Marine and Coastal

National Environmental Science Program

FINAL REPORT

Project 1.23 – Conservation of spotted handfish

December 2022

Conservation of spotted handfish and their habitats

Tim P. Lynch, Leah Soo
Felicity McEnnulty and Carlie Devine

University of Tasmania | IMAS Institute for Marine & Antarctic Studies

CSIRO

SEALIFE Melbourne

Seahorse World

Handfish Conservation Project

Milestone number: 5

Research Plan number: RP2021

Please address inquiries to:
Dr Tim P. Lynch, Principal Research Scientist
CSIRO, Castray Esplanade, HOBART TAS 7000. GPO Box 1538 HOBART TAS 7001
Ph: (03) 6232 5239
Mob: 0416 089 749
tim.lynch@csiro.au

Preferred citation

Lynch, T.P., Soo, L., McEnnulty, F., and C. Devine (2022) Conservation of spotted handfish and their habitats - Annual report. Report to the National Environmental Science Program. CSIRO.

Copyright

Acknowledgement

This work was undertaken for the Marine and Coastal Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Science Program (NESP).

NESP Marine and Coastal Hub partners

The Australian Institute of Marine Science, Bioplatforms Australia, Bureau of Meteorology, Charles Darwin University, Central Queensland University, CSIRO, Deakin University, Edith Cowan University, Flinders University, Geoscience Australia, Griffith University, Integrated Marine Observing System, James Cook University, Macquarie University, Murdoch University, Museums Victoria, NSW Department of Planning and Environment, NSW Department of Primary Industries, South Australian Research and Development Institute, The University of Adelaide, University of Melbourne, The University of Queensland, University of New South Wales, University of Technology Sydney, University of Tasmania, The University of Sydney, University of Western Australia, The University of Wollongong.

Disclaimer

Cover images: Handfish with eggs image on front cover credit to Matt Testoni, Handfish & flathead, CSIRO image.

This report is available on the NESP Marine and Coastal Hub website:
www.nespmarinecoastal.edu.au

Project Leader's Distribution List

Arm End Pty Ltd	Nigel Palfreyman
Derwent Estuary Program	Ursula Taylor
Zoo and Aquarium Association (ZAA)	Laura Simmons
TasPorts	Susan McLeod
Clarence City Council (CCC)	Allison (Alli) Coombe Glen Popowski
Natural Resource Management (NRM) South	Nepelle Crane Jennifer Hemer
MAST	Peter Hopkins and Keegan Higgs
Royal Yacht Club of Tasmania	Shaun Tiedemann
National Handfish Recovery Team (NHRT)	See list below
Marine and Freshwater Species Conservation, Biodiversity Conservation Division, Department of Climate Change, Energy, the Environment and Water (DCCEEW)	
Threatened Species Policy and Conservation Advice Branch Department of Primary Industries, Parks, Water and Environment (DPIPWE)	Racheal Alderman
Office of the Threatened Species Commissioner (DCCEEW)	Fiona Fraser

The project will also report its findings on a semi-annual basis to the National Handfish Recovery Team (NHRT) – see below. This is a governance body that is constituted between the Tasmanian State and the Commonwealth government with other interested parties:

Chair IMAS & CSIRO scientist	Jemina Stuart-Smith
Secretary, Department of Natural Resources and Environment (Tas)	Holly Wiersma
CSIRO	Carlie Devine
Department of Natural Resources and Environment (Tas)	Karen Richards
Department of Climate Change, Energy, the Environment and Water	Lesley Gidding-Reeve
Department of Climate Change, Energy, the Environment and Water	Alex Hulme
CSIRO	Tim Lynch
University of Tasmania	Neville Barrett
Seahorse World	Rachelle Hawkins
CSIRO	Mark Green
University of Tasmania	Tyson Bessell
University of Tasmania	Lincoln Wong
NRM South	Nepelle Crane

Derwent Estuary Program	Inger Visby
Zoo and Aquarium Association of Australia	Sarah Cordell
Sydney University	Carolyn Hogg
Marine Life Tassie	Michael Jacques
Marine Solutions	Laura Smith
University of Tasmania	Rick Stuart-Smith
Aquenal, marine consultant	Joe Valentine
Community representative	Christine Coughanowr
University of Tasmania	Andrew Trotter
Jennifer Hemer	NRM South

Contents

Project Leader's Distribution List ..... **ii**

Executive summary **1**

1. Introduction **3**

2. Methods **5**

3. Results **6**

3.1 2022 Survey 6

3.2 Development proposals and additional sightings 9

3.2.1 TasPorts Development 9

3.2.2 Clarence City Council stormwater development 11

3.2.3 Tasman Peninsula sighting 12

3.3 Captive breeding 12

4. Discussion **14**

5. Conclusions **17**

6. Acknowledgments **17**

7. References **18**

List of figures

Figure 1 2022 density estimates of spotted handfish at the 9 long term monitoring sites in the Derwent Estuary monitoring sites (BP = Battery Point, BR = Bellerive, HB = Howrah Beach, HMB = Half Moon Bay, MAB = Mary-Ann Bay, OB = Opossum Bay, RB = Ralphs Bay, SB = Sandy Bay, TR = Tranmere)..... 6

Figure 2 Time-series (1997–2022) of modelled estimated densities of spotted handfish per hectare with standard errors at nine sites within the Derwent Estuary for both breeding (blue) and non-breeding (orange) season surveys and with an annotation demarcation (dashed green line) of set-line transect vs GUVC surveys 7

Figure 3 Density of Stalked Ascidians in 2022 at the 9 long term monitoring sites in the Derwent Estuary monitoring sites (BR = Bellerive, BP = Battery Point, HMB = Half Moon Bay, HB = Howrah Beach, MAB = Mary-Ann Bay, OB = Opossum Bay, RB = Ralphs Bay, SB = Sandy Bay, TR = Tranmere)..... 8

Figure 4 Transect lines of a ROVS survey conducted by Marine Solutions 9

Figure 5 Spotted handfish observed by ROVS by Marine Solutions 10

Figure 6 Observed spotted handfish close up by Marine Solutions 10

Figure 7 Clarence City Council stormwater outlet pipeline, initial length 11

Figure 8 Clarence City Council stormwater outlet pipe, reduced length 11

Figure 9 White Beach near Nubeena on the Tasman Peninsula. Observation of the spotted handfish was approximately at the red and white dot..... 12

Figure 10 Spotted handfish juveniles hatched at Melbourne SEA LIFE Aquarium on 31 January 2022, photos were taken 19 Sept 2022 (8 months old) 13

Executive summary

Spotted handfish (*Brachionichthys hirsutus*) are a Critically Endangered coastal anglerfish endemic to south-eastern Tasmania. CSIRO and partners have been conducting research and conservation interventions on spotted handfish since 1997. A recent publication, modelling the 23–year (1997–2019) dataset, suggests that the spotted handfish population has stabilised since at least 2014, but densities of individual local populations can be highly dynamic. There are now 14 known locations that support populations of spotted handfish, an increase from 9 prior to commencement of the Conservation of spotted handfish and their habitats project in 2015. This is a rare conservation success story.

Stabilisation of spotted handfish population was linked to the long-running, conservation intervention of planting Artificial Spawning Habitat (ASH) (~14,000 deployed in total since 1998). Spotted handfish prefer natural habitat to ASH so habitat assessment prior to the spawning season as part monitoring surveys provides an efficient method for targeting deployments. No ASH have been deployed since 2019.

After a two-year data gap due to a COVID-19 lockdown (2020) and lack of funding (2021) surveys recommenced in 2022. These surveys showed continued persistence of all monitored local populations in line with the stabilisation trend.

Genomics of local populations indicate that even within the Derwent estuary local spotted handfish populations are genetically isolated from one another. A common and dire scenario for the conservation of demographically un-connected species is local extinctions due to chronic pressures and/or stochastic events. Chronic threats to spotted handfish through habitat degradation include the reduction in suitable spawning substrates through declines in seagrasses and predation on stalked ascidians by the introduced northern Pacific seastar (*Asterias amurensis*) and more general physical disturbance by vessel chain moorings. Stochastic events include blooms of filamentous algae and other species that rot and turn the habitat anoxic, storms, anchoring of large ships and a recent acceleration in regional coastal developments.

Spotted handfish also face an existential threat as they are highly vulnerable to extinction due to rapid climate change. Already on the edge of their temperature tolerance (~18C) in summer, their cool temperate marine niche and, based on historical records, their known range, has contracted poleward over the same period as rapid climate change has occurred. As they are a shallow water coastal species, they have no available habitat south of Tasmania. Future marine heatwaves may cause extinction or severe depletion of remnant *in situ* populations.

Following 4 years of development an Environmentally Friendly Mooring (EFM), with a cost neutral design and mature deployment and servicing methods, is ready to be rolled out to a larger scale test. We have 15 EFMs in the water in Tasmania and as part of this work, a further 12 will be deployed in NSW. This large fleet will provide generic build advice (depth, vessel size, exposure) for widespread mooring replacement. For spotted handfish

conservation, replacement of all chain moorings with EFMs between Battery Point and Sandy Bay should be considered as a next step.

Repeatedly, the stochastic events of coastal development have been mollified or avoided through advice to permitting and development proponents and authorities by the Principal Investigator (PI) with co-ordination with the chair of the National Handfish Recovery Team. Several examples are provided in this report. In particular, Clarence City Council has extensive exposure to potential development interactions with spotted handfish with 7 of the 9 long term monitoring sites adjacent to their council boundary.

Besides *in situ* conservation actions, *ex situ* captive husbandry in aquariums is a further strategy to manage both the risk of extinction from localised stochastic events and the existential risk of marine heat waves. Following development of husbandry methods at Seahorse World and Melbourne SEALIFE aquarium, successful captive breeding events have occurred and ~31 juveniles are currently being raised in captivity for potential release or transfer to other aquariums in 2023.

All the original captive brood stock collected in 2018 are now dead. Apart from several mishaps early in the captive husbandry development, veterinary assessment suggest that these deaths were due to natural senescence. As the captive population were composed of adults (3 years or older) at capture 4 years ago. Otolith and age and growth work suggest that >5 years old is geriatric for spotted handfish. While there are now more animals in captivity than have been collected, their genetic diversity is limited, and another round of collection is required.

As local populations can be dynamic, the functional life span of the ASH is limited and threats to the species – chronic, stochastic and climate – are ongoing, spotted handfish are a ‘conservation reliant’ species. They require annual site-specific monitoring, *in situ* interventions and *ex situ* captive husbandry. They are particularly dependent on the conservation interventions of ASH, which has now not occurred since 2019. Eradication or massive suppression of *Asterias amurensis*, restoration of seagrasses, removal of moorings and consideration of other threats would be needed if ASH planting were to be permanently abandoned.

Greater acceptance may be needed that recovery of endangered species are often ‘wicked problems’ that are not solvable but rather require on-going conservation interventions. The long timescale required of even reaching stability and the dependence of the spotted handfish on interventions also mean short duration research projects are not appropriate, and an operational governance model would be better suited for their conservation.

1. Introduction

Spotted handfish (*Brachionichthys hirsutus*) are listed as Critically Endangered under Australia's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and the International Union for Conservation of Nature's Red List of Threatened Species. A national recovery plan sets out research and management actions to support the recovery of handfish species in Australian waters.

Once more widely distributed around the coast of north-eastern, eastern and southern Tasmania (Australia), spotted handfish were originally collected and described by François Péron, as part of Nicolas Baudin's French scientific expeditions to Van Diemen's Land in 1802 (Last et al. (2007). Until the late 20th Century spotted handfish were described as 'common' (Last et al. 1983), and so abundant in the Derwent Estuary that they were collected for practical demonstrations by the University of Tasmania (Last pers. comm.). Since their declines, first noticed in the 1990s (Barrett 1996), and subsequent recovery efforts the species has become both a local and to some extent an international conservation icon (Roberts & Hawkins 1999; Powles et al. 2000; Diamond 2005).

Spotted handfish are now found only in southeast Tasmania, where about 2000 individuals are thought to remain in fragmented and genetically isolated local populations (Appleyard et al. 2021). A coastal, shallow water, benthic anglerfish (Last & Gledhill 2009), their geomorphic niche is also further limited to inshore depths from 1–60 m (most commonly 5-15 m) with low wave intensity (Last et al. 2007). They are one of 14 members of the family Brachionichthyidae, which are considered the most endangered marine bony fish family (Stuart-Smith et al. 2020). Spotted handfish are a soft sediment species and have strong preferences for micro-habitat complexity; in particular for detritus filled depressions and various forms of low relief such as fields of ascidians (Wong et al. 2018). Spotted handfish have undergone a major recent range reduction, with historic collections between 1909 and 1974 occurring as far north as eastern Bass Strait and up Tasmania's East Coast (Last & Gledhill 2009). Spotted hand fish are now restricted to a much narrower geographic range, which includes the nine, small well-studied Derwent estuary sites but also recent presence observations in Storm Bay, the D'Entrecasteaux Channel. Two new sites reported below include an additional site in the Derwent Estuary and a credible sighting from White Beach near Nubeena (Alex Hormann pers comm).

A mid-trophic ambush predator that feeds on small invertebrates, female sexual maturity is reached in 2-3 years at around 75-80 mm (males perhaps slightly later at 85 mm+), with growth then slowing dramatically (Bruce et al. 1998). Fish can grow to a maximum total length of 130 mm (Last et al. 2007). Spotted handfish may live up to of 10 years, but most do not live past 5 years (Bessell 2018). As they take several years to reach sexual maturity this leaves only a short window for reproduction. Spotted handfish lay relatively large, benthic eggs in September through October as egg-masses of between 80-250 eggs, often onto stalked ascidians, (*Sycozoa pedunculata* and *Sycozoa pulchra*), but also onto seagrasses, sponges, small macrophytic algae and polychaete worm tubes (Bruce et al. 1999; Ross 2001). Eggs are provided with parental care for 6-10 weeks until they hatch as fully metamorphosed juvenile fish, avoiding any planktonic stage, to directly recruit onto the benthos in the immediate vicinity of the spawning site (Bruce et al. 1999). Juveniles are much more cryptic than adults, actively hiding in interstitial spaces in debris pits or seagrass

beds when disturbed (Lynch pers obs), whereas adults will first freeze, then make a threat display.

Dispersal is further limited by the movement behaviour of adult spotted handfish that prefer to walk over the seafloor than swim. They will, reluctantly, swim for very short bursts when disturbed before splaying their hands and 'parachuting' back to the bottom; though as they lack swim bladders (Green & Last pers comms) long distance swimming is unlikely. Several capture, mark, recapture studies suggest small adult movements (10m – 460 m, average 4 m per day) (Moriarty 2012; Lynch et al. 2015a; Bessell 2018). Genomic studies of fin tags collected in 2006–2008 profiled gene flow between sites and provided further evidence of low levels of dispersal. Three genetically distinct spotted handfish populations clusters are present even at the very small scale of the Derwent estuary at: South Arm, Tranmere and Ralphs Bay; at Bellerive and Howrah; and at Battery Point and Sandy Bay.

Threats to the spotted handfish include by-catch from dredge fisheries, ecosystem regime shifts from historic coastal scallop/bivalve and other demersal fisheries, climate change, urbanisation, siltation, pollution, chain moorings and introduced marine pests such as the northern Pacific seastar (Bruce et al. 1998; Pogonoski et al. 2002; Lynch et al. 2022). Stalked ascidians are thought to provide critical breeding habitat for handfish in the Derwent estuary following long-term declines in other spawning substrates such as seagrasses (Ross 2001). In both its native range and in Tasmania, the seastar is a known predator of ascidians and studies have suggested that an increase in seastar abundance coincides with very low numbers of ascidians, very little spawning activity by handfish and a subsequent decline in recruitment success of handfish (Ross 2001). Control efforts for the seastars via trapping proved ineffective (Andrews et al. 1996) hence a recovery action has been the deployment of plastic and then ceramic Artificial Spawning Habitats (ASH) (Hormann 2019), which are inedible to the seastars. The ASH work well, but fish still prefer natural habitat if it is available. A community-based diver program to suppress specific areas of northern Pacific seastars has also commenced. A particular focus has been known spotted handfish locations, especially Sandy Bay. Other recovery actions have included the development and deployment of Environmentally Friendly Moorings (Lynch et al. 2020a; Stuart-Smith et al. 2021).

Captive breeding work for ambassador fish, insurance populations and re-introduction events have also occurred at Seahorse World and Melbourne SEALIFE Aquarium (Hawkins 2021). Cumulative knowledge gained over the course of the project is slowly unravelling the right environment in which handfish will breed on cue in captivity. Due to the COVID-19 pandemic, fieldwork was abandoned in 2020 this was followed by a year's gap in funding in 2021. Over this period, we curated the data time series for spotted handfish and developed a time-series model for all data collected between 1997–2019. We assessed this 23-year, multi-site, time-series of population surveys for spotted handfish density as well as the performance of a conservation intervention, the planting of ~14,000 ASH. We found an overall decline in fish observed between 1997 and 2019 but, at least since 2014, there has been stabilisation of the population. Local populations of spotted handfish can either be highly dynamic or relatively stable but population increases were linked to the long-running, conservation intervention of planting ASH (Lynch et al. 2022). Data collection recommenced in 2022 and we continued our assessment of spotted handfish population densities at our nine long term monitoring sites.

2. Methods

The nine long-term monitoring local populations of spotted handfish in the Derwent estuary were surveyed using our established methods (Lynch et al. 2015b; Lynch et al. 2022). Fish were located and counted by SCUBA divers via Underwater Visual Census while towing GPS floats (GUVC). GUVC transects are of variable length (200–300 m) but this difference in search effort is accounted for in our statistical model with a logarithmic link function based on swath area. Transect start points and directions were determined using spatially balanced randomisations (Foster et al. 2017) and then followed the depth contour. Dive bottom time was set at 60 min, but to avoid short transects, an additional 2 min was added to each dive if a fish was observed to account for processing time. Dive bottom time was capped at 70 min, regardless of the number of fish observed.

Our count data of spotted handfish was analysed with a generalised linear model (GLM), which utilised a logarithmic link function and a Poisson residual distribution. This model was used to produce estimates of handfish density per hectare with standard errors. The 2022 estimates were then added to the long-term dataset (1997–2019). This dataset includes historic data collected using set-line transects and also during the breeding season. Potential confounding issues around this variation in the dataset are discussed in Lynch et al. (2022).

Estimates of stalked ascidian densities per site were calculated with a similar sampling and statistical model to those used for handfish, with count data analysed with a GLM using the Poisson distribution and a logarithmic link function for swath area searched.

In addition to surveys, notes were made on numerous meetings with development proponents and other around both additional sightings of spotted handfish and mitigations to reduce impacts of developments.

Advice was also received from SEALIFE Melbourne Aquarium on a successful captive breeding event for spotted handfish and the fate of all fish collected as brood stock in 2018.

3. Results

3.1 2022 Survey

Surveys were conducted outside of the breeding season through February and March. Fish were observed at all sites (Fig 1). Population dynamics showed no differences by sites comparted with the last time period sampled in 2019 (Fig 2). The Sandy Bay site has overtaken the Mary-Ann Bay site as the location with the densest population of handfish.

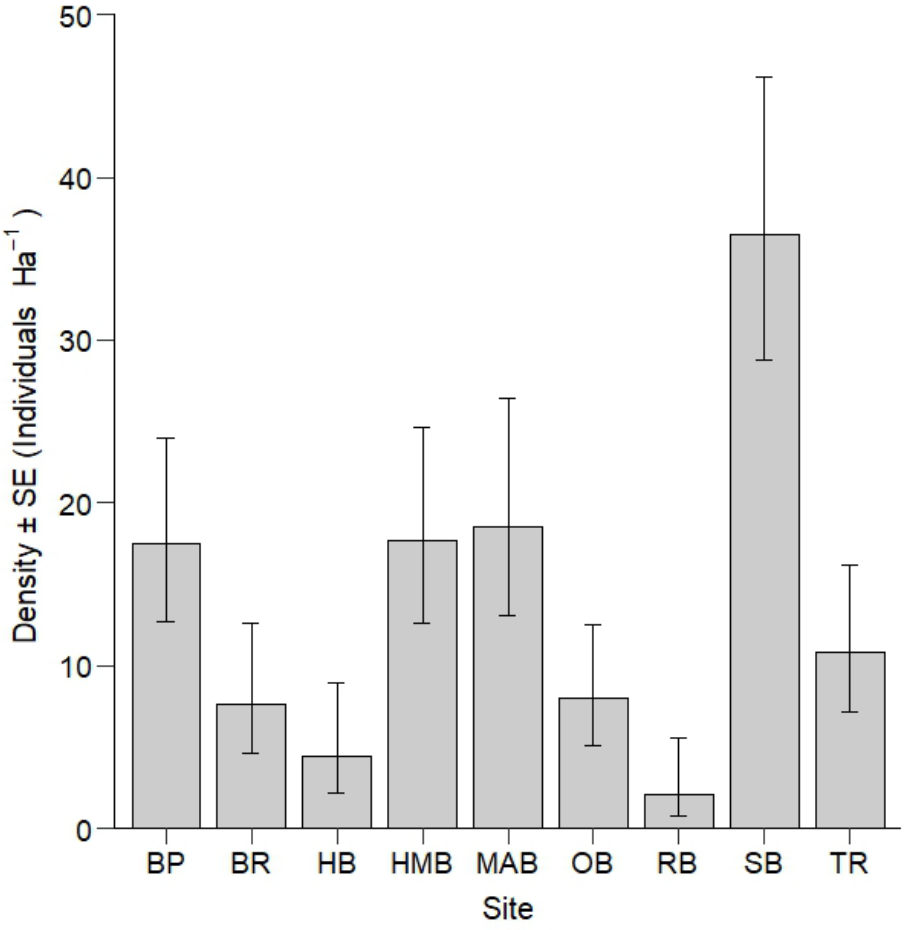

Figure 1. 2022 density estimates of spotted handfish at the 9 long term monitoring sites in the Derwent Estuary monitoring sites (BP = Battery Point, BR = Bellerive, HB = Howrah Beach, HMB = Half Moon Bay, MAB = Mary-Ann Bay, OB = Opossum Bay, RB = Ralphs Bay, SB = Sandy Bay, TR = Tranmere)

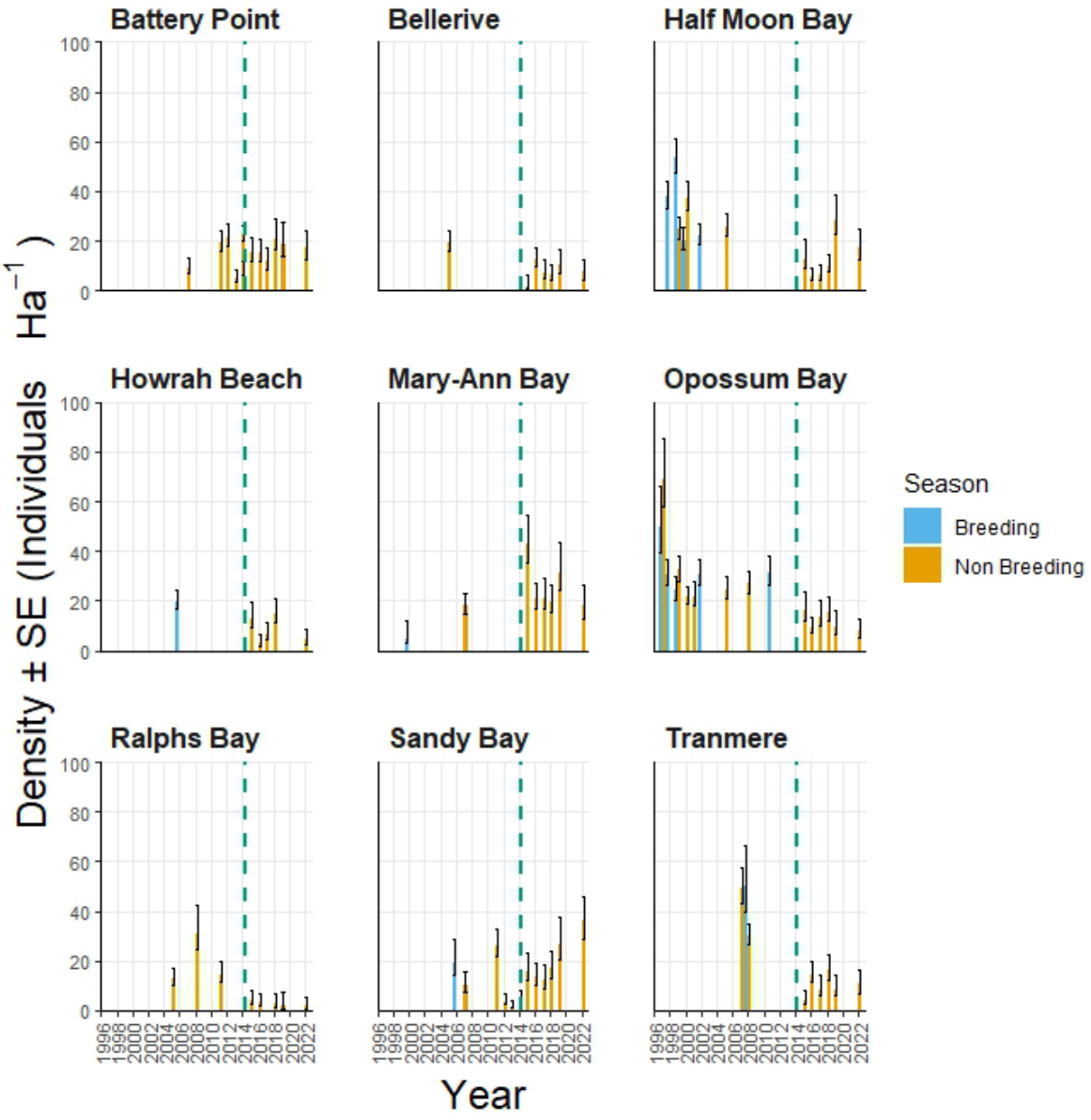

Figure 2. Time-series (1997–2022) of modelled estimated densities of spotted handfish per hectare with standard errors at nine sites within the Derwent Estuary for both breeding (blue) and non-breeding (orange) season surveys and with an annotation demarcation (dashed green line) of set-line transect vs GUVC surveys.

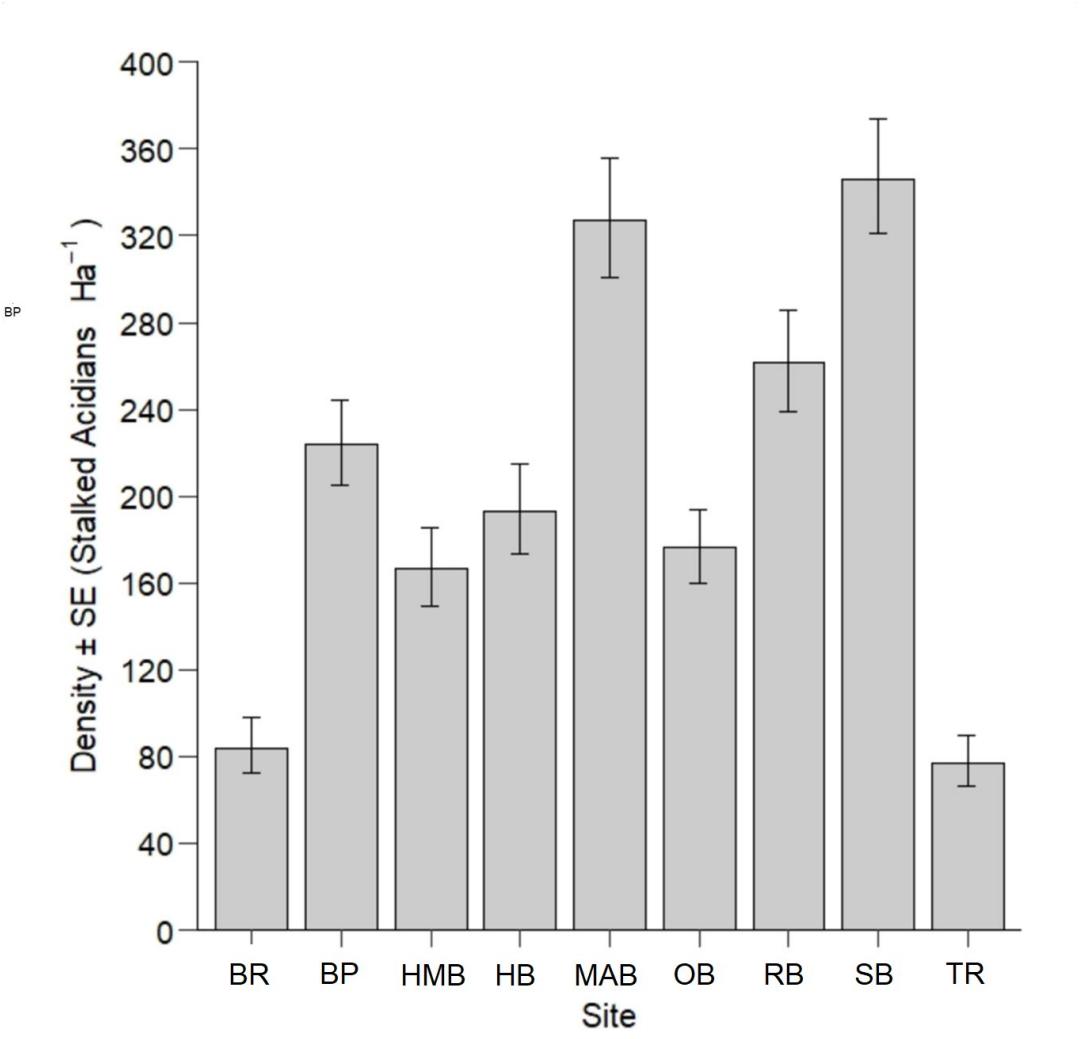

Figure 3. Density of Stalked Ascidians in 2022 at the 9 long term monitoring sites in the Derwent Estuary monitoring sites (BR = Bellerive, BP = Battery Point, HMB = Half Moon Bay, HB = Howrah Beach, MAB = Mary-Ann Bay, OB = Opossum Bay, RB = Ralphs Bay, SB = Sandy Bay, TR = Tranmere).

3.2 Development proposals and additional sightings

3.2.1 TasPorts Development

Due to their conservation status, spotted handfish are a key consideration for sub-tidal developments in southeast Tasmania. Recently, surveys by environmental consultants have been conducted with Remote Operated Vehicle Systems (ROVS) rather than divers. The environmental consultancy, Marine Solutions, conducted ROVS surveys for TasPorts in 2022 for a proposed extension to a wharf (Fig 4).

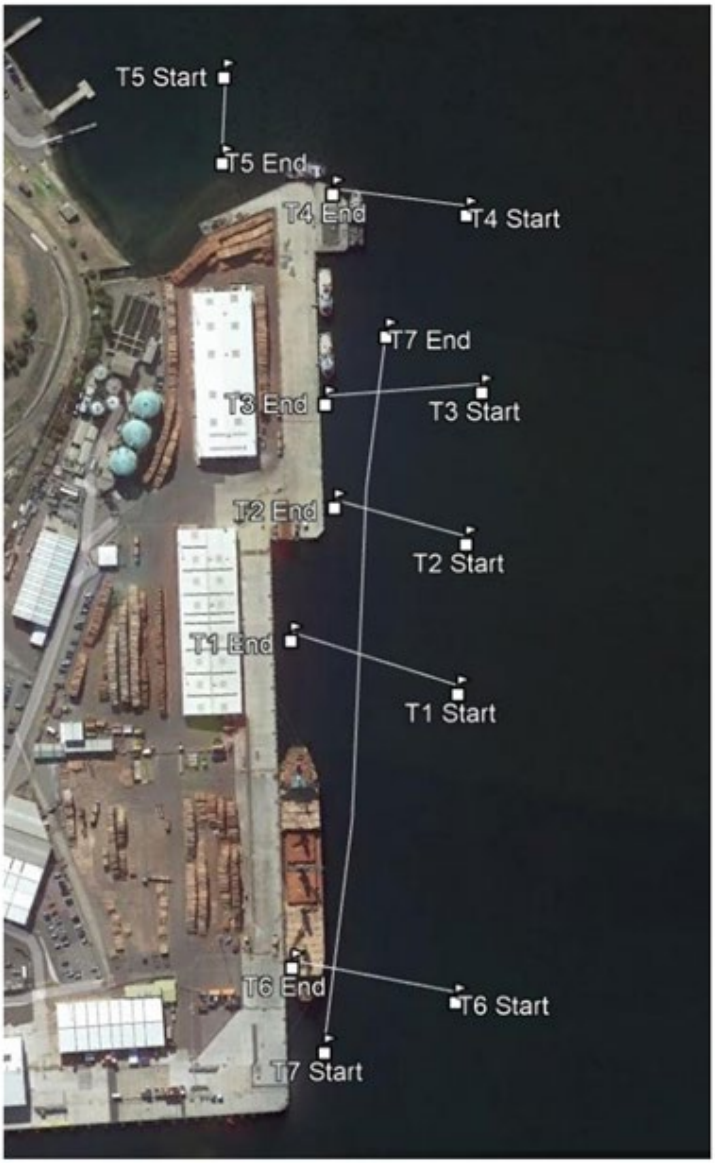

Figure 4. Transect lines of a ROVS survey conducted by Marine Solutions.

On these transects they both found suitable handfish habitat as described by Wong et al. (2018) and also observed one spotted handfish (Fig 5 and 6). The handfish was found midway along Transect 1 (see Fig 4).

Figure 5. Spotted handfish observed by ROVS by Marine Solutions.

Figure 6. Observed spotted handfish close up by Marine Solutions.

The NHRT chair (Jemina Stuart-Smith) and the primary author participated in several meetings with TasPorts and the consultancy and made recommendations to move fish away from pile driving and other construction activities and to avoid construction during the breeding season.

3.2.2 Clarence City Council stormwater development

The NHRT also participated in discussions with the Clarence City Council over the expansion of a storm water drain at Bellerive. The main issue with the drain was the extent of the pipe that ran through spotted handfish habitat and that it may bisect the local population (Fig 7). Following negotiation, the pipe design was shortened to emerge at a shallower depth (Fig 8.). In agreement with previous advice, the NHRT requested that construction occurred outside of the spring breeding season.

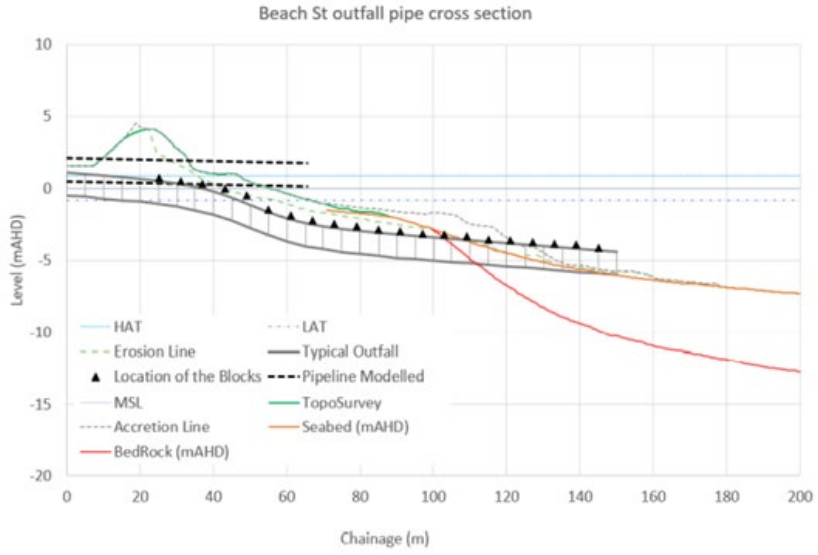

Figure 7 Clarence City Council stormwater outlet pipeline, initial length.

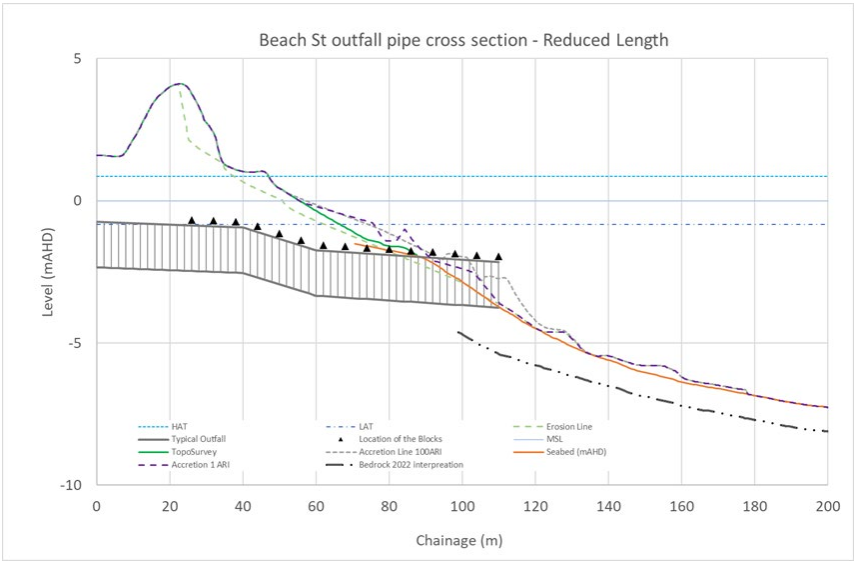

Figure 8 Clarence City Council stormwater outlet pipe, reduced length.

3.2.3 Tasman Peninsula sighting

We also had a credible observation of a spotted handfish at a previously unknown location on the Tasman Peninsula at White Beach, Nubeena (Fig. 9) by Mr Alex Hormann (pers obs) who has previously completed a Masters thesis on spotted handfish. The author and Alex attempted confirm this photographically but without success. The habitat was scallop beds.

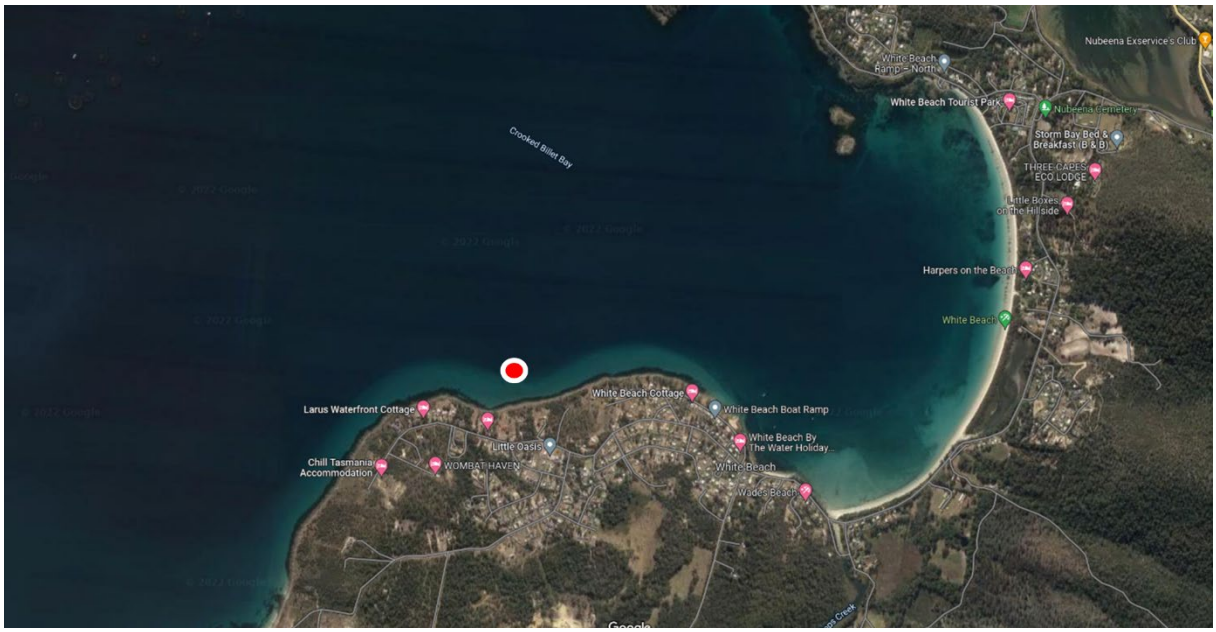

Figure 9 White Beach near Nubeena on the Tasman Peninsula. Observation of the spotted handfish was approximately at the red and white dot.

3.3 Captive breeding

The Ambassador Fish program with partner institutes; Melbourne SEA LIFE Aquarium and Seahorse World had successful breeding events from the adults in the 2018 season but with only unfertilised eggmasses since then, however this changed in 2022. Using ultrasound techniques fish have been successfully sexed when eggs in the female hydrate and they become gravid. The female and a male were removed to a quiet and simple tank, with only a breeding pole. The individuals successful bred and the eggs hatched at Melbourne SEA LIFE Aquarium from a single clutch on 31 January 2022 (Fig 10). There are currently 31 individuals remaining and have been separated into size classes; 17 of them have an average total length of 2cm and 14 have an average total length of 4cm.

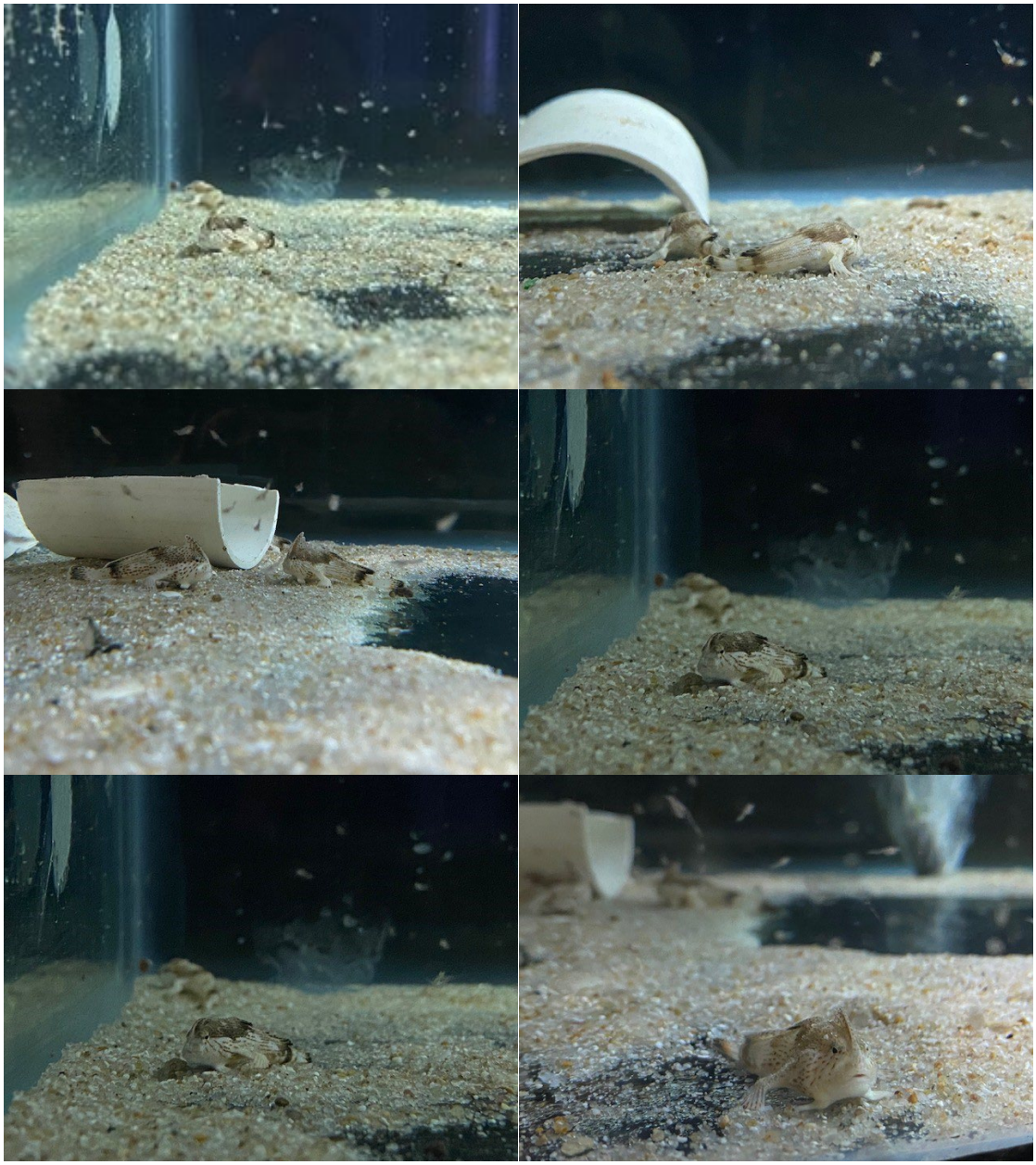

Figure 10 Spotted handfish juveniles hatched at Melbourne SEA LIFE Aquarium on 31 January 2022, photos were taken 19 Sept 2022 (8 months old).

4. Discussion

Spotted handfish are known from the 9 long term monitoring sites in the Derwent Estuary (Lynch et al. 2022) and have also been confirmed from photographic images from deeper waters at 2 sites on either side of Storm Bay (Lynch et al. 2020b): Flathead Bay in the D'Entrecasteaux Channel (Wong & Lynch 2017) and Macquarie Wharf in the Port of Hobart. A further creditable sighting occurred at White Beach near Nubeena on the Tasman Peninsula. Many of these recent sightings have come from industry conducted Remote Operated Vehicle Surveys (ROVS). We suggest that there are now 14 known sites for spotted handfish in southeast Tasmania.

This project established methods for estimating population densities for monitoring and conserving handfish populations, performance assessment of conservation actions, such as the deployment of ASH, captive husbandry techniques and the development of an environmentally friendly mooring system. It also helped to foster ongoing community support and collaboration. It had a direct impact on species recovery by stabilising handfish numbers and expanding the number of known sites where they occur. The project has also provided evidence to support management measures under Tasmania's Derwent Estuary Program and nationally under EPBC Act, including implementation of the national recovery plan. Information sharing between scientists, industry, and government planning authorities about the location of handfish populations, and collaboration to manage spawning habitat, have regularly occurred across the project.

This shared knowledge has raised awareness, including the need to consider the location of populations of this critically endangered fish in relation to development applications. Research advice was incorporated in Tasmanian guidelines for estuarine and marine development proposals, and handfish location information was used by regulatory authorities to work with a development proponent planning a water pipeline between Hobart's western and eastern shore. This was then used as a framework when providing the advice to TasPorts and the Clarence City Council outlined in the report. The Clarence City Council, with 7 of the 9 long term monitoring sites adjacent to the council's boundary, has many spotted handfish populations that may need to be considered with development applications.

Vessel mooring fields in the Derwent estuary tend to overlap with spotted handfish habitat. The chains of conventional moorings scrape across the seafloor, removing handfish habitat. A new, environmentally friendly mooring design that costs the same as chain moorings was developed and tested. Engineering modelling showed the EFMs reduce the shock loading on vessels (by 39–58%) during extreme weather conditions (Lynch et al. 2020b). By avoiding disturbance to the seafloor, they also allowed the recovery of spotted handfish habitat. The New South Wales government is using the project findings to help develop the first Australian Standard for EFMs. This work has been multidisciplinary with concurrent studies for engineering modelling of performance, servicing, biodiversity recovery and social-economic motivations of mooring licence holders.

Spotted handfish mostly inhabit soft sediments in 5–18 m depths that are populated by stalked ascidians which provide a substrate for eggmasses. The fish also inhabit depressions created by skates and rays (Wong et al. 2018). These microhabitats can be destroyed by vessel moorings and the removal of skates and rays. Another ongoing problem is the presence of the introduced northern Pacific seastar that eats stalked ascidians.

In the absence of stalked ascidians, spotted handfish will lay eggs on artificial spawning habitat (ASH). CSIRO researchers worked with a Hobart artist to develop ceramic ASH as an alternative to the earlier use of plastic. Since 1998 close to 14,000 ASH have been 'planted' by divers in areas where stalked ascidians have been lost (Lynch et al. 2022). Handfish use ceramic in preference to plastic ASH and stalked ascidians in preference to any ASH (Hormann 2019). It appears that declines in spotted handfish have stabilized and this is linked to the deployment of ASH (Lynch et al. 2022). Counts of ascidians during the non-breeding monitoring survey work provide a way to efficiently target ASH planting leading up to the breeding season, though no ASH has been planted now since 2019. Stalked ascidians were in low numbers this year at Bellerive and Tranmere and these two sites have had declines in spotted handfish densities since the mid 2000s. It is unknown how stable ascidian densities are at sites over time.

Removal or suppression of northern Pacific seastars would benefit spotted handfish and many other species. However, due to the seastars ubiquitousness and fecundity, a population-wide approach, such as a species-specific pathogen or genetic control such as a CRISPR mediated gene drive, would be required as a control method. However, on the very local level of spotted handfish populations, seastars may be controlled in the short term through repeated and ongoing collection by divers. It is interesting to note that the Sandy Bay population of spotted handfish is now the densest of the 9 monitored sites. Since February 2021 this site has been the subject of on-going removal of northern Pacific seastars by a volunteer dive group.

A hallmark of the work was close collaboration with government, industry, aquarists and the community through the National Handfish Recovery Team and the Handfish Conservation Project. Seahorse World and SEA LIFE Melbourne Aquarium helped develop husbandry techniques and IMAS and CSIRO invested in aquarium facilities. SEA LIFE Melbourne Aquarium and IMAS are engaged in handfish sex-determination research to aid in success of captive breeding programs. If captive breeding can be established as routine, restocking could occur in areas where populations are locally extinct. Seahorse World and SEA LIFE Melbourne Aquarium assisted with the captive rearing of insurance populations. The current cohort of captive bred animals could form the base of a breeding program across multiple institutes, being supplemented genetically by additional wild caught brood stock.

Future research work

Recently, surveys by environmental consultants have been conducted with Remote Operated Vehicle Systems (ROVS) rather than divers. There is an unknown comparison with diver UVC and ROVS surveys, but they certainly can provide 'presence/absence' data.

As remote inspections appear to be becoming more popular there is a need to undertake calibration of ROVS surveys against the SCUBA diver UVC at the long-term monitoring sites. This will allow for methods advice to industry and government for the use of ROVS. Based on the existing monitoring database various statistical power and other analysis could be developed to provide simple tabulated advice on comparative survey effort for UVC and ROV surveys and the effectiveness of these two different methods in developing an estimate of the local population density. Part of this work could include modelling of the numbers of transects required for different scaled target areas. This advice already exists in government documents (DSEWPac 2011) but was provided as a 'rule of thumb' based on expert review. A quantitative study would provide assurance of the adequacy of current guidelines for environmental assessments.

Experimental work on the behaviour of spotted handfish towards sub-sea pipes and cables would also be useful. Our current hypothesis is that spotted handfish avoid these structures.

5. Conclusions

A range of management actions are recommended to maintain local spotted handfish populations. These recognise that specific locations and populations need to be prioritised for conservation of spawning habitat. Activities should include population monitoring; deploying artificial spawning habitats; deploying eco-friendly moorings; captive rearing; and replenishment of wild populations. Annual monitoring should be undertaken of both handfish populations and stalked ascidian habitat as the populations can be quiet dynamic and ASH needs to be planted in areas where habitat has been degraded. Another management challenge is to encourage yacht owners to swap from chain moorings to environmentally friendly moorings (EFMs). A whole of field replacement of chain moorings with EFMs between Battery Point and Sandy Bay would probably benefit two spotted handfish local populations.

As handfish are extremely local in their distributions they are a prime candidate for spatial management. Consideration of handfish locations by planning authorities is hence another important practical way to conserve the species.

Spotted handfish may now be in a stable but precarious conservation position. Each isolated population group is highly vulnerable to being lost to a chance event and requires individual management. As local populations can be dynamic, the functional life span of the ASH is limited and threats to the species are chronic, stochastic and existential through climate change, spotted handfish may be a ‘conservation reliant’ species that require ongoing management.

6. Acknowledgments

We would like to thank the CSIRO Hobart dive team for all of their efforts across this year’s work Chalk, Curt, Chloe James, Claire Davies, David Flynn, Tim Fountain, Matt Lansdell, Lincoln Wong, Helen O'Neill and Lincoln Wong

Glenn Popowski from Clarence City Council for providing maps and collaboration on engineering mitigations.

Marine Solutions, TasPorts and Mr Alex Hormann for providing images and observations of handfish

Alex Hormann for his observations of spotted handfish; Matt Testoni for the cover photo of handfish with eggmass and SEALIFE Melbourne Aquarium for photos of the juvenile handfish.

7. References

Andrews D, Whayman G, Edgar GJ. 1996. Assessment of optimal trapping techniques to control densities of northern Pacific seastars on marine farm leases. FRDC, Hobart.

Appleyard SA, Lynch TP, Green MA, Encinas-Viso F. 2021. Genetic diversity and restricted genetic connectivity in an endangered marine fish (*Brachionichthys hirsutus*) provides a model for conservation management in related and data-deficient species. Marine and Freshwater Research.

Barrett NS. 1996. Spotted Handfish Survey. Hobart.

Bessell TJ. 2018. Using autonomous photo-identification systems and otoliths to estimate age, growth and movement of the spotted handfish (*Brachionichthys hirsutus*). Page 82. IMAS. University of Tasmania, Hobart, Tasmania.

Bruce BD, Green MA, Last PR. 1998. Threatened fishes of the world: *Brachionichthys hirsutus* (Lacepede, 1804) (Brachionichthyidae). Environmental Biology of Fishes 52:418-418.

Bruce BD, Green MA, Last PR. 1999. Aspects of the biology of the endangered spotted handfish, *Brachionichthys hirsutus* (Lophiiformes: Brachionichthyidae) off southern Australia. Pages 369-380 in Seret B, and Sire JY, editors. Proceedings of the 5th Indo-Pacific Fish Conference. Soc. Fr. Ichtyol., Paris.

Diamond J, editor. 2005. Collapse: How Societies Choose to Fail or Survive. Viking Press.

DSEWPac. 2011. Survey guidelines for Australia's threatened fish: Guidelines for detecting fish listed as threatened under the EPBC Act. Barton.

Foster SD, et al. 2017. Spatially balanced designs that incorporate legacy sites. Methods in Ecology and Evolution 8:1433-1442.

Hawkins R. 2021. Aquarium industry offers hope for Tasmania’s critically endangered handfish. Papers and Proceedings of the Royal Society of Tasmania 155:71-77.

Hormann A. 2019. A Behavioral Study of the Spotted Handfish (*Brachionichthys hirsutus*) and the Species Use of Artificial Spawning Habitat. Page 40. Institute of Marine and Antarctic Science (IMAS). University of Tasmania, Hobart.

Last PR, Gledhill DC. 2009. A revision of the Australian handfishes (Lophiiformes: Brachionichthyidae), with descriptions of three new genera and nine new species. Zootaxa:1-77.

Last PR, Gledhill DC, Holmes BH. 2007. A new handfish, *Brachionichthys australis* sp nov (Lophiiformes: Brachionichthyidae), with a redescription of the critically endangered spotted handfish, *B. hirsutus* (Lacepede). Zootaxa:53-68.

Last PR, Scott EOG, Talbot FH. 1983. Order Lophiformes: Anglerfishes and allies. Pages 249-528 in Last PR, Scott EOG, and Talbot FH, editors. Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart.

Lynch T, Green M, Davies C. 2015a. Diver towed GPS to estimate densities of a critically endangered fish. Biological Conservation 191:700-706.

Lynch T, Green M, Davies C. 2015b. Short communication: Diver towed GPS to estimate densities of a critically endangered fish. Biological Conservation 191:700-706.

Lynch TP, Appleyard SA, Bessell T, Wong L, Martini A, Jemina Stuart-Smith J, Soo S, Faber S, Devine C. 2020a. Conservation of handfish and their habitats – annual report. Report to the National Environmental Science Programme, Marine Biodiversity Hub. Hobart, Tasmania.

Lynch TP, Appleyard SA, Bessell T, Wong L, Martini A, Stuart-Smith J, Leah Soo L, Faber S, Devine C. 2020b. Conservation of handfish and their habitats – annual report. Hobart, Tasmania.

Lynch TP, Green M, Wong LSC, Bessell TJ, Cooper A, Valentine J, Barrett N, Ross DJ, McEnnulty FR, Foster SD. 2022. Assessment of conservations actions for the critically endangered spotted handfish (Brachionichthyidae), following curation of data collected by multiple investigators into a long-term time-series. Journal for Nature Conservation:126237.

Moriarty T. 2012. Can a Spotted Handfish (*Brachionichthys hirsutus*) change its spots? Assessing photo-identification and spot matching software to study a critically endangered species. Page 103. Institute of Marine and Antarctic Studies (IMAS). University of Tasmania, Hobart.

Pogonoski JJ, Paxton JR, Pollard DA 2002. Conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes. Canberra : Environment Australia, 2002.

Powles H, Bradford MJ, Bradford RG, Doubleday WG, Innes S, Levings CD. 2000. Assessing and protecting endangered marine species. ICES Journal of Marine Science: Journal du Conseil 57:669-676.

Roberts CM, Hawkins JP. 1999. Extinction risk in the sea. Trends Ecol Evol 14:241-246.

Ross DJ. 2001. An assessment of the impacts of the northern Pacific seastar, Asterias amurensis, on the endangered spotted handfish *Brachionichthys hirsutus*. UTAS, Hobart.

Stuart-Smith J, Edgar GJ, Last P, Linardich C, Lynch T, Barrett N, Bessell T, Wong L, Stuart-Smith RD. 2020. Conservation challenges for the most threatened family of marine bony fishes (handfishes: Brachionichthyidae). Biological Conservation 252:108831.

Stuart-Smith J, Lynch T, McEnnulty F, Green M, Devine C, Trotter A, Bessell T, Wong L, Hale P, Stuart-Smith R. 2021. Conservation of handfishes and their habitats – final report 2020. Marine Biodiversity Hub.

Wong L, Lynch T. 2017. Monitoring of Spotted Handfish (*Brachionichthys hirsutus*) populations and on ground conservation actions. Programme NES, Hobart.

Wong LSC, Lynch TP, Barrett NS, Wright JT, Green MA, Flynn DJH. 2018. Local densities and habitat preference of the critically endangered spotted handfish (*Brachionichthys hirsutus*): Large scale field trial of GPS parameterised underwater visual census and diver attached camera. PLOS ONE 13:e0201518.

CONTACT

Tim Lynch

tim.lynch@csiro.au

https://www.nespmarinecoastal.edu.au

This project is supported with funding from the Australian Government under the National Environmental Science Program.