in the sub-tropics at about 26°S. This range covers a wide variety of seasonal temperature regimes which have important effects on survival, growth and reproduction. Temperature is not a limiting factor for *L. calcarifer* culture in equatorial areas but it is of prime importance to Australian culture. In spite of this importance little information exists on barramundi temperature requirements.

The effects of temperature on growth of juvenile barramundi are clearly demonstrated by Q.D.P.I. tank rearing trials. Fish held at 22°C grew at an average daily rate of 2.1 % while fish held at 27°C grew at an average daily rate of 4.5 %. (D.J. Russel, pers. comm.). These results suggest that at least part of the growth differential between fish in Lake Tinaroo and fish in Lake Morris is due to temperature effects. The two lakes are at slightly different altitudes and data from monthly water temperature sampling suggests that mean annual surface water temperatures in Lake Tinaroo (≈ 25°C) are approximately 1°C cooler than those of Lake Morris (≈ 26°). The tank trials with small fish together with various observations on captive fish of all sizes indicate that a 1°C temperature differential over prolonged periods could produce significant size differences in fish.

House (1979) reared Western Australian barramundi in an aquarium at 27-28°C and recorded weights approaching 10 kilos at four years old. He reported that fish were disinterested in feeding when temperatures were allowed to fall to 24°C. Fish from stocks near the southern limit of distribution were held in tanks at Q.D.P.I. Southern Fisheries Research Centre. They fed little during winter when temperatures sometimes fell to 19°C. but fed enthusiastically at temperatures at around 25°C (J. Burke, pers. comm.). Specimens from the Cairns area held in ponds at Q.D.P.I. Walkamin Research Station became very inactive during winter months when mean monthly surface water temperatures fell to 18-20°C. Embley river fish reared in freshwater tanks at around 25°C continued to grow throughout the winter but day to day variation in food consumption was obvious with minor temperature fluctuations.

Marked seasonal variation of growth rate has been noted in wild barramundi populations. Dunstan (1959) indicated a slower growth during winter months in Queensland east coast stocks and Davis and Kirkwood (1984) showed that growth of age 0+ fish was very seasonal in the Gulf of Carpentaria and Northern Territory waters. Most growth took place during summer months and seasonal growth variation was most marked in the areas with lowest winter water temperatures. Barramundi stocked to Lake Tinaroo showed very clear seasonal growth variation. Growth ceased completely between June and September when surface water temperatures in the storage ranged between 20°C-23.5°C. Fastest growth was from October to February when water temperatures were 27°-30°C.

Fragmentary observations such as those above suggest that barramundi from several stocks and over a range of sizes show similar growth responses to temperature. Below about 20-22°C little or no growth occurs and feeding is greatly reduced. A great increase in general activity and feeding with each degree of increase is noticeable at temperatures around 25°C and optimal temperatures for growth and food conversion lie above this level, probably in the range 27-30°C.

Although the general relationship described above probably holds true for most stocks there may be minor latitudinal shifts in the response to temperature. Studies of wild populations have not detected markedly slower growth rates in stocks near the southern end of the range (D.J. Russell, pers. comm.). Published information on water temperatures at the southern end of distribution is lacking but data from other sites in Queensland shows close correlation between mean monthly temperatures of inshore/estuarine surface waters and mean monthly air temperatures. Air temperatures at southern Queensland coastal centres suggest that if the southernmost stocks of barramundi had growth/temperature responses identical to those of fish stocked to Lake Tinaroo then they would only grow rapidly for 1-2 months of the year and would show little or no growth for 6-7 months. If this was true, slow growth in comparison to northern stocks would almost certainly have been detected in field studies.

Dunstan (1959) suggested that the latitudinal limits to distribution are probably determined by temperature, and mentions that minimum sea temperatures are in the vicinity of 21°C at both northern and southern extremities of the species distribution. This temperature probably has little direct relevance to survival of barramundi and is well in excess of the critical minimum temperature for survival of the species which Dunstan suggests may be in the vicinity of 15.5°C. Mortalities of wild barramundi during spells of cold weather have been reported from as far north as the tropic of Capricorn. Fish held in ponds at Walkamin Research Station have survived water temperatures as low as 13°C overnight however when these fish were handled at 16°C severe stress was obvious in all specimens and some deaths resulted. These observations suggest that Dunstan's estimate of the critical thermal minimum for survival over extended periods is reasonably accurate though perhaps slightly high.

Temperature requirements for breeding may be just as important as ability to withstand winter temperatures in determining the limit of distribution. Differences in the timing and duration of spawning are apparent throughout the latitudinal distribution of barramundi. Near the equator spawning of captive broodstock may occur throughout the year (Hussin Mat Ali, 1987) and at Songkhla in Thailand (7°N) spawning occurs for at least half of the year at water temperatures of 28-34°C (Maneewongsa and Tattanon, 1982). In the Northern Territory at 12°S Davis (1985) found larval barramundi from September to February at water temperatures of 28-35°. At Weipa in northern Cape York peninsula spawning appears to commence in September or October and is mainly finished by late November or early December (Garrett et *al.*, in prep.). Estuarine water temperatures at Weipa were over 27°C throughout the spawning season. In the Cairns/Tully region young larvae were first detected in late October when water temperatures were 26.5-28°C (Russell and Garrett, 1985) although most spawning in this area apparently occurs from December to February. Further south in the Fitzroy estuary Dunstan (1959) identified two spawning peaks in November and January and in the Burrum River very close to the southern limit of distribution spawning appears to take place between late December and February when water temperatures reach 25-27°C (J. Burke, pers. comm.). Based on limited data it seems that water temperatures above 26-27°C may be necessary for spawning of *Lates calcarifer* and it may be this factor rather than winter water temperatures which determines the southern limit of distribution.

There is a need for formal studies on temperature responses of barramundi. It is clear that even small climatic variations between potential culture sites could have considerable impact on economics of hatchery and grow-out operations. Similarly a shift of only 1°C in growth/temperature responses between populations could have a significant impact on production costs. Studies comparing the temperature responses of genetically isolated stocks from northern and southern ends of the distribution would be especially valuable.

GENETIC CONSIDERATIONS

The existence of many genetically distinct stocks of Australian *Lates calcarifer* (Shaklee and Salini, 1985; Salini and Shaklee, 1987) creates both problems and opportunities for the culture industry. The precise number and extent of the individual discrete stocks is still unknown, much less any differences existing between them which may represent adaptation to their particular environments or differing suitability for culture.

Two possible examples of genetic differences between populations affecting aquaculture potential have been mentioned in preceding sections viz. different growth rates of Embley river fish and Cairns district fish in neighbouring reservoirs which may be due partly to genetic factors, and sexual precocity of stocks in the Weipa area which makes them particularly easy to handle and maintain as captive broodstock.

In order to protect the genetic integrity of the individual wild stocks and to reduce possible risks of reduced viability through mixing stocks, barramundi released to Queensland public waters must be bred from the stocks occuring in the locality. It is not practical to maintain separate captive brood stocks from each area to be stocked and production of fish for stocking public waters usually has involved field operations to obtain ripe fish from spawning grounds and or/near ripe fish for hormone induction. Costs and difficulties of such exercises have been considerable and in some river systems attempts to obtain fertilized eggs so far have been unsuccessful.

The restrictions on source of seed do not apply to the grow-out culture industry. Provided that risks of escape are considered negligible seed material does not necessarily have to be of local origin and most fish grown out to date are descended from stocks in the Weipa area.

GENERAL INDUSTRY PROSPECTS

In marketing terms barramundi is one of the most promising aquaculture candidates for Australian conditions. There is an existing market for the species and a long tradition of high market prices. The species is well known to most Australians and is strongly identified as Australian. Many people are surprised to learn that the species has a wide distribution in Asia. Ever increasing prices suggest the market is presently undersupplied but it seems unlikely that production from Australian capture fisheries will increase. Because only large fish may be taken by commercial fishermen and because of the remoteness of commercial fishing operations from markets, the fish is currently marketed almost exclusively in the form of frozen fillet. Farmed barramundi would almost certainly be marketed in the form of whole plate sized fish, either chilled or frozen. Such a product will appeal particularly to the restaurant and hotel trade and because of uniform quality and freshness, should enjoy a price advantage over product from the capture fishery. Sea Hatcheries Ltd receives approximately $A15/kg for its current production. Marketing of fish in the whole form allows easy identification of the species and this also improves market appeal as widespread substitution of cheaper product for barramundi fillet has attracted adverse publicity in recent years.

The labour intensive nature of fish culture means that the Australian industry is somewhat vulnerable to competition from imports of frozen barramundi, however the ability to market a fresh chilled product of guaranteed quality will probably continue to allow the Australian product to sell at a premium.

The prospects for export of Australian cultured barramundi do not look as promising. It apparently costs Sea Hatcheries Ltd about $A5 per kg to produce plate sized fish. This is roughly equivalent to the supermarket retail price of similar product in Thailand. The premium price paid for fresh chilled product in Australia would be much harder to obtain on overseas markets where cultured barramundi would have to compete as a frozen product against barramundi produced in Asia, Nile Perch from Africa, and European Sea bass, *Dicentrarchus labrax*. Sea Hatcheries Ltd. considers there are few prospects on Asian markets but there could be opportunities in Europe where taste evaluation of the companies product was recently carried out (D. Hallam, pers. comm.).

The development of dry pellet diets has been a major factor allowing the development of the barramundi grow-out industry in Australia. Problems with cost and continuity of supply would probably preclude any large scale culture based on trash fish feeding. Further trials comparing growth and food conversion in salt and fresh water over the entire grow-out period would be valuable as some published information indicates more rapid growth in freshwater.

The prospects for hatchery production in Australia are good and are not limited to supplying the grow-out culture industry. As mentioned above there are prospects for a major expansion of the recreational fishing industry through the stocking of large public reservoirs. In Queensland alone there are over than 100 large reservoirs with individual capacities in excess of $1 m^3 \times 10^6$ (MacKinnon, 1987b) and the majority of these have thermal regimes suitable for survival of barramundi.

In addition to the public pressure for the stocking of reservoirs there has been considerable public pressure for the « restocking » of river systems where barramundi populations are perceived as declining. A number of complex issues have to be considered if such programs are to be effective and they can easily be counterproductive to the conservation of the naturally reproducing population. Q.D.P.I. is evaluating such stockings as a possible management tool however the current indications are that they should be approached with caution.

There is also potential for sales of fingerlings to owners of numerous private dams. Stocking of these small farm dams forms a significant part of the market for several hatcheries producing native freshwater fish. Judging by the enquiries made to Q.D.P.I. barramundi is a highly favoured species for farm dams.

Differing hatchery techniques might be adopted to produce fingerling fish for different purposes. At present cost savings in production of fingerling fish can be achieved by transferring advanced larvae to ponds and this may well be the best method to provide stock for farm dams, reservoirs and natural waters. The grow-out industry however will presumably require fish of a uniform size which are weaned onto artificial diets and unless methods for weaning and grading pond reared fish are developed most production for grow-out will continue to be by intensive tank culture.

The Australian hatchery industry is protected from possible import competition by quarantine regulations which prohibit the import of live fish except for an approved list of aquarium species. At the present time there seems to be little opportunity for export of hatchery product however the possible future development of *L. calcarifer* strains with superior characteristics for aquaculture could create markets overseas as well as increasing profitability of Australian grow-out operations.

General prospects for future development of Australian barramundi culture are good but experience to date shows that speculators cannot be guaranteed a quick return. Adaptability, patience and close contact between researchers and culturists are essential to realizing the full potential of the industry.

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