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Culture of Larval Sea Bass, *Lates calcarifer* (Bloch), in Saltwater Rearing Ponds in Queensland, Australia

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Abstract

Larval sea bass (*Lates calcarifer*) were stocked into a saltwater rearing pond 48 hours after they had hatched. The pond had been fertilized with a combination of organic and inorganic fertilizers using techniques developed for saltwater hatchery ponds in Texas. Approximately 63,000 fingerlings were harvested from two trials after 25 and 22 days growth in the pond, respectively. Mean total length was 38.8 and 35.5 mm for the two trials, representing growth rates of 1.6 and 1.4 mm per day, respectively. Pond management and fertilization techniques used on saltwater hatchery ponds in subtropical Texas were applicable to conditions in tropical Queensland. These techniques can be used to produce large numbers of sea bass fingerlings for aquaculture and to enhance sea bass populations in recreational fisheries.

Introduction

Sea bass (*Lates calcarifer*), known in Australia as barramundi, is a highly valued food fish throughout its range and supports both commercial and recreational fisheries (Grey 1987). It provides the basis of a large aquaculture industry in Asia and more recently has generated interest in the aquaculture potential of rearing fingerlings to enhance wildstocks. Rimmer (1989) noted that sea bass are catadromous and cannot support self-maintaining populations in freshwater

impoundments, which are important recreational fishing areas throughout eastern Australia. For this reason there is considerable public demand for sea bass to be stocked into impoundments as well as rivers and streams where existing sea bass populations are believed to be in decline. The Queensland Department of Primary Industries (QDPI) began research into the culture of sea bass in 1984-85, primarily to stock freshwater reservoirs as well as to develop techniques for the aquaculture of this species in Australia (Pearson 1987).

Techniques for the culture of sea bass were developed in Thailand (Wongsomnuk and Manevonk 1973) and many countries are producing sea bass and supporting further research into culture techniques (SCS 1982). Basic techniques vary slightly between countries. Broodstock are either collected from the wild (Garrett et al. 1987) or maintained in captivity and induced to spawn naturally or with hormone injections (Kungvankij 1987). Larval sea bass are reared on rotifers and brine shrimp (Stewart et al. 1987) until they reach a size suitable for growout at which time they are stocked in external ponds, cages, or reared in tanks (SCS 1982). The most labor-intensive, and cost-prohibitive phase of sea bass production, is the "nursery stage" where larvae must be maintained for 18-20 days on a diet of rotifers and brine shrimp until they reach a size suitable for weaning on to artificial feed (10 mm total length [TL]) or for stocking (>25 mm TL).

Red drum (*Sciaenops ocellatus*) are presently cultured in saltwater ponds in Texas from first feeding larvae to 25 mm TL, thus by-passing the indoor nursery stage (McCarty et al. 1986; Rutledge 1988). Larvae feed on naturally occurring marine copepods whose numbers have been enhanced using fertilization techniques developed for freshwater ponds (Geiger 1983). Survival rates in ponds average over 50% and over 50 million fingerlings have been produced since 1983. This paper reports the pond rearing of sea bass from first feeding larvae to fingerling size using the techniques developed for saltwater ponds in Texas.

Materials and Methods

These experiments were conducted from October 1989 to February 1990 in a 0.12-ha earthen pond located on a commercial shrimp farm 10 km south of Innisfail on the Moresby River, Queensland. Water for the pond was pumped from the river and flowed by gravity from a large canal through a 300-mm diameter pipe. Incoming water was filtered

through a 420-µm or 300-µm nylon mesh filter to prevent the introduction of wild fish or macro-invertebrates. The pond was initially treated with 0.25 tonne of agricultural lime (38.8% calcium) and fertilized with a combination of organic and inorganic fertilizers according to Rutledge (1988). The fertilization schedule and rates were modified (Table 1) to account for reduced pond size (shorter time for filling). Lucerne (alfalfa) pellets were applied at a rate of 907 kg·ha^{-1} (109 kg total). D.A.P. (NPK 18-19-0) was applied at rates calculated to provide approximately 1 mg·l^{-1} P_2O_5 and N (5 kg per application, respectively).

Eggs were obtained from spawning sea bass broodstock captured in the vicinity of Weipa in Far North Queensland using methods described by Garret et al. (1987). Fertilized eggs were transported by air to the Northern Fisheries Centre, Cairns. Approximately 48 hours after hatching, at which time the larvae had developed functional mouthparts, they were transported to the pond site in plastic bags filled with water and oxygen. Fry were tempered for 30 minutes to compensate for differences in salinity, temperature and pH.

Water quality and plankton samples were collected periodically before and after fish had been stocked to monitor conditions in the pond and determine the abundance and status of food organisms for larval sea bass. Dissolved oxygen (DO), water temperature, salinity and pH were measured daily with a Water Checker U-7 (Horiba Scientific Instruments). Plankton were collected with a plankton net having a 15-cm diameter opening, 40-cm bag and 25-µm mesh. Ichthyoplankton tows were made with a conical ichthyoplankton net with a 39-cm opening, 110-cm bag and 297-µm mesh. Plankton were preserved in FAA (Gurr 1973), identified to the lowest taxon practical and enumerated. Juvenile sea bass were captured in small bait traps or with a 1-m^2 lift net with 1-mm mesh.

The pond was drained 25 and 22 days after stocking for the second and third trials, respectively. The number of fish harvested was determined by weight or volumetric subsampling.

Results

First Rearing Trial

The initial attempt to rear first-feeding sea bass in extensive ponds was not successful. Pond fertilization was initiated to coordinate with the first new moon cycle in October. Inorganic fertilizer (5 kg D.A.P.)

Table 1. Modified schedule for pond fertilization including types of fertilizer, amounts and time of application in the rearing cycle.

First and second rearing trials			Third rearing trial		
Day	Fertilizer	Amount	Day	Fertilizer	Amount
1	Begin filling pond Initial inorganic	(5 kg 18-19-0)	1	Begin filling pond Initial inorganic	(6 kg 18-19-0)
3	1/2 organic	(54 kg Lucerne)	3	1/2 organic	(54 kg Lucerne)
12	Inorganic	(5 kg 18-19-0)	6	Inorganic	(6 kg 18-19-0)
14	Stock with fish		8	Stock with fish	
17	1/8 organic	(13.6 kg Lucerne)	10	1/8 organic	(18 kg Lucerne)
22	Inorganic	(5 kg 18-19-0)	12	Inorganic	(6 kg 18-19-0)
24	1/8 organic	(13.6 kg Lucerne)	14	1/8 organic	(18 kg Lucerne)
27	1/8 organic	(13.6 kg Lucerne)	18	Inorganic	(6 kg 18-19-0)
31	1/8 organic	(13.6 kg Lucerne)	20	1/8 organic	(18 kg Lucerne)

and organic fertilizer (27 kg lucerne) was applied. However, mature sea bass broodstock were not obtained and subsequent applications were cancelled. Copepod populations (*Paracalanus* and *Eucalanus* spp.) did respond to the initial fertilizer application rising in density from 23 to 261·l^{-1} in seven days. To prepare for the next full moon cycle, approximately 60% of the water was drained, the pond was refilled and re-fertilized. Fertilization rates were halved to account for the fertilizer already in the pond. Water quality parameters during both periods were acceptable (Table 2). Copepod population density again responded to the fertilizer, rising from 31 to 72·l^{-1} the day before stocking.

Table 2. Summary of water quality data for pond rearing trials.

Trial	Temp. (°C)	Salinity (ppt)	D.O. (mg/l)	pH
1	25.2-28.7	26 -28	7.1-13.7	7.7-8.3
2	28.9-35.6	18 -27	8.3-16.8	7.8-8.9
3	28.4-36.5	18 -25	4.5-14.0	8.1-9.2

Approximately 50,000 2-day-old sea bass (2.5 mm TL) were stocked 12 days after refilling the pond. Three days later, an ichthyoplankton tow failed to indicate the presence of any larval sea bass. Cone jellyfish (Pleurobrachia) and arrow worms (Chaetognatha) were both present in the sample. Copepod densities had fallen to 5·l^{-1} and 13 arrow worms were collected in the 33-l plankton tow. Alvariño (1965) noted that chaetognaths are voracious animals feeding on copepods, other chaetognaths and young fishes. Larval sea bass that were placed in a petri dish containing chaetognaths were attacked immediately, indicating the highly predacious nature of these organisms. These combined factors indicated little chance for survival of the initial stocking, so the pond was drained to prepare for another attempt.

Second Rearing Trial

Approximately 100,000 2-day-old larvae were stocked 15 days after the pond was filled according to the schedule in Table 1. During the next four days, 47 cm of rain fell. Salinities of 8 ppt were recorded in the upper 3 cm of the pond and salinities below this layer dropped from 24 to 19 ppt. An ichthyoplankton tow taken three days after stocking captured only

three fish suggesting poor stocking survival (Erickson et al. 1986); therefore, a second stocking was made. Fish in the second stocking were one day older and had received a single feeding of rotifers (*Brachionus plicatilis*) prior to introduction into the pond. These fish had to be tempered for two hours with water drawn from the pond bottom to compensate for water quality differences caused by heavy rain. Larvae were introduced through a 150-mm PVC pipe to penetrate the freshwater barrier at the pond surface. Mortalities during the tempering process were excessive (approximately 90%).

Initial plankton densities in the pond were $6 \cdot l^{-1}$ and only rose to $47 \cdot l^{-1}$ three days before stocking. One week after the heavy rains, a marine cladoceran (*Penilia* sp.) appeared in the plankton tows and comprised 97% of adult copepods in the samples. Salinity at stocking was 27 ppt but had dropped to 18 ppt by the time of harvest (Table 2).

A total of 20,000 fingerlings weighing 22.8 kg were harvested from the pond 25 days after stocking. Production rate of fingerlings was equivalent to $170{,}000 \cdot ha^{-1}$. Average TL was 38.8 mm (range 22-60 mm). Average growth rate was 1.6 mm per day and many of the fish reached 2 mm per day. Sea bass reared in the pond grew 2-3 times faster than sea bass larvae reared in the hatchery and fed rotifers and brine shrimp (Fig. 1).

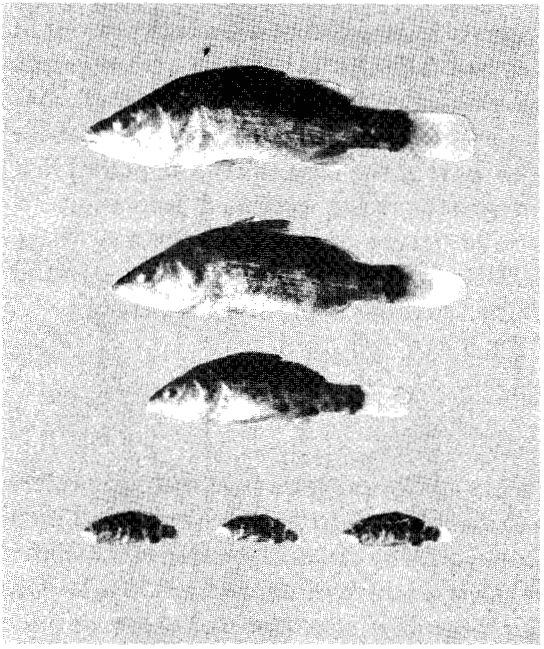

Fig. 1. Size comparison of sea bass reared in a saltwater pond for 25 days (top 3) to 30 day-old fish reared in a hatchery and fed a diet of rotifers and brine shrimp (bottom 3).

Third Rearing Trial

Approximately 100,000 2-day-old larvae were stocked eight days after the pond was filled and fertilized according to the schedule in Table 1. No larvae were captured in ichthyoplankton tows despite considerable sampling effort. Juvenile sea bass were captured on a 1-m^2 vertical lift net from day 18 onwards.

Plankton densities were notably higher during this trial. Numbers of copepod nauplii peaked (410·l^{-1}) the day after sea bass larvae were stocked (Fig. 2), while copepod adults and cladocerans reached maximum densities (245·l^{-1} and 61·l^{-1}, respectively) on day 16. Numbers of all zooplankton groups declined rapidly after peaking (Fig. 2). Water quality data for this trial are shown in Table 2.

An estimated 43,000 sea bass juveniles were harvested from the pond 22 days after stocking; a fingerling production rate equivalent to 360,000·ha^{-1}. Average TL was 35.5 mm (range 22.0-48.5 mm TL). Average growth rate was 1.4 mm per day (range 0.9-2.0 mm per day).

Discussion

The initial rearing attempt, although a failure, provided information valuable to future extensive rearing programs. The initial ten-fold increase in copepod densities demonstrated the potential of culturing naturally occurring food organisms under an intensive fertilization regimen. Both the amount and rate of increase in copepod numbers was consistent with observations from saltwater hatchery ponds in Texas (McCarty et al. 1986). The attempt to prolong the productivity in the pond by partial draining and re-fertilization may or may not have been successful. Copepod densities were increasing steadily until the occurrence of arrow worms and cone jellyfish, both noted zooplanktivores. C.E. McCarty (pers. comm.) reported that the presence of these organisms indicates that the pond had matured and was on the decline. Ichthyoplankton tows during the second and third trials, however, failed to capture any arrow worms. Either the initial infestation was a single event occurrence, the use of a 297-μm mesh filter during the second trial prevented their introduction, or the sea bass fingerlings in the pond prevented their establishment through predation. Alvariño (1965) noted that tropical chaetognaths breed to some extent throughout the year. If this is the case, the use of a 297-μm filter may be warranted.

This mesh size does affect the number of copepod adults entering the pond, however, and if not needed for predator control should be changed to a larger mesh (420-500 μm).

Plankton densities peaked faster than is seen in saltwater ponds in Texas. This may be due to higher water temperatures in the Queensland ponds (25-37°C) compared with Texas ponds (18-30°C). The optimal time for stocking larvae is at about the time that copepod nauplii numbers peak, since copepod nauplii are an optimal size for first feed of marine fish larvae (i.e., about 50-100 μm wide). These trials indicated that the copepod nauplii numbers peak around day 8-9, in contrast with saltwater ponds in Texas where copepod nauplii peak around day 14.

The harvest of over 60,000 fingerlings from the second and third rearing attempts demonstrates the feasibility of using saltwater ponds to rear larval sea bass to fingerling size. Gut content analyses were not undertaken, but the decline in plankton densities to negligible levels observed in the third rearing trial (Fig. 2) suggest that all the plankton groups were heavily predated. Sea bass were observed feeding heavily on dense concentrations of mosquito larvae which developed 30 days after pond filling. Cannibalism was also observed during the later stages (days 18-20) and particularly during pond harvest. Experience with predatory fish raised in hatchery ponds in Texas indicates that once cannibalism is established, mortality rates as high as 50% per day can be expected. If the sea bass larvae were harvested at a smaller size (e.g., 25 mm TL) it is likely that survival would be higher.

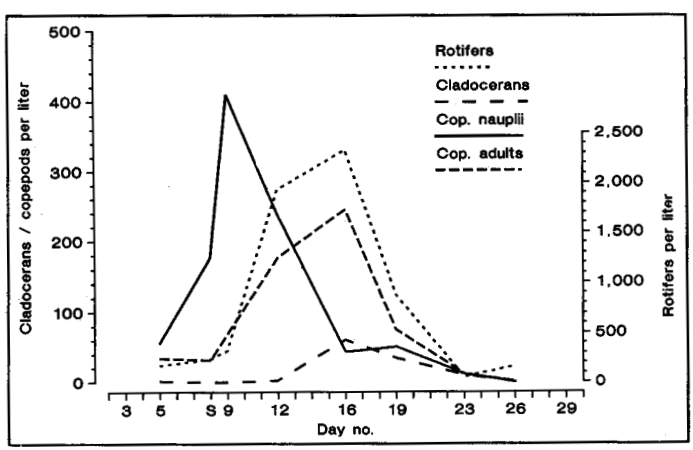

Fig. 2. Densities of copepod nauplii, copepod adults, cladocerans and rotifers during the third rearing trial. 'S' represents the day sea bass larvae were stocked.

Although these experiments indicate that extensive rearing of sea bass larvae in saltwater ponds is an alternative to the intensive techniques traditionally used to rear this species, further research is necessary to increase the reliability of extensive larval rearing of sea bass. In particular, further research on the population dynamics of zooplankton in saltwater ponds and the effects of physicochemical factors, such as temperature and salinity, is necessary to develop a detailed model of the dynamics of extensive larval rearing ponds. The development of reliable sampling techniques for sea bass larvae in the pond would enable rapid assessment of the success of larval stocking in the critical few days immediately following introduction of larvae to the pond.

Growth of sea bass during the experiment was exceptional compared to rates reported for intensive systems in the literature. Maneewong (1987) reported sea bass that were 30 mm after 45 days in Thailand, while Russell et al. (1987) produced 7-10 mm larvae in 16 days in intensive systems in Queensland. MacKinnon (1987) reported a mean length of 50 mm after 42 days for sea bass reared intensively for 16 days and subsequently transferred to freshwater ponds for an additional 25 days. Methods presently used by the QDPI to produce fingerlings of a suitable size for stocking freshwater impoundments (40 mm TL) require this two-tiered approach. However, the freshwater phase could be eliminated by rearing fingerlings in saltwater ponds.

The growth rate observed (1.4-1.6 mm per day) could also provide benefits to the sea bass aquaculture industry. Sea bass reared in saltwater ponds would be approximately 23 mm long in 15 days, which is more than adequate for transfer to freshwater (Rasmussen 1991) or conversion to a pellet diet. With a 15-day growout and a 10-12 day period for pond preparation, it would be possible to produce one crop each month of the spawning season corresponding with the lunar cycles. This would greatly increase the availability of fingerlings and alleviate this major impediment to the development of the industry (MacKinnon 1984).

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