AQUARIUM INDUSTRY OFFERS HOPE FOR TASMANIA'S CRITICALLY ENDANGERED HANDFISH

by Rachelle Hawkins

(with two text-figures, one table and ten plates)

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Southeast Australia, and most notably Tasmania, is the last home to the Handfishes, a unique group of marine fish that use their fins for walking. A range of threats occur across all species, with four listed as endangered, two as critically endangered, and the Red Handfish now on the brink of extinction. This paper summarises the contribution being made to the national recovery of the Spotted Handfish and Red Handfish by a captive breeding project underway at Beauty Point in northern Tasmania. Information is provided on husbandry techniques, survival and growth rates in captivity and a trial underway to identify their reproductive strategies. This program highlights the contribution the aquarium industry can make to improving the survival of two of the world's most unique species of marine fishes and the collaboratives efforts of those involved.

Key Words: Spotted Handfish, *Brachionichthys hirsutus*, Red Handfish, *Thymichthys politus*, Tasmania, critically endangered species, IUCN Red List.

INTRODUCTION

Handfishes (Family Brachionicthydae) are the most threatened bony fish family in the world, with seven of 14 species now listed as either Critically Endangered or Endangered on the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (Stuart-Smith *et al*. 2020). In 1996 the Spotted Handfish *Brachionichthys hirsutus* was the first marine fish to be placed on the IUCN Red List of endangered species, and their range is limited to the temperate waters of southeastern Australia, predominantly Tasmania (Stuart-Smith *et al.* 2020). However, this was not always the case as fossil evidence shows they once inhabited many estuary systems around the world (Carnevale & Pietsch 2010), but their tendency to inhabit shallow waters near urban areas and their low mobility has made them vulnerable to a range of disturbances, and over the past 40 years there has been a rapid decline in Spotted Handfish numbers. Furthermore, in the 1960s and 1970s handfish were routinely collected for practical demonstrations at Hobart's university (Lynch 2017) as they made attractive teaching tools, and their numbers were presumably more abundant at this time. This decline triggered the CSIRO (Commonwealth Scientific and Industrial Research Organisation) in Hobart to commence regular field research, population monitoring and habitat protection measures.

In 1997 scientists at CSIRO conducted their first trial of captive-rearing young, with the view to releasing them back to the wild to boost natural populations (Bruce *et al.* 1997). Field research has continued to be a strong focus for CSIRO, especially population monitoring, but also monitoring habitat quality and extent and trialling protective measures (Lynch 2019). Three main factors have been identified as significantly contributing to the Spotted Handfish's demise: the limitations of their biology, the invasive Pacific Seastar *Asterias amurensis* and urban development degrading their habitat.

In 2019, the critically endangered Red Handfish *Thymichthys politus* was estimated to have fewer than 100 individuals left in the wild and restricted to just two small localities in southeastern Tasmania (Stuart-Smith *et al.* 2020). Its dramatic decline is attributed to its fragmented populations and local increases in the density of native Purple Sea Urchins *Heliocidaris erythrogramma* which overgraze the seaweed habitat it requires for shelter and spawning (Stuart-Smith *et al.* 2020).

Scientists are also addressing the demise of the Spotted and the Red Handfish by breeding and raising them in captivity to learn more about their biology and to provide surplus animals for restocking. Initial breeding and re-stocking attempts were conducted with Spotted Handfish at CSIRO as early as 1997, and due to the continued critical status of the species, this work is being expanded with support from practitioners at Seahorse World in Tasmania, the Zoo and Aquarium Association, the National Environmental Science Program (NESP) and the SEA LIFE Melbourne Aquarium (Lynch *et al.* 2017).

This paper provides an overview of two handfish species currently being managed in captivity by Seahorse World in northern Tasmania as part of national recovery efforts to improve their conservation status (Commonwealth of Australia 2015). It presents new information on their behaviour, housing and husbandry conditions and demonstrates how the aquarium industry can play an important role in their recovery program.

HANDFISH BIOLOGY AND THREATS

Handfish belong to the Family Brachionichthyidae, which comprises 14 extant species all globally restricted to southeastern Australia, with 11 occurring in the seas around Tasmania (Threatened Species Section 2020). Brachionichthyids produce relatively few eggs (approximately 50 to 150 for the three species for which this is known). In addition to these species' low fecundity, their eggs have low dispersal ability due to the lack of a larval stage – meaning the fish hatch as demersal, fully formed juvenile handfish (Stuart-Smith *et al.* 2020). Their unique biology includes their preference to walk on their pectoral fins rather than swim, and this feature compounds the low level of dispersion of the species.

Pacific Seastar

The Pacific Seastar *Asterias amurensis* is a pest from the northern hemisphere introduced into Tasmania in ballast water in the 1980s (Rainer 1995). While it now occurs all around Tasmania, it is most common in the Derwent Estuary. During reproduction (which can occur sexually or asexually), a female Pacific Seastar releases up to 20 million planktonic larvae into the water, where they remain pelagic for 120 days before metamorphosing into juvenile starfish and becoming sexually mature within 12 months (NSW Department of Primary Industries 2017). The Pacific Seastar is well known as an opportunistic predator, consuming a diverse range of epifauna, including stalked ascidians, the preferred natural spawning habitat of Spotted Handfish (Stuart-Smith *et al.* 2020). The control of Pacific Seastar populations is very difficult and experiences in Port Phillip Bay suggest that once a population is established there is little chance of successfully eradicating it (Parry & Cohen 2001).

Habitat degradation

Some of the preferred habitat for the Spotted Handfish is on the seafloor in shallow waters which are ideal sites for urban developments, especially marinas. Marinas with traditional mooring systems are catastrophic for the Spotted Handfish, as every time the wind swings the boat around its moorings, the heavy chain mooring drags along the sea-floor, destroying any egg-mass laid in its path and at the very least, disturbing the handfish, if not causing it physical damage or death. CSIRO are now developing a type of mooring to mitigate these problems. These environmentally friendly moorings do not have a heavy chain but instead they float above an anchor-based weight thereby minimising any interaction with the sea floor (Lynch *et al.* 2020).

Artificial Spawning Habitats (ASH) have been developed and planted out in known handfish habitat where the natural stalked ascidians have been depleted and repeat monitoring has shown these ASHs have been utilised successfully for spawning by the handfish (Lynch *et al.* 2020).

PROGRAM AIM

The goals of the initial project at Seahorse World were:

- to hold and maintain handfish in captivity
- to breed handfish in captivity
- to educate the public about handfish, their plight and conservation efforts
- to raise the next generation of handfish
- to re-stock the Derwent River with healthy juvenile handfish

To achieve these aims it was necessary to:

- research previous Spotted Handfish projects carried out by CSIRO in 1997.
- assign a staff member to be singularly responsible for handfish daily care.
- invest in a high-quality, reliable chiller and lighting equipment to provide their fundamental needs for dissolved oxygen, correct salinity and stable water quality but also mimic the changing photoperiod conditions of the Derwent Estuary to promote breeding.
- have access to a continuous source of live amphipods for food.
- be equipped to provide adequate live food for offspring, should we achieve a successful breeding event.
- have multiple safeguard systems in place to ensure adults and eggs were not all at-risk should systems fail.

HUSBANDRY

In late 2017, ten wild-caught, adult Spotted Handfish were transported to Seahorse World, which is located on the Tamar River in northern Tasmania. They were housed in an off-display research area until they acclimatised and were deemed comfortable enough to be on public display. In December 2018, 16 Red Handfish hatchlings were transported from CSIRO to the same facility. Husbandry methods employed and refined over 22 years of seahorse farming proved invaluable for caring for the handfish, and both species were found to be readily amenable to aquarium conditions.

Diet

Live adult amphipods were fed to both species of adult handfish at this time. The dominant species of amphipod in the lower Tamar area is *Bellorchestia pravidactyla* (pl. 1), a common sandhopper species that burrows in sand beaches (Hughes & Ahyong 2017).

On day four of housing the wild Spotted Handfish adults, it was exciting to find they had laid eggs on the artificial ceramic spawning pole (ASH) that had been supplied by CSIRO (pl. 2).

By day 21, eyes were visible inside the eggs. After an incubation period of 54 days the eggs hatched over a two-hour period, with 81 hatchlings resulting. Like Pot-bellied Seahorses *Hippocampus abdominalis*, the Spotted and Red handfish hatchlings were capable of feeding on Instar II *Artemia salina* from day one, and this was their

PLATE 1 — Amphipod *Bellorchestia pravidactyla* fed to handfishes. Body length approx. 9 mm. (Photograph: Tegan Blackwell)

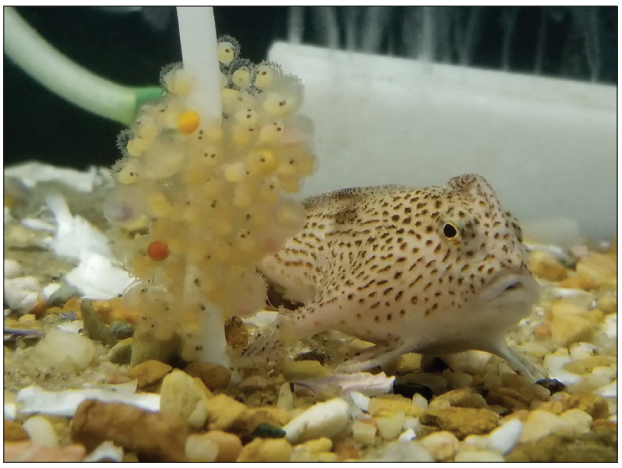

PLATE 2 — Adult Spotted Handfish *Brachionichthys hirsutus* with eggs. (Photograph: Christopher Carey)

PLATE 3 — Juvenile Spotted Handfish feeding on live *Artemia salina*. Hatchling body length approx. 12 mm. (Photograph: Christopher Carey)

PLATE 4 — Juvenile Red Handfish. Note prominent illicium. (Photograph: Jesse Chippindall)

sole diet for four weeks until they were large enough to ingest larger prey. *Artemia salina* were an excellent prey candidate, as they exhibited the 'live prey' movement, could be enriched to suit dietary needs, and could be grown to larger sizes to suit the changing prey size needs of the growing handfish. The limitations of *Artemia salina* as a prey item was that the handfish are typically demersal, and so would only pursue the *Artemia* that swam close to the substrate. This resulted in the vast majority of *Artemia* remaining unconsumed at each feeding session and subsequently flushed out of the outlet resulting in a significant waste of the food source. While it is possible that the uneaten *Artemia* could be re-offered, this poses problems with pathogen transfer and loss of enrichment, and so was never employed, opting instead for fresh, high-quality *Artemia* for every feed session. This was where weaning on to live amphipods was important. As soon as a reliable quantity of amphipods could be sourced that were a suitable size for the juvenile handfish gape (pl. 3), they were transferred onto this diet. The handfish readily switched over to this diet and were regularly observed to use their illicium to attract the prey (pl. 4). The full role of the illicium is still being studied.

Temperature and light regime

It was important to be conservative with temperature throughout the project, as a fatal problem encountered in previous experiments by CSIRO scientists occurred when temperature exceeded 18°C, to an unknown extreme. Therefore, while attempting to mimic the temperature trends of the Derwent Estuary as much as possible, temperature settings erred on the culture water being cooler, rather than overly warm. While this may have potentially slowed handfish rate of growth, ensuring survival was considered a higher priority in the early stages of the project. A focus of future work would be to identify the optimum temperature regime promoting growth while ensuring survival.

Considerable efforts were undertaken to supply aquaria with a source of light that could mimic the photoperiod of the Derwent Estuary and be programmed for wavelength and intensity throughout this period. The lights purchased were employed for the first 12 months of the project; however, their unreliability caused constant power interruptions, and they were eventually abandoned due to safety concerns.

While on display, handfish were housed in tanks which had a more natural appearance including a substrate they could forage in for food (pls 5, 6), but when off display they were housed in bare-bottom tanks which allowed easier removal of faecal matter, uneaten/dead amphipods, and improved disease control. The handfish did not appear to be adversely affected by being housed in a non-natural environment and in these tanks it was also found that less food was wasted, as the live amphipods could not retreat under the substate to escape being eaten. After two years of growing the young, and prior to their re-stocking in the Derwent River, the Red Handfish were transferred to CSIRO laboratories to a tank which more closely resembled the natural environment, to aid their transition to the wild.

Daily care

Daily care involved providing live food, tank cleaning and water quality management. This involved frequent trips to the beach to collect live Amphipods (*Bellorchestia pravidactyla*). To feed the juveniles, live *Artemia salina* were hatched out and grown in this facility and delivered to the handfish twice daily.

Tanks were siphoned to remove faeces and uneaten food. Water quality parameters were measured regularly and maintained within the optimum range by water changes. Natural seawater was pumped up from the Tamar River and filtered to 0.2 µm through a membrane filter and chilled or heated to the appropriate temperature. UV sterilisation was used on some of the handfish systems. The temperature of the handfish was controlled by air-conditioning and in-line chillers.

Handfish health

Health was also monitored with any signs of disease treated promptly and all mortalities investigated by the University of Tasmania or Mt Pleasant Laboratories. Post-mortem results often showed the presence of scuticociliates (free-living marine unicellular organisms) colonising the fish, but it was unknown as to what extent this occurred before fish death. Some of the wild-caught handfish were also infected by parasites; however, these infections were considered unlikely to have led to fish death.

GROWTH RATES IN CAPTIVITY

Figure 1 and figure 2 show growth rates of the two handfish species maintained in captivity at Seahorse World. The fastest growth rate in Spotted Handfish occurred during the first year, followed by a year when the average length did not change before resuming growth (fig. 1).

A more uniform growth rate was observed for the Red Handfish under culture over a two-year period.

Much of the project has also been devoted to observing the handfish and documenting their behaviour including using their fins and illicium (pls 7, 8). Handfish research is very much in its infancy, and therefore any information that could be gleaned on their behaviour, interactions and responses was recorded. This included watching them feed, swim, their startle response, interactions with each other, defecation and respiration.

PLATE 5 — Spotted Handfish. Note the illicium below the eye. (Photograph: Tegan Blackwell)

PLATE 6 — Red Handfish investigating foraging substrate. (Photograph: Rachelle Hawkins)

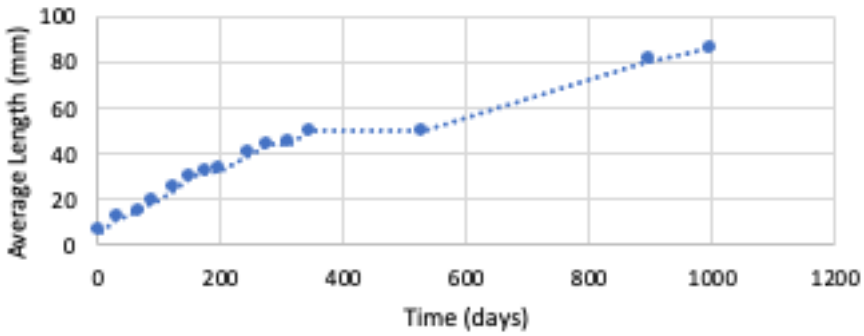

FIG 1 — Growth rate of Spotted Handfish *Brachionichthys hirsutus* in captivity (n = 25).

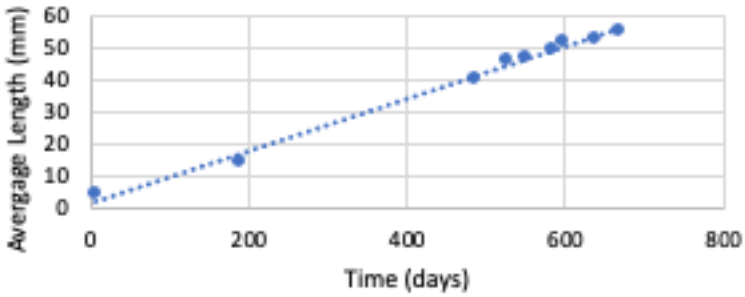

FIG. 2 — Growth rate of Red Handfish *Thymichthys politus* in captivity (n = 16).

SPAWNS

As mentioned, a highlight of the project occurred in November 2017 when the wild-caught adult Spotted Handfish successfully spawned in captivity using the ASH pole provided. This resulted in the batch of young now raised to maturity. A second spawn occurred in a Spotted Handfish tank containing two handfish and, although these eggs were not fertilised, the female tended them in a similar manner to the female tending fertilised eggs. When these two adult handfish died later in the project, it was revealed that both fishes were female, hence why no fertilisation occurred. Learning how to differentiate between the sexes will be essential for the ongoing success of this project.

The Red Handfish that produced the hatchlings is housed in an off-display production area. She has spawned

PLATE 7 — Red Handfish, adult body length approx. 67 mm. (Photograph: Tegan Blackwell)

PLATE 8 — Spotted Handfish with fully erect fins. Adult body length approx. 95 mm. (Photograph: Tegan Blackwell)

PLATE 9 — Gravid female Red Handfish. (Photograph: Tegan Blackwell)

PLATE 10 — Female Red Handfish tending her eggs. (Photograph: Jesse Chippindall)

twice since (pls 9, 10), but no fertilisation has occurred, despite the presence of two additional adult handfish (of unknown sex status).

An exciting development has recently occurred at SEA LIFE Melbourne, which is housing wild adult Spotted Handfish. Ultrasound technology has been utilised to inspect the gonads of mature handfish to determine their sex and this technology could be invaluable in assisting future breeding programs.

TRIAL IN PROGRESS

Studies investigating the role of stocking densities on breeding success are currently underway at Seahorse World. It has been observed that the Red Handfish adult held at the facility produced eggs three times in three years, while being alone in a tank. Spotted Handfish are almost always observed alone in the wild, except during the breeding season when they come together (Tim Lynch pers. comm. 2020). To test the hypothesis that handfish more readily develop mature eggs while being separate from other adults, and before coming together for breeding, we are trialling seven systems (table 1).

Each system has its own water recirculation system. Tanks within a system share water and have largely similar water quality to each other. Each tank contains at least one artificial spawning pole. After 30 days of isolation, the Spotted Handfish in Systems 3 and 4 will be combined and their behaviour observed. The major limitations of this trial are that the sexes of adult handfish remains difficult to determine and only a relatively small number of individuals are available to undertake multiple replicates.

More studies underway include observation and monitoring of handfish respiration, handfish colouration in various coloured substrate, and the species' startle response.

CONCLUSION

All the stated goals of this program were achieved to varying degrees of success:

- Seahorse World was able to successfully provide the conditions needed for keeping Spotted and Red Handfish in captivity.
- One successful breeding event occurred during the project, and a further three unfertilised spawns occurred, confirming that females can produce eggs in captivity.
- During 2018–19, over 90,000 visitors to Seahorse World were able to view Spotted and Red handfish on display, helping raise awareness about handfish vulnerability and efforts underway to aid their recovery. For the majority of 2020, visitation was interrupted by the COVID-19 pandemic.

Though captive breeding was not without its losses, 25 Spotted Handfish have now been successfully raised to maturity, and 11 Red Handfish are approaching mature size. In October 2020, eight Red Handfish juveniles born and raised in captivity were individually marked with a fluorescent marker and released into the Derwent River, in an undisclosed location determined by the Handfish Recovery Team as an optimal site for re-stocking. Being able to provide animals for this action confirms the contribution captive breeding can make towards boosting population numbers of handfish in the wild and the significant role the aquarium industry can play in this recovery program.

FUTURE FOCUS

The work underway at Seahorse World in northern Tasmania has identified several future research areas to aid handfish recovery. These include:

- being able to sex handfish to aid captive pairings and breeding success
- varying nutritional input by varying diet
- determining optimal temperature for growth and survival
- understanding the role of the illicium
- identifying optimal stocking density and sex ratio for breeding
- varying photo period to determine the effect on breeding.

Ongoing fieldwork to monitor wild handfish populations and to re-sight released individuals is also needed to help measure program success.

TABLE 1 — Aquaculture systems varying the stocking densities of Spotted and Red handfish

System	Tank A	Tank B	Tank C	Tank D
1	1 Spotted	3 Spotted	2 Spotted	2 Spotted
2	10 Spotted			
3	1 Spotted			
4	1 Spotted			
5 Ambassador	5 Spotted	2 Spotted		
6 Ambassador	3 Red			
7	1 Red (wild)	2 Red (wild)		

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