COMPARISON OF INTENSIVE AND EXTENSIVE CULTURE OF THE TASMANIAN WHITEBAIT *LOVETTIA SEALII* (JOHNSTON)

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History of the whitebait fishery

The fishery dates back to the early 1930's. Large scale commercial fishing began in the early 1940's and reached a peak catch of 515 tonnes in 1947. The fishery could not sustain this kind of pressure and declined dramatically the following year. Subsequent to this the catches remained severely depressed (< 50 t) and the fishery was closed in 1974.

The whitebait runs consist of six species of fish:

Tasmanian whitebait	*Lovettia sealii*
Jollytail	*Galaxias maculatus*
Spotted galaxias	*G.truttaceus*
Climbing galaxias	*G.brevipinnis*
Tasmanian mudfish	*G.cleaveri*
Smelt	*Retropinna tasmanica*

The Tasmanian whitebait and Jollytail are the predominant fish and the Tasmanian whitebait is especially at risk since the fishery collects adults before they spawn.

Biology

Lovettia sealii (Sub-order Salmonoidei, family Aplochitonidae) is represented by a single genus, found only in Tasmania.

Lovettia is anadromous and adults collect in estuaries during winter and in early spring move up the rivers to spawn. At this stage they are known as whitebait. Mature fish are 1 year old, 45-49 mm long and weigh 0.8 to 0.9 g. Females carry up to 350 eggs and spawn in rivers at the upper reaches of tidal influence.The eggs, 1.1 mm diameter, are adhesive and attached to submerged logs, stones and branches, below low water mark and located in areas of high flow. Following several spawns per fish they progressively deteriorate and die. *Lovettia* are essentially a one year fish and less than 0.01% of fish survive for two years. Larvae hatch about 20 days later and are carried downstream into the estuaries, returning one year later as adults (Blackburn 1950; Fulton and Pavuk 1988).

Little is known about the life history of *Lovettia* between hatch and maturity. Work by Fulton and Pavuk (1988) using isozyme electrophoresis indicates that there are at least five genetically distinct populations in Tasmania. This suggests that *Lovettia* move only short distances in the sea.

Aquaculture investigations

Aquaculture investigations of *Lovettia* began in 1987 as a private venture by Frish Pty. Ltd. on the east coast of Tasmania, near Triabunna. At the time of writing (1991) fish have been reared through three generations.

The low individual weight of fish means that a large number of larvae must be reared to achieve a commercially useful harvest. The labour and infrastructure requirements for growing large amounts of rotifer and *Artemia* make this kind of culture uneconomic. As a result of this a new approach has been developed. Live zooplankton are harvested from local estuaries using a vessel designed for this purpose. A description of the presently accepted technique of intensive marine fish culture, together with the new approach, follow.

Intensive culture

Adult *Lovettia*, when fully mature, spawned and deposited eggs on the sides of fibreglass hatching troughs. Spawning was stimulated by increased flow and lowered salinity.

Eggs were incubated in freshwater using recirculating or flow through systems. Dead eggs readily become infected with *Saprolegnia*. Since the small adhesive egg is not easy to remove, the *Saprolegnia* can rapidly overcome the surrounding live eggs. Treatment to successfully control the spread of the fungus involved increasing the salinity in the hatching troughs to 25 ppt for 30 minutes daily. Turbulent flow also assists in controlling the fungus.

Newly hatched larvae, 5 mm long, were removed to 4 m^3 fibreglass tanks where they were acclimatised to marine water of 34 ppt over a period of 2 days. The larvae were active swimmers and began feeding in the first 24 hours at 12-14°C. A recirculating system including a high pressure sand filter and biological filter was used to maintain water quality in the tanks.

Feeding - standard method

Brachionus plicatilis was used for initial feeding. Levels of highly unsaturated fatty acids in the rotifer were boosted using emulsified marine oil for direct enrichment (Watanabe *et al.* 1983). Uneaten rotifers were flushed out of the system overnight. Observations of food in the gut indicate that *B.plicatilis* is readily digested leaving only traces of the mastax in recognisable form. Eggs of the rotifer however, remain intact throughout the digestive tract. Mean time to 90% gut evacuation following feeding to satiation with rotifers is 3.5 hours at 12°C in fish 7.7 mm long and 18 days old.

Feeding with rotifers continued for 20 days. At this time *Artemia* instar II nauplii were introduced. Instar I nauplii remain almost intact during their passage through the gut suggesting that they are not well digested, whereas this is not the case for the instar II nauplii. *Artemia* instar II were enriched with marine oil in a similar manner to the rotifers.

After day 30, *Artemia* were the sole food. Fish were weaned onto salmon starter crumble at day 45. Following weaning, fish were fed standard salmonid pelleted food up to 2 mm in diameter.

Feeding - live zooplankton

Live natural marine zooplankton was the sole food source for *Lovettia* from hatch to adult.

The zooplankton was harvested daily from local estuaries and split into different size fractions. Initial feeding commenced with zooplankton in the size range 63 to 250 μm. This was increased to 500 μm at day 50.

Feeding with live zooplankton has benefits in terms of water quality in the larval rearing tanks. Compared to feeding with *Artemia* and pellets, there are no *Artemia* cysts, turbidity is increased, surface film is not present and ammonia levels remain very low. As a consequence daily feeding and maintenance including syphoning and screen cleaning is reduced from 3 hours per tank per day for the standard method to 45 minutes per tank per day for the new approach, which includes harvest time on the zooplankton harvester.

Extensive culture

Lovettia were spawned and eggs incubated as described for the intensive technique.

Just before hatch the hatching troughs were drained of water, covered and transported to culture ponds. Culture ponds were partially filled with fresh water filtered to 500 µm to exclude predators. Larvae were introduced to the ponds and the ponds progressively filled with seawater, filtered to 500 µm, over a period of several weeks. Fish were fed by adding live zooplankton daily to the pond. Systems are now in place to provide nursery ponds and tanks at the culture ponds so that larvae can be acclimatised to fully marine before they are placed in the ponds. Ponds can then be manipulated to produce a bloom of zooplankton prior to larvae entering. Fish are fed additional zooplankton as required.

Harvesting of live zooplankton

Harvesting of live zooplankton in commercially useful quantities has been made possible due to the development, by Frish Pty. Ltd., of a special boat designed for this purpose, illustrated in Figure 1. The trailerable vessel is 7.5 m long, 2.5 m wide, weighs 475 kg and has a minimum operating depth of 0.8 m.

The patented device harvests and concentrates zooplankton in the upper waters by scooping them onto a primary dewatering screen then size sorting through a series of sieves. The stainless steel mesh for the sieves and primary screen may be changed to accommodate different screening requirements. Harvested and concentrated zooplankters are stored in 700 L wells on board the boat and unloaded by pumping directly into ponds or a transport tank. The device is operated by one person and powered by an outboard motor and auxiliary petrol engine which provides power for pumps and hydraulic rams.

Results and discussion

Zooplankton

The harvesting boat is presently operated on local estuaries, primarily Little Swanport and Spring Bay, Triabunna.

Primary screen size is 63 µm mesh (Swiss Screens, stainless steel, dutch twill) when feeding larval fish. This is increased to 105 µm as fish grow. The water filtering rate is 200 L per second using the 63 µm mesh, and 300 L per second with the 105 µm mesh.

Zooplankton harvest rates in open systems such as estuaries vary according to time of day, state of tide and season. Monitoring of zooplankton catches indicates the most favourable times to harvest. Harvest rates at present (spring, 1991) in Spring Bay are :

63 - 250 µm size fraction 2.4 - 3.0 x 10^6 zooplankters/hour

250 - 500 µm size fraction 1.8 - 2.4 x 10^6 zooplankters/hour.

About 10% of harvested zooplankton are damaged during harvest and die. The remaining organisms stay active in the water column for at least 24 hours. Zooplankton are not fed to fish after 24 hours.

Future developments include the construction of specialised zooplankton ponds filled with filtered sea water to exclude predators of zooplankton. This is expected to increase harvest rates by a factor of 10 to 1000 times.

Zooplankton from the estuaries contains predominantly copepods, including the calanoids *Acartia tranteri* and *A.danae* and the cyclopoid *Oncae media*. For short periods in summer the zooplankton may consist almost entirely of oyster (*Crassostrea gigas*) larvae in the estuaries that support an oyster industry. These are readily consumed by *Lovettia*.

Copepods may be important in the early life history of marine fish. Copepodites and adult copepods are, in general, the main food of marine fish larvae (Hunter 1980). Copepods have high levels of free amino acids (Dabrowski and Rusiecki 1983) which are absorbed directly by the morphologically simple gut of newly hatched fish larvae and may potentially provide a valuable source of energy (Fyhn 1989). Copepods also have high levels of n-3 highly unsaturated fatty acids even when feeding on foods low in these fatty acids (Robin *et al.* 1984). Highly unsaturated fatty acids are essential for most marine fish larvae.

Zooplankton from Spring Bay, 2 day old *Artemia* and adult *Lovettia* whole fish have been analysed for metals by Division of Sea Fisheries , Hobart. Metal levels in harvested zooplankton are higher than in *Artemia* nauplii (Table 1). Data on maximum acceptable levels of metals in feed for marine fish larvae are not available in literature searches. The concentrations found in the *Lovettia*, which had been fed entirely on the harvested zooplankton for 7 months prior to analysis, did not show an excessive accumulation of the metals (Table 1). Cadmium and zinc levels in pelleted feed, of 1.02 and 161 µg/g dry weight respectively produced levels of 0.11 and 7.6 µg/g wet weight respectively, in the flesh of farmed salmon on Hawaii (Fast *et al.* 1990). This also suggests that accumulation of metals from feed is not excessive. Growth of *Lovettia* fed the zooplankton was not significantly different from *Lovettia* fed on rotifers, *Artemia* and pellets, and survival was significantly better in the zooplankton fed fish. This suggests that the levels found in the zooplankton are not detrimental to larval development. Levels of metals in *Lovettia* were lower than maximum permissible levels in fish flesh for human consumption (Table 1).

Intensive culture

There was no significant difference in growth between the fish fed on rotifers, *Artemia* and pellets (1989-90) and the fish fed entirely on harvested zooplankton (1990-91). Growth in cultured *Lovettia*, measured as total length, is almost linear from hatch to maturity. Mean weight of cultured fish at harvest, 1.1 g, is larger than wild fish (0.8-0.9 g).

Major mortalities occurred in the 1989-90 season with peaks occurring at 15 and 37 days accounting for 70% losses. Overall mortality was greater than 90%. During the 1990-91 season no mortality peaks occurred and overall mortality was less than 50%. This suggests that zooplankton is nutritionally more competent than the standard diet of rotifers, *Artemia* and pellets.

Extensive culture

Culture of *Lovettia* in a pond has been attempted once to date (September 1991). Final biomass in the pond will be determined at harvest. Recent sampling of the pond has shown that many fish are small and immature compared to the larger fish in the pond and those in the intensive culture system. Previous samplings were done at night by attracting fish to a light and it is possible that only the larger fish were sampled by this method.

The most likely cause of the underdeveloped fish is food limitation, which can be a significant problem in extensively reared fish. In general extensively reared fish are more difficult to sample and are not graded. This can give rise to faster growing fish that outcompete others and leads to a greater range of sizes compared to intensive culture.

However, the advantages of extensive systems are such that these problems are worth pursuing. Advantages include:

- using natural productivity to produce fish
- diversity of prey species should promote improved growth and survival especially in larval stages
- mechanical failures do not have immediate and potentially catastrophic consequences as they may in intensive culture
- low infrastructure costs

- lower skill level of work force
- lower work time input per fish produced
- lower cost of fish produced.

References

Blackburn, M. (1950). The Tasmanian whitebait, *Lovettia sealii* (Johnston), and the whitebait fishery. *Australian Journal of Marine and Freshwater Research* **1**(2), 155-198.

Dabrowski, K, and M. Rusiecki (1983). Content of total and free amino acids in zooplankton food of fish larvae. *Aquaculture* **30**, 31-42.

Fast,A.W., F.M. D'Itri, D.K. Barclay, S.A. Katase and C. Madenjian (1990). Heavy metal content of Coho *Oncorhynchus kisutch* and Chinook salmon *O.tschawytscha* reared in deep upwelled ocean waters in Hawaii. *Journal of the World Aquaculture Society* **21**(4), 271-276.

Fulton, W., and N. Pavuk (1988). The Tasmanian whitebait fishery. Inland Fisheries (Tasmania) Report, Inland Fisheries Commission, Hobart, Tasmania.

Fyhn, H.J. (1989). First feeding of marine fish larvae: Are free amino acids the source of the energy? *Aquaculture* **80**, 11-120.

Hunter, J.R. (1980). The feeding behaviour and ecology of marine fish larvae, pp. 287-330. In: J.E. Bardach, J.J. Magnuson, R.C. May and J.M. Reinhart (eds.) Fish behaviour and its use in the capture and culture of fishes. ICLARM Conference Proceedings 5, 512 pp. International Centre for Living Aquatic Resources Management, Manila, Philippines.

National Health and Medical Research Council (1985). Model Food Standard Regulation, A 12. Metals and Contaminants in Food. Australian Government Publishing Service, Canberra.

Robin, J.H., G. Stephan, H. Le Delliou, and G. Salaun (1984). Production of live food organisms using mixed diets. Technics (sic) and effect on biochemical composition. Acts of the Norwegian-French workshop on Aquaculture, IFREMER, Brest, France.

Watanabe, T., T. Tamiya, A. Oka, M. Hirata, C. Kitajima and S. Fujita (1983). Improvement of dietary value of live food for fish larvae by feeding them on w-3 highly unsaturated fatty acids and fat soluble vitamins. *Bulletin Japanese Society of Scientific Fisheries* **49**(3), 471-479

Table I. Metal concentration (μg/g) in harvested zooplankton, *Artemia* nauplii 2 days post-hatch, adult *Lovettia* and maximum permissible levels in fish flesh for human consumption (Control)

Metal	Concentration (μg/g)				
	Zooplankton[a]		*Artemia*	*Lovettia*[b]	Control[c]
	wet wt.	dry wt.	wet wt.	wet wt.	wet wt.
Cadmium	0.15	1.22	0.02	0.04	0.2
Copper	3.02	24.9	6.5	1.4	10.0
Zinc	57	473	19.6	19.9	150
Mercury	0.01	0.08	n.d.	n.d.	0.5

n.d. not determined

[a] single mixed zooplankton sample, Spring Bay, August 1991.

[b] adult whole *Lovettia* grown entirely on harvested zooplankton.

[c] National Health and Medical Research Council (1985) recommendations.

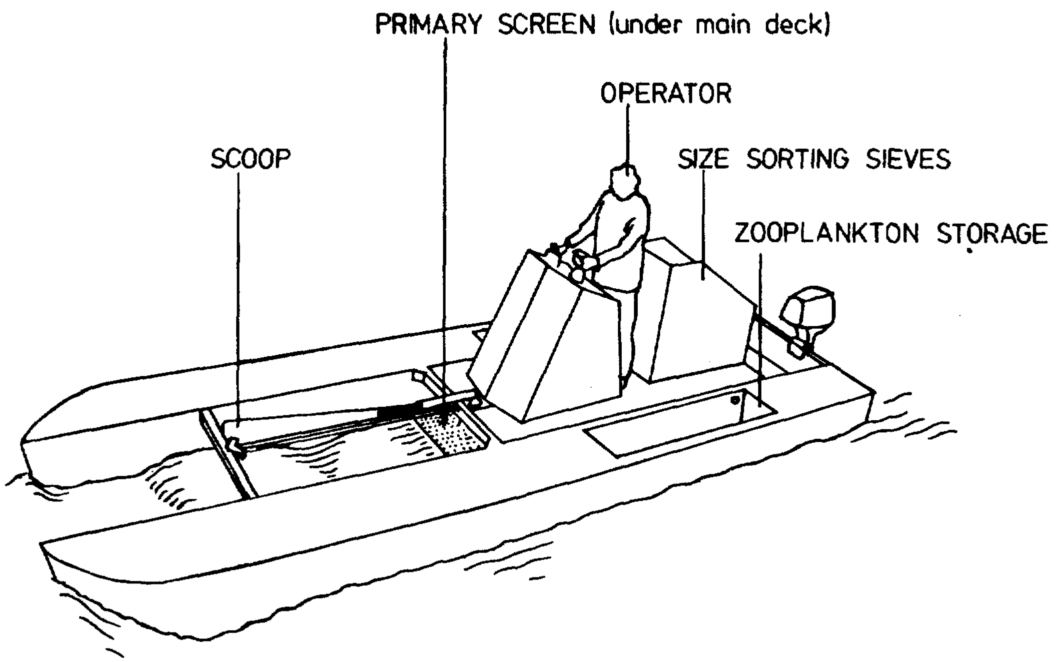

Figure 1. The zooplankton harvesting vessel.