Marine Life Network

RED HANDFISH STUDY REPORT

Edited by Michael Jacques

Progress report to 30 December 2016

Contents

Introduction

What are red handfish?

Red handfish are a small fish less than 80mm long found only in south-eastern Australia. They are 14 currently known handfish species and red handfish are one of the few handfish species that can be found in shallow water.

Handfish have fins that are modified as 'walking legs'. Handfish can both swim and walk across the seabed. They are similar in appearance to frogfish and anglerfishes, but form part of a separate and unique family.

It is likely that this uncommon fish, living in fragmented habitat is vulnerable to extinction. The currently estimated population of 1000 fish, would make this species rarer than the Giant Panda, but it has attracted relatively little conservation interest.

What is the study project about (and methodologies)?

Handfish are novel animals that can attract public interest due to their unusual appearance. Most of the funding and research activity to date has predominantly been focussed on the Spotted Handfish, and this study effort has only rarely been extended to include other species of handfish.

A small group of Hobart amateur SCUBA divers decided to locate a red handfish colony and make observations. It was hoped that this activity might be helpful in stimulating further research and conservation activity.

A red handfish breeding location was previously known to exist in Norfolk Bay, SE Tasmania although it had been reported that an urchin barren had destroyed the site. The site proved not to be abandoned and from Spring 2010 a small number of fish (often no more than 7 individuals) were found in a 750 square metre patch of reef.

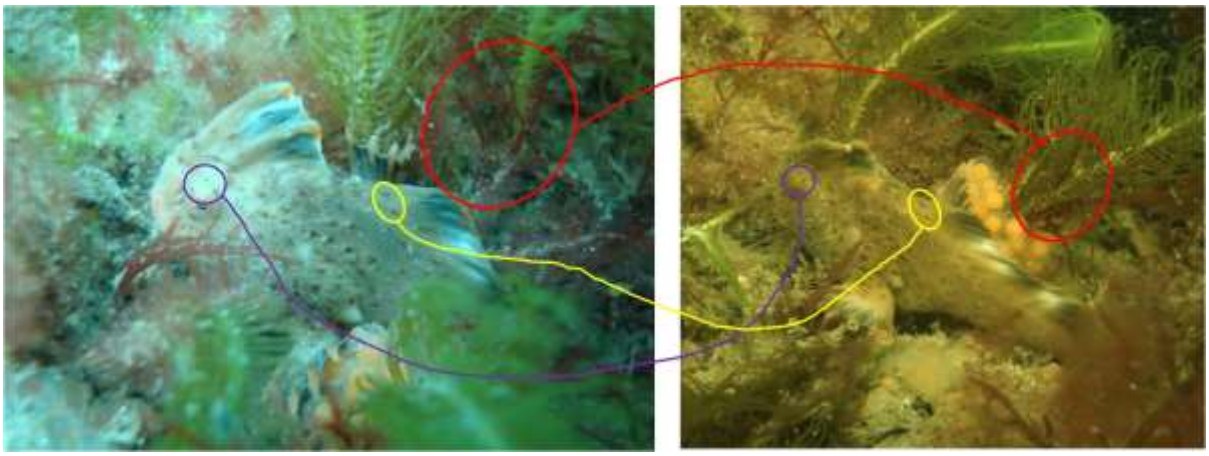
A record of observations were kept in a narrative form and photographs taken of each individual fish.

We also reviewed literature and talked with other divers and scientists to collate information about other prior sightings.

Red handfish proved to be the ideal amateur study subject. They occupy a small, sheltered and shallow habitat close to the city of Hobart. They have such wide colour variations that individual fish can often be identified. The fish generally freeze rather than swimming off when discovered, allowing for detailed examination. Because they are so distinctive, amateurs often become attached to this "cute" iconic species, meaning that sustained study is easier to organise.

This study does not pretend to be a scientific study based on rigorous methodology and controlled experimentation. Even if it had attempted to do so, the available data from this small population, could probably only lead to indicative results. The discussion that forms a part of this study is highly speculative, which may nonetheless provide some focus for further professional study. Often we draw in the work of others, including previous studies on spotted handsfish.

Handfish Identification



An analysis of markings by Emma Flukes showed the two sightings of "Martha" were indeed the same fish.

Analysis of observations

Red handfish behaviour and life cycle

Stimulation to breed

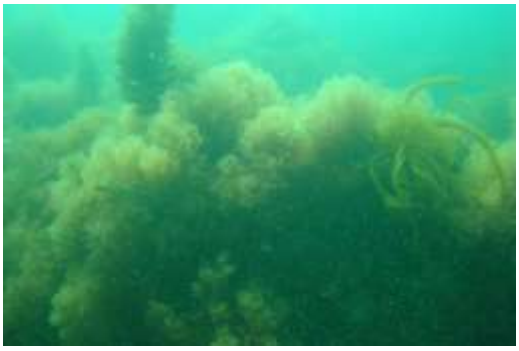
Like many animals, handfish appear to become 'excited' by the Spring sunshine, a time of bountiful growth when breeding is more likely to succeed.

We speculate that breeding behaviour is triggered when the hours of sunshine in early Spring. It is suspected that this triggers females to head to suitable areas, including the inshore reef of Primrose Sands, to select breeding rocks. It may also stimulate males to aggregate towards females. It is possibly that they cross considerable distances from the nearby sediments and onto the adjacent coastal reef to seek out suitable mates and breeding habitat.

These seasonal changes also trigger growth on the reef itself. By that time (generally September) the reef has largely recovered from winter storm damage and is carpeted in a winter cover of Caulerpa and freshly sprouted Sargassum fronds. In late spring (late November) a particularly vigorous red algae covers to rocks, and a filamentous red algae has been observed growing on egg cases that are unhatched by early summer. Egg hatching is 'timed' to occur before warming water causes green algae dieback and before red algae overgrowth dominates the algal understory.

Seaweed health

7 nov



23 Nov

27 nov

When do they come inshore?

Inshore sightings increase in the lead-up to breeding in July/August/September. During this study, older and larger breeding fish appeared to arrive later. it was not until mid-September that sightings included a repeat sighting of an older female fish detected in previous years ("Candice"). The earliest repeat sighting of a male from a prior season is early November ("Head injury"). While the statistical sample group and the frequency of survey dives is small, it is possible that these older fish are moving inshore in a more leisurely way, or from a more distant site than some other smaller fish observed on the reef.

While some adult fish clearly make repeat visits to Primrose Sands reef, each year there is a high proportion of fish that are first time visitors. Some are obviously new recruits that loosely conform to the patterning of an earlier juvenile, but others include large and apparently mature fish that are difficult to link to a known juvenile. It should be noted though, that linking new recruits with known juveniles is difficult due to juvenile marking changes, and the heightened difficulty in locating all the juveniles during the year due to their small size.

Where they go while on the reef - Small scale Habitat preference

Handfish did not return to exactly the same rocks each year, but did aggregate in the same weedy 750square metre section of the reef. The urchin damaged area to the south, and the shallow and sparsely vegetated areas to the north do not appear to have been used regularly.

Although divers will tend to find more fish where they are easier to see, after a lengthy number of dives, it was possible for study participants to anticipate likely resting and breeding spots for red handfish. These tended to be on the top of small rocks partly covered with medium to low density Caulerpa, with often at least one large stand of brown macroalgae (like sargassum) draping over the site for additional camouflage.

The handfish and their eggs masses were generally on the flatter profile reef in 4-5m, just behind the reef edge, so that at least one row of low rocks provide some shelter from the swell.

Red handfish are generally not found in very dense caulerpa, assumedly as it is hard for a small animal to move through such densely packed seaweed thallii. Handfish were also found on one occasion sitting cryptically down cracks between rocks. This may not be an uncommon behaviour but handfish behaving in this manner would be more rarely observed.

When they are moving around, eg, in the lead-up to breeding (especially males), they are also often found on the sand around the edges of rocks, hiding under sargassum fronds.

Red handfish tend to cluster. Find one handfish and one or two others are usually only a couple of metres away on adjacent rocks. This rule applied throughout the year.

Preferred Egg laying attachment points

At the Primrose Sands reef sites, females appear to be particular about where they laid their eggs.

Prior CSIRO research (Bruce et al 1997), indicated that handfish show a strong preference for one species of green seaweed for egg-laying attachment. During this study, red handfish were actually found to be less particular, and will attach their egg masses to, C*.trifaria, C. simpliscula, C. cactoides, C. longifolia*, but also *Sargassum sp*. and even thin red algae. It seems more likely that overall density of short seaweed cover on a suitable rock that is well camouflaged, rather a seaweed species, is a significant factor in egg laying site selection. However, caulerpa was the most common attachment point. Repeat breeding females did not show a particular preference for a single species of Caulerpa, and would vary the attachment plant species from year to year.

The importance of site selection was shown by the exceptions to the rule. A handfish called "India" lay on an isolated rock more exposed to the swell, despite apparently suitable alternatives in the area. She was constantly covered in fine sand particles. Her egg masses were also placed on thin red algae of an unknown species. The eggs detached prior to hatching, as did another egg mass placed on thin red algae by another red handfish.

Courtship and Mating

The courtship behaviour observed has been limited to the clustering of males within two or three metres of a female early during the mating season, and approaching with a 'head to tail' posture.

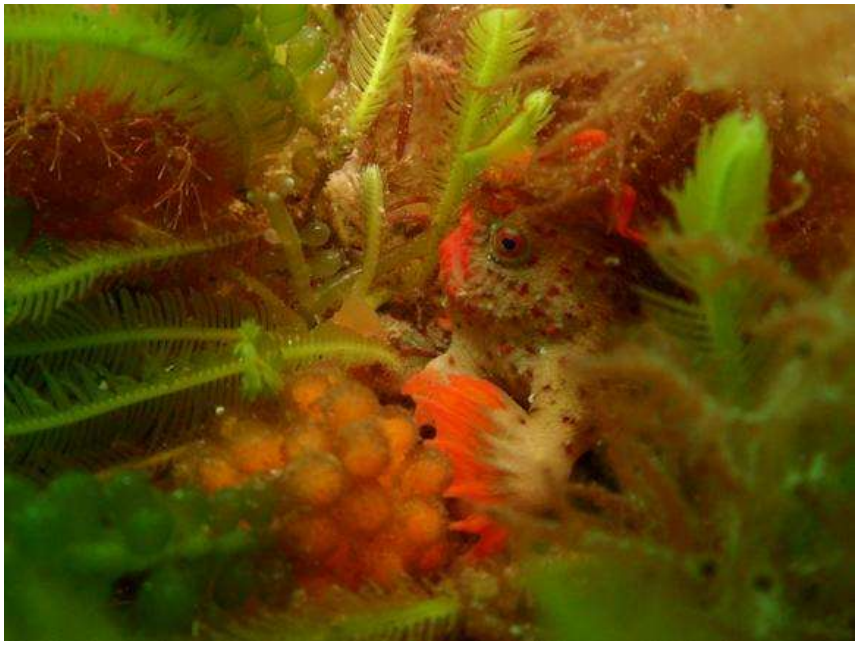
In 1996 the CSIRO were capturing gravid females in July (that laid in a tank in September). In this study egg masses were first sighted in September and early October.

Egg laying was not observed during the study, although it has been observed in previous aquarium studies. In prior studies, mating occurs in September and consists of a male approaching a female and waiting until egg laying starts. The female swims around a stalk of seaweed, wrapping her eggs around the thallus. She can lay approximately 80-150 eggs, according to prior aquarium studies. The process takes up to 9 hours (Bruce

et al 1997). The male fertilises the eggs immediately afterwards. Once egg laying is completed males have been observed 'lingering' in the immediate area prior to dispersal.

A private night time study of spotted handfish has photographed several males aggregating around one female who was ready to spawn (Adriaan Van Huissteden pers comms 2012). It is likely that multiple red handfish males compete to fertilise a female, although due to the lower population densities, this is unlikely to be as competitive as with spotted handfish. It is not clear how dominance is asserted, assumedly by the larger males pushing in ahead of other males at the time of laying. It is possible that some eggs clusters have more than one fertiliser.

Tending the eggs

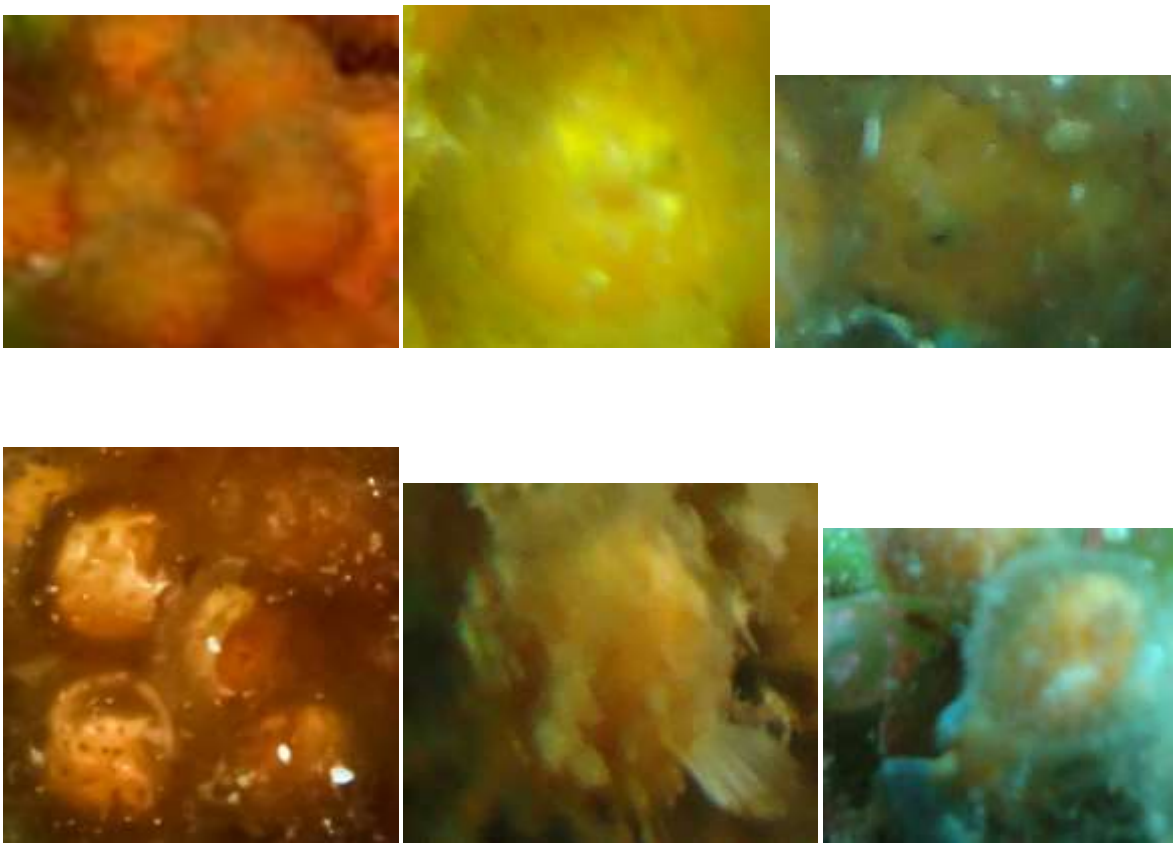


Emma with her egg mass – Photo Emma Flukes

The eggs consist of transparent leathery sacs that are camouflaged with dark spots. Females were observed in prior aquarium studies to brush the egg cases with the illium or lure on top of the head, mouth them and brush them with their 'feet'. It is assumed that this movement helps to oxygenate the eggs and discourages algae from forming on the egg cases. The females will remain with the eggs and respond to the approach of divers by freezing. If that fails, then they adopt a threatening posture with all fins raised and the body raised off the bottom to appear larger. The bright colours of these fins may have a role in scaring predators, or advertising that handfish are poisonous to eat. Even close contact during measurement will not generally scare a female off her egg mass.

Hatching and dispersal

Emmas eggs



7 Nov 2010 , 20 Nov 2010, 27 Nov (most developed egg)& 27 Nov , 1 Dec (see emergingtail), 2 Dec (different egg, later stage)

The females will stay with the egg mass until the eggs are fully developed and beginning to hatch, approximately by late November (approx. 6 weeks later). This was broadly consistent with the maturation times noted in aquarium studies. The eggs hatch as almost fully developed juveniles, although they are an almost uniform pale colour. The hatching process has been observed on two occasions during this study. The juvenile will break out of the egg sac very slowly taking lengthy rests. When the sac is sufficiently open they have been seen to swim vigorously upwards and land in the weed above the egg mass. After a rest they again swim off vigorously, assumedly in a random direction, and land in other weed. It is suspected that they could sustain several of these 'hops' across the vegetative cover and disperse randomly around the breeding rock before they tire and sink to the substrate.

Very small juveniles have not been found during the study once they have dispersed. An attempt to photograph the entire surface of the breeding rock and the bottom one metre around the rock within a few hours of a known hatching incident did not reveal any juveniles. They would be very hard to see anyway and alternatively could be resting in the canopy seaweed, or have dispersed under cracks in the rock.

It is assumed juveniles seek the cover of cracks and crevices. It is likely that they are yet to acquire a full range of defensive chemical from their food, and are likely to be very vulnerable to predation at this stage. They also appear to have a specialised requirement for very tiny, almost plankton sized food, as CSIRO aquarium raising studies experienced difficulty in finding suitable sized food for juveniles. The reef may contain this food, which would explain the effort taken by handfish to lay eggs in this habitat.

This sojourn on the reef must be brief as handfish as small as 23mm (CSIRO sighting) have been found on open sediment. Juveniles may venture out onto the reef alone, or opportunistically join up with other handfish that periodically visit the reef in Autumn.

Recruitment

The median number of handfish breeding at the Norfolk Bay site was three, with perhaps 150 eggs hatching. Over the four breeding season studies the median number of handfish visiting the reef was approximately stable at 7 mature fish. With fish having a life span of perhaps only 4 years, mortality is probably at or about 99%, quite common for a bony fish.

Feeding

Previously it was thought that red handfish feed on small worms and tiny crustaceans. In aquariums adults will eat amphipods. During this study, no obvious red handfish feeding activity was observed during daylight dives.

From the manner in which the egg-laying females lose condition while they are guarding the eggs, it seems that female red handfish do not feed very much if at all while tending the egg masses during the breeding season.

On one twilight dive, a female that had recently finished breeding and was emaciated. She was observed to swim into a clump of sargassum sp. The fish was apparently 'shaking' the bush with presumably quick strikes on small crustaceans or on fouling epiphytes. This is consistent with the assumptions of previous publications and captive breeding trials that red handffish feed on small worms and crustaceans, such as amphipods (sea lice).

It is presumed that handfish feed more actively at night, but no night dives were conducted. It is also possible that they feed during the day, but as they freeze when approached, they may not be exhibiting normal feeding behaviour while under daytime observation.

Growth

Red handfish hatch at a size of approximately 10mm when they are of a fairly uniform pale colour. It is not known how rapidly they grow. According to CSIRO studies they follow the usual pattern for bony fishes of gaining size rapidly before annual growth slows as they approach maturity.

Small fish in the 40mm range have been sighted in November aggregating around mature breeding fish. Presuming that hatching only occurs in Spring, these small fish would have to be "first year" juveniles. A juvenile 40mm fish has been identified again in the following May in the 60-65mm range, meaning they are assumedly "two year olds". By that November they appear to have reached 65-70mm and have reached, or are about to reach reproductive maturity.

In 2013, some newly identified female fish of around 70mm length did not appear to be fecund or lay eggs. Other red handfish females have reproduced at this size, suggesting that 70mm is at the point of breeding maturity.

Fish then slow, with adult sizes ranging to 90mm, although larger spotted handfish have been found. Size does not appear to be an identifying feature of gender.

This is broadly consistent with prior studies (Bruce et al 1997) which concluded an age/length relationship for spotted handfish as follows;

Year one of life	***Year Two***	***Later Years***
6-7mm at Hatching		Sizes for spotted handfish usually ended at 90mm, the same as for red handfish.
25-30mm by May	55-65mm by May	
35mm by September		
45-47 mm by November	75-80mm by November (breeding maturity)	

How long do they live?

This study indicated that female fish breed for two or three seasons before no longer appearing in the study area during Spring, suggesting they possibly age and die after 4 years. Sightings of males also suggest they appear for only two breeding seasons as adults. This is not conclusive. Small population numbers make something more certain like ear bone analysis, unwarranted.

Colour variations

Newly hatched red handfish are a uniform pale colour. By year one they have adopted an intricate and very individual range of colours. These fish are not usually been re-identified with certainty, although some shared characteristics suggest that at year two they undergo a significant colour change. By this stage any markings and dots have become larger and more spread out across the handfish's pale background. The markings then stabilise as the fish's "adult" colours.

Red handfish from Primrose Sands are not really uniformly "red". The red handfish was given its name after sightings of fish from the Actaeon Reefs in the 1980s. These fish were a predominantly red colour. Historic photos from eastern Tasman Peninsula indicate the colour morph there is red or purple with white 'socks'.

Norfolk Bay red handfish populations tend to have a pale background colour, with complex dots, patches and mottling in varying colours in the red –orange-yellow spectrum. The patterning can be very intricate and individual fish can be identified readily from photographs, and sometimes by sight.

Predation

Wrasse often follow divers and were seen to show an interest in handfish egg masses and uncovered handfish, but did not attempt to attack. No attacks on eggs were observed by other predators such as sea snails and starfish. It is suspected that the egg cases have a chemical repellent as well as being defended by the female.

Prior reported incidents relating to handfish toxicity include, a cat dying after eating a spotted handfish, and

a failed fish attack on a Ziebell's handfish. Both incidents suggest that handfish flesh is highly toxic. In the latter incident a Butterfly Fish spat out the handfish rapidly, although the handfish was sufficiently injured to die afterwards (James Parkinson pers comms 2009).

During the study some fish were noted as having injuries that were consistent with fish attack. Adults appear to be very resilient to fish attack injury. One male handfish had unhealed damage to the head that had blinded one eye. He survived and participated in a subsequent breeding season. One spotted handfish has been seen previously by the CSIRO, surviving for a lengthy period after having its tail bitten off (Mark Green pers comms 2011).

Other injured fish looked like they had experienced targeted 'nips' around the illium area from inquisitive fish like wrasse or leatherjackets, rather than full-force predation attacks from an ambush predator like a flathead or stargazer. This highlights the risky nature of the fish's movements every year, around the reef and across sediment flats with relatively little cover.

Their apparently clumsy body shape and bright colours suggest an animal that has not needed to evolve a high performance escape strategy, although they do have a relatively large (for their size) and muscular tail fin. Spotted handfish can put on short bursts of speed to escape into the silt cloud of survey divers. Predation by other fish as an adult may not be a great risk and is possibly deterred by chemical and visual signals. Fish attacks are more likely to be fatal for younger fish, as they would be more vulnerable to physical damage and are likely to have acquired less deterrent toxicity.

Sexual dimorphism – Telling males from females

Dr Karen Gowlett-Holmes had undertaken extensive observations of red handfish at this study site during the late 1990s. She suggested that nostril size during breeding was an indicative feature of gender (*pers comms 2012*). When tested against the collected red handfish photographs, small nostril size was consistent with all of the egg laying females, while fish presumed to be male had larger nostrils year round, not just in the breeding season.

Some research (eg, Bruce) had suggested that size might be an indicator of sex, but an aquarium breeding program was not successful when based on this criterion.

External colouration appears to have no relationship to gender.

Sensory capability

The prominence of the nostrils in males implies that red handfish locate other handfish at long distances by using chemical triggers. Red handfish have exhibited behaviour suggesting an 'attraction to smells'. They have been noted aggregating around breeding rocks, even well after the female has moved away (five months or more, and this was by fish that were not present during earlier breeding). Multiple (spotted and red) handfish males aggregate to fecund females.

A keen sense of smell would allow this animal to locate other red handfish, despite the poor visibility, dense vegetative cover and low red handfish population density. Without some sensory ability of this kind, it is difficult to see how such a slow moving and widely dispersed fish population could be genetically viable.

The illium ('lure' on the head) is also an item of some interest. This intricate and delicate object seems like a considerable ecological investment. In anglerfishes it serves as a lure, but it intuitively seems to have little value in this role for handfish, who probably don't need a lure to ambush amphipods. It has been observed being used as an egg brush, but possibly also has some sort of sensory role. Some anglerfishes of the family

Ogcocephalidae (seabats) have been shown to emit chemicals from the illium, and other deepwater angelfish use it as a lighted lure.

Handfish eyesight, and perhaps even the ability to sense vibrations like the rustling of weed and scuba tank noise, appears to be good as handfish react to the imminent approach of divers. This is more clearly noticeable with Spotted handfish survey dives on sediments. Handfish living on mud have a clear field of view and their reactions are more easily observed. They often react to divers with alarm (raised dorsal fins) while they are still some distance away, at the maximum extent of the range of visibility (personal observations).

Where do they go? - A possible migration pattern

Although they are more commonly seen by divers on weedy reef, red handfish prefer both sediment and rocky reef habitat. Red handfish have previously been trawled in areas of flat sediment adjacent to rocky reefs (*Last et al*). CSIRO surveys of Primrose Sands during 1999 also found red handfish on the sediments adjacent to the breeding reefs, as well as in the rocky reef itself.

Identification of individual fish during this study showed that there isn't a 'resident' population of red handfish occupying the Primrose Sands reef fringe, but rather that there is a regular pattern of movement into and away from the reef fringe. There is a relatively large movement around breeding, but various small groups of red handfish (3-4) come and go at other times of the year too.

With the average red handfish population of the reef rarely exceeding 7 fish, to be genetically viable there must be interaction with other populations in the area, with red handfish circulating from aggregation to aggregation. It seems probable that the majority of the red handfish population at Primrose Sands is occupying the sediments in the adjacent bay, rather than the small area of fringing coastal reef currently known to divers.

Attempts to find handfish on nearby sediments post breeding (by searching out to 8.5M) were unsuccessful. Failure to relocate fish on the sediment during this survey may be because the post-breeding dispersal involves a relatively rapid migration to deeper areas where they become less densely associated. This significantly increases the search area and the difficulty in locating aggregations of handfish.

In a previous amateur study of spotted handfish, the breeding handfish at Bellerive Beach were photographed over several nights and their movements logged by a towed GPS. Spotted handfish appear more mobile than previously thought, and after breeding were noted to move rapidly over several nights into deeper water in excess of 20M, deeper than was then considered their normal preferred depth range and muddier than their presumed habitat preference (Adriaan Van Huissteden pers comms 2011).

We can only speculate about their movements while out on the sediments. Despite their ungainly appearance and static posture when observed during the day, they may be quite mobile. They may move across the bottom regularly as areas are depleted of food, or to socialise with other detected handfish. The areas where they aggregate may shift from year to year or even month by month. The dispersal pattern may include cyclical abandonment of some breeding areas in favour of alternative aggregation sites.

They may also breed on sediment (e.g. on sea squirts like spotted handfish), but until further aggregations are found, this cannot be established. This will be a difficult undertaking. These muddy areas of Norfolk Bay are recreationally unattractive and rarely dived, except perhaps by amateur scallop divers. Scallop diving is not prominent in this section of Primrose Sands Bay. In low densities these inconspicuous fish would be rarely seen or noticed, especially by untrained people. The search area is vast.

Is the bay regularly scouring, forcing handfish to be mobile?

In April 2014 and attempt was made to resurvey an area where the CSIRO had found handfish in 1999. CSIRO records indicated a depth at this location of 8.6M approx. CSIRO provided the GPS marks (sample dive undertaken at 42°53'52.35"S 147°39'56.35"E).

Mark Green described the habitat in 1999 as follows, "When we did the 1999 surveys (as for those before), the bottom was composed of regular patches comprised mainly of Caulerpa (trifaria, simpliciuscula, longifolia) and some fluffy brown algae that were almost always associated (anchor) with clumps of those ascidians buried in the sediments.

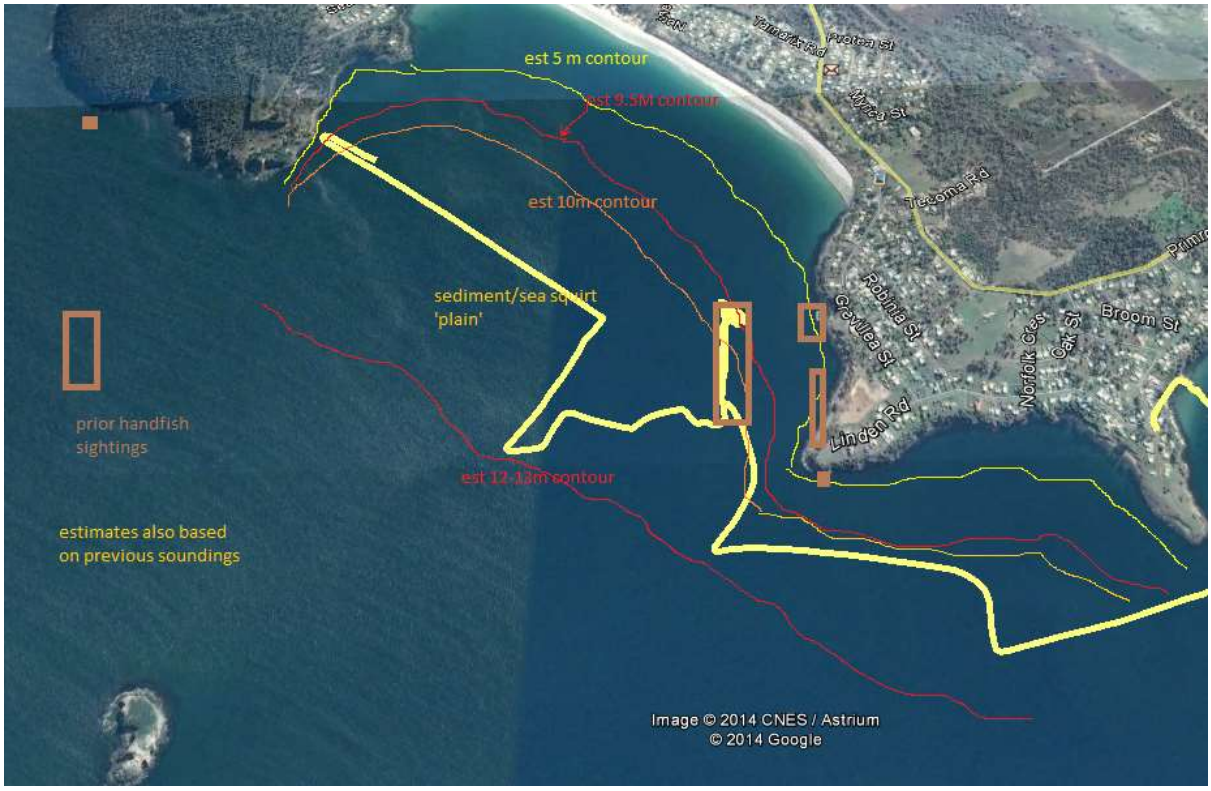
Mark green then provided a photo of South Arm, that is typical of the Primrose Sands habitat at that time,

Photos of the area nor showed little but sediment and patchy growth.

The depth was also 11 metres, suggesting that scouring of perhaps 2 metres of the bottom sediments occurred from 1999-2014. The 8.6M depth contour is now 100 inshore of the previous CSIRO sightings, and this area has also been relatively devoid of structure during this study, apart from isolated stands of sea grass.

Making the great assumption that the changes are uniform, it is possible that around 130mm of sediment has been removed annually from this end of the bay, and quite possibly deposited in banks at other locations, or out on the sediment flats further out to sea.

A very rough bathymetry of the bay taken with a boat mounted sounder indicated a underwater profile as follows (part of the boat track is marked in yellow);



Rather than the static sediment plain observable to divers, Primrose Sands Bay may a series of shifting microhabitats of varying stability, with handfish moving to older more stable areas of biodiversity until they are forced to move on as these richer areas are buried or undermined by small current changes.

A GoPro mounted video sled towed behind a boat perfomed well enough to show a bay largely barren but for isolated spots of weed and sea squirts. One of the tows, carried out roughly along the 11-12m contour from the eastern point to western point showed poor habitat on much of the eastern side of the bay. Close to the middle of the bay (about 700 metres from the point) there is a spot of heavy caulerpa and squirts, good habitat for at least 200 linear metres then it thins in the middle of the bay. Another rich patch of squirts and weed is found nearer Carlton Bluff. This area requires more investigation by divers.

Possible search areas for current habitat in yellow, 1999 CSIRO sightings in red

Threats to Handfish Survival

Population fragmentation, genetic decline

The conservation status of this species is still of concern. Few known populations exist and only the Primrose Sands site is known to still be viable. Red handfish sightings outside of the studied Primrose Sands breeding colony are rare, averaging about one sighting every 5 to 10 years. Samples have been collected from 5 known sites, but many of these are not recent. There have been no red handfish sightings at one site for nearly 70 years). Some sites have suffered from intervening impacts (Southern Cross Reef – bottom trawling; Actaeon, Lagoon Bay and Fortescue Bay – giant kelp forest loss or reduction) that raise concerns about the ongoing viability of these sites.

The concerns raised about their conservation status summarised in the EPBC Issues Paper are not significantly varied by this study. "These factors make it unlikely that the overall population of the species exceeds one thousand individuals in the wild" (DEH 2004).

The currently limited known numbers and range of handfish, and their fragmented known populations, are the major issues for their future survival. They are susceptible to any catastrophic change, even of a short duration. They are particularly vulnerable during breeding times to even short-term disturbance like adjacent dredging works.

Development, Sediments and Nutrients

During the study red handfish vulnerability to coastal development was discussed in the public domain, in the context of potential contamination from a proposed hazardous waste disposal site in the water catchment area. Such a development is only be one of the many potentially harmful human disturbances to Norfolk Bay since European settlement.

The area is becoming increasingly populated with the "southern beaches" area attracting holiday shack development since the 1960s. In more recent times the permanent

population of the area and building activity has increased. New building sites have been recently surveyed along the foreshore directly facing the breeding site.

This creates increasing issues with industrial pollution, sedimentation from land clearing, stormwater nutrient runoff and sewerage overflows, most notably after heavy rains. The area is at present unlikely to be heavily affected by nutrients from septic tanks. The Sorell Council Recreational Water sampling programme runs Dec 1st to March 31st each year and focusses on indicators of faecal contamination. In the years prior to 2011 at Primrose Sands Beach (off Tamarix Rd) and Susans Bay boat ramp all samples returned low levels for Enterococci contamination (email Sorell Council 2011).

Nutrient levels in the area are likely to vary greatly and may be naturally high. The area is affected by high nutrient levels that are normal in the Southern Ocean after winter storms. Nutrient flows may not be a decisive factor in red handfish survival, unless point sources became so severe they caused direct changes to the breeding habitat, such as installation of a new sewerage treatment plant outfall in the nearby area. A small stormwater culvert currently discharges at the site, but does not show evidence of high nutrient levels, unlike a similar outfall at Susan's Bay which has previously encouraged a localised green algal bloom.

New development would have to be so great it resulted in a high volume stormwater or sediment outflow directly discharging at the breeding site, however brief, especially if discharged during breeding. However, new development is also more likely to have better on-site wastewater management systems in place than the older shack sites. Best practice during building, such as use of temporary sediment traps on drainage channels would be a sensible precaution during building and landscaping works.

In-water developments need to be closely scrutinised, particularly if there are major changes to the hydrodynamics of an area, or there is an immediate impact such as smothering by dredge spoil or other sediment disturbance, especially if it will occur during the breeding season.

Point Source pollution

Frederick Henry/Norfolk Bay also receives water from nearby river systems like the Derwent River, Carlton River and Pittwater which are, or could be, polluted. Point source chemical pollution from larger industrial sites can be relatively easily detected, depending on the nature and volume of the material. The risks would appear to be low on the proviso that such uses were intensively monitored and managed.

Largely unmonitored are the low level chemical pollutants from residential and agricultural sources, such as medicinal compounds that enter sewerage systems. Handfish are likely to suffer from chemical discharges if they are in sufficient quantities to interfere with their sensory functions. There is little research to indicate the point at where a source of pollution might be creating a problem. As spotted handfish survive in a river very much more exposed to these sources of chemical interference, it is not clear that current levels of pollutants are a threat to red handfish habitat in Norfolk Bay.

If developments in the region were to significantly increase sediments and pollution sources to the degree that they were likely to create long-term broad-scale sedimentation of the bay, severely reduced visibility, chronic nutrient overload, or chemical contamination at detectible levels likely to damage fish physiology, then they would create an issue for handfish conservation.

The unusual feature of this site is not that it is a clear, pristine habitat, with a large biomass of diverse species, but that it is a naturally cloudy, partly exposed, high nutrient area of habitat.

Sea urchin barrens

A sea urchin barren formed at the Primrose Sands breeding site some time before 1997. This reduced the red handfish breeding habitat on the eastern side of the bay to around 750 square metres. According to local divers, the whole area from the beach to adjacent Renard Point was previously suitable habitat and handfish were found there (M.Barron pers comms). A local resident arranged for commercial urchin divers to remove urchins from the area which is now the remnant breeding area. Urchins have previously been cited as a reason for the subsequent abandonment of the locality as a breeding area some time prior to 2002.

The failure to find handfish prior to 2010 may have caused by habitat damage from urchins as previously suggested, or it could be some other cyclical behavioural or environmental factor. It could also have been as a result of inadequate knowledge on the part of survey parties. At least one of the reports that appeared to confirm that handfish had 'abandoned' the Primrose Sands site, was a 2010 report based on a Summer dive. At this time of year (immediately post-breeding) we have also failed to observe handfish, even though they can more readily be found at other times of the year.

The reasons for the formation of urchin barrens by native purple urchins has been recently studied (Ling et al 2015). Fishing removes large predators like crayfish that act to control urchin numbers. Without this control purple urchins can breed up in large enough numbers in an area to eat down any available drift algae. They then slowly remove other macroalgae. Unlike invasive NSW black urchins, native purple urchins tend to be more selective, leaving an area that is partly bare, rather than eaten down to bare rock. The impact of urchin numbers on the area to the south of the breeding area still appears to be entirely devastating to the type of low vegetative cover preferred by handfish. None were seen breeding there during the study. The area is also subject to relatively heavy sedimentation and is likely to recover very slowly even if urchin numbers fall (Johnston).

In 2011, urchin densities inside the breeding area were noticed as possibly increasing with vegetative cover in the breeding area becoming apparently poor. Urchin numbers were assessed at averaging 4 mature urchins per square metre, and were the same as densities within the barren area to the south. When the population was further analysed the urchins were very dense at the edge of the shallows in approximately 3 metres where they can collect drift algae from a robust foreshore weed bed. They were also very dense along the wide 'boundary' area between the barrens and the breeding area, although this 'urchin front' was not noticeable to the naked eye.

A controlled cull reduced the urchin numbers in the breeding area from an average of 4 psm to 1 psqm approximately. Attempts to set up pens as control sites were quickly wrecked by swells. Removed large urchins were quickly replaced by smaller urchins that had presumedly been cryptic up to that time. It was also noted that areas in the barrens that were temporarily penned, had four times the urchin density (16 psm) a short time after the pens were removed, suggesting that even a thin layer of ungrazed fresh algal growth attracts urchins from nearby densely populated barrens.

The results of the cull were inconclusive overall. The barren front remained relatively stable post-removal. Apparent declines in weed cover in the breeding area fluctuated, but this may have had more to do with natural cyclical factors than urchin removal or predation.

The reasons for the formation of urchin barrens here is also unclear. The area is noted for the very high levels of crayfish larvae settlement, having plenty of small crays when other areas are notably bare after high fishing pressure and poor recruitment. The area behind the main 2010 handfish breeding area contains a rock called the "crèche" which is often packed with small crayfish. The area appears to be little visited by cray divers, and craypots have never been noted at the site. The area appears to lack the large boulders that create den space for larger crayfish. The small crayfish appear to move

away or succumb to predators. No crayfish of a legal size have been seen at the site, and none of these smaller crayfish would be large enough to be able to predate upon any of the mature sea urchins.

It is likely then that this area is usually noted for high urchin abundance. It would be prone to tipping over into barrens whenever drift algae density drops. The most noted change in algal composition in the area in recent times is the disappearance of giant kelp down the eastern Tasmanian coast. Navigational charts of 1893, identified beds at Carlton Bluff, Isle of Caves and Fulham Island. Scientific searches in 2001 showed these beds were still there and others were found at Renard Point and Whale Rock (Edvane 2003). The latter were small and intermittent and weren't noticed in aerial and satellite sweeps in 1986 and 1999. Local people *(Pat Riley pers comms 2010)* have also asserted that the kelp disappearance at the site coincided with the appearance of urchin barrens and the disappearance of handfish. We noticed that by 2010 giant kelp was all but absent at Primrose Pt and Renard Pt, with nothing more than the odd strand in the shallows. Recently, new isolated plants have re-sprouted in pockets along the coast, in very shallow areas. In 2016, they again disappeared, perhaps due to natural fluctuations in nutrients, or storms.

Another recent development (2013) was the appearance of the pest species *Undaria pinnatfida* in these same shallow areas. They have only slowly increased and appear to be confined to disturbed areas in the shallows (2016 observation).

Removal of large brown canopy algae may be increasing urchin stress on these breeding beds. However, it should not be assumed that lowered algal density is always bad for handfish. They appear to have particular requirements for medium density rather than high biomass algal beds and may have a very finely balanced interrelationship with urchins and canopy kelp. When the balance tips into a large urchin barren, this will preclude handfish breeding.

In 2016 a visible improvement in the vegetative cover was noticed in this barren area for the first time. Areas well inside the barrens close to the handfish breeding area that had been pegged for study, are now covered in noticeably more dense seaweed, but not yet the usual range of growth to be found in the adjacent healthier handfish breeding area. Oddly, this may complicate study by allowing the handfish to spread out over a larger area.

Trawling

Handfish are not a fisheries target species but may suffer from the secondary impacts of fishing, particularly bottom trawling. More historical information exists on the spotted handfish than the red handfish. The shared habitat types and may well have similar threat exposures.

The spotted handfish was reasonably common in Great Oyster Bay before the First World War and was likely to be abundant in the D'Entrecasteaux Channel in the early 19th Century. Periodic sightings indicate that these populations remained viable up until at least the mid 1980s. These areas were subjected to aggressive scallop harvesting from the 1960s through to the 1980s, using dredges. Sightings have been rare since (Last et al 2009). Dredges are very efficient in catching small, slow-moving benthic fishes, such as adult handfishes, and can impact on breeding populations by damaging critical spawning substrate. "The likely extirpation of *B. hirsutus* from these regions flags the need for strong management approaches to be put in place to conserve the remaining populations." (Last et al 2009)

Recreational scallop dredging has since been banned in Tasmania, but commercial trawling is still permitted and is common in Bass Strait. Bottom Trawling should not be permitted in any area of know handfish habitat. At the present time only Lagoon Bay and

Southern Cross reef are likely to be exposed to these impacts. Bottom trawling is likely to be a significant threat to surviving handfish populations.

Climate change

Slow changes to water temperature, acidity and oxygenation levels are less likely to directly affect handfish. The modelled changes would create conditions that are more like the ocean conditions present when handfish evolved in the Tethys Sea over 50 million years ago, and they appear to be hardy fish to changing ocean conditions.

Direct mortality from storm events of increased severity is not likely to be a major threat. During the study two major winter storm events, one a 1 in 35 year extreme, failed to make a noticeable impact on breeding. The timing of these events may be more relevant. The later they are in the year, the greater the risk of overlapping with breeding and causing loss of seaweed cover and egg detachment. However, adult handfish appeared very resilient to being covered in fine sand and the heavy surge after storm events that had previously precluded diving activity at sites. The Actaeon Island handfish sites are very exposed. It is possible that the scouring of the site by winter storms creates the most favourable seaweed assemblage and/or juvenile prey abundance. This may make these sometimes apparently marginal sites for many fish species, preferred by handfish.

Handfish don't appear to require the thriving biodiversity and biomass one would find in prime recreational diving sites. They have been found in sites of varying biodiversity. Surveys of the Primrose Sands site show low fish and invertebrate species diversity, the larger fish species being particularly dominated by blue-throated wrasse and purple wrasse only. This is in contrast with other known sites such as the western Actaeon Island's sites and eastern Tasman Peninsula where clear open ocean waters and (formerly) thick adjacent kelp forests could be found. The particular seaweed assemblage and prey abundance at a site may be more the issue and the fish will go to wherever this is found. If conditions cause a sediment patch at Primrose Sands to decline, they appear to be able to move over modestly long distances, perhaps hundreds of metres or a few kilometres with time, to adjacent sites. Handfish appear adaptable and willing to utilise alterative breeding structures.

However, they are apparently in fragmented populations that cannot readily adjust to rapid habitat changes over large distances where entire coastlines may be affected.

Alterations to seaweed assemblages and breeding substrate will be likely to have a significant impact on handfish. Changes food availability (especially abundance of prey species suitable for juvenile development), increased competition from new invasive/pest species (like north Pacific sea stars), early dieback or overgrowth of suitable breeding substrate as waters warm, and acceleration of urchin barren growth are all changes anticipated to occur with climate change. Many of these impacts are already noticeable on the East Coast of Tasmania. In this area where there have now been few reported red handfish sightings in recent times. Anecdotal evidence from abalone divers suggest Actaeon Islands sightings have also declined with declining giant kelp biomass.

Inshore red handfish colonies might well decline due to these 'indirect' ecosystem impacts of climate change.

Poaching

Red handfish are protected by Tasmanian law and it is illegal to collect them. Early anecdotal reports that divers had been capturing them for aquariums, do not appear to have been accurate. They relate to sightings of a dive group that placed the fish in an onshore aquarium for photography purposes before returning them to the water, an

unwelcome disturbance to the fish of itself. While the fish may be attractive to private collectors they are difficult to locate and keep alive in captivity. Websites listing aquarium fish potentially available for sale, appear to list every known fish family, rather than suggesting a focus on handfish collection.

Successful commercial poaching would need to be conducted as part of an organised criminal venture. Frogfishes are similarly iconic and supply is more likely to be available. As handfish are in extremely short supply and demand is seemingly low while there profile is relatively low, it would not yield the high returns likely to be expected by such an organised operation. As the Primrose Sands site is monitored by surrounding residents the risks to a criminal venture are reasonably high. The site is also less likely to be disturbed by opportunistic captures by curious divers. From the size of the abalone on the reef, it appears to be a recreationally unattractive site that is rarely visited by SCUBA divers.

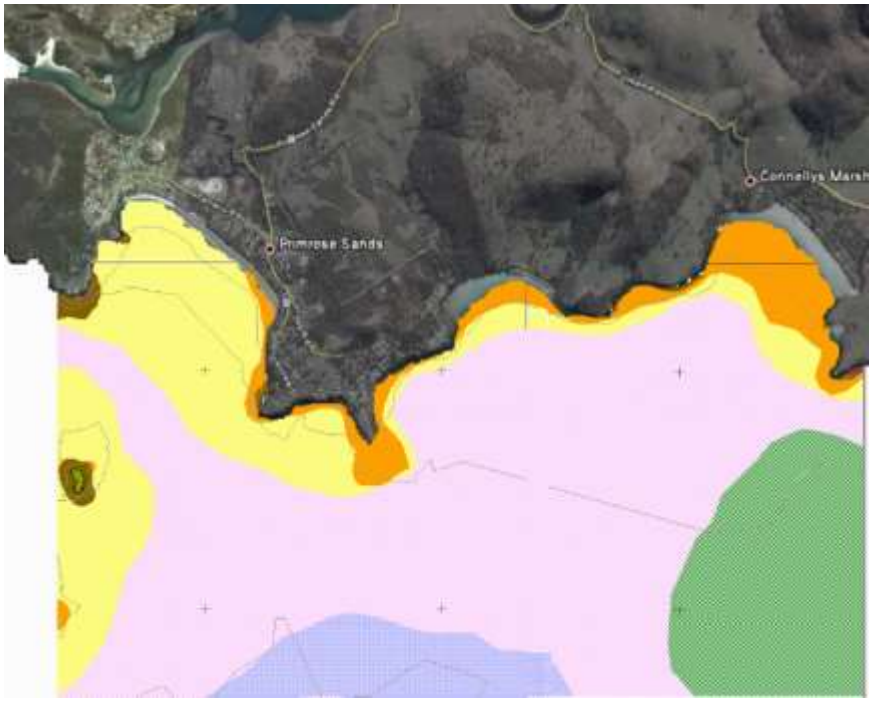
The Primrose Sands site has had a low profile for some time, being known predominantly only to a few locals and conservation-minded dive groups. This has altered recently when opponents of a development affecting Frederick Henry Bay, widely advertised the existence of these rare fish at this site. The low population and range of this fish does make them vulnerable to misguided attempts at poaching, or private aquarium collection, but it is likely to be a relatively low risk.

Known Red Handfish aggregations

It is important to know where red handfish are likely to be found. This aids desktop population assessment, as well as providing further study opportunities.

Site A: Primrose Sands, Norfolk Bay SE Tasmania (The Primary Study Site)

A breeding site on inshore rocky reef site located in the mid 1990s by marine biologist Karen Gowlett-Holmes. It was studied from CSIRO 1996. The site was studied by this project from 2010 to 2014, with intermittent observations since that date.



Previous sightings

The known numbers of red handfish are limited to 7-30 fish with a high inter-annual variation in sighting numbers. Handfish are found at the breeding reef in 4-5 metres on the eastern side of the bay.

Out on the sediments nearby the breeding site, the CSIRO 1999 study also found red handfish in the 8.6m depth, in an area that is now 9.5 to 11 metres deep.

Red Handfish photos from Primrose Sands (note the distinctive and variable colour morph)

Reef profile

The breeding reef profile is an unremarkable gentle reef slope from the weedy foreshore shallows of the reef to reef of 5m depth to the sand.

The foreshore area is a flat strip of reef 50m wide with a wide diversity of seaweed species including isolated fronds of giant *Macrocystis spp* at times. More recently the introduced pest species *Undaria pinnatafida* has begun to establish itself in this area.

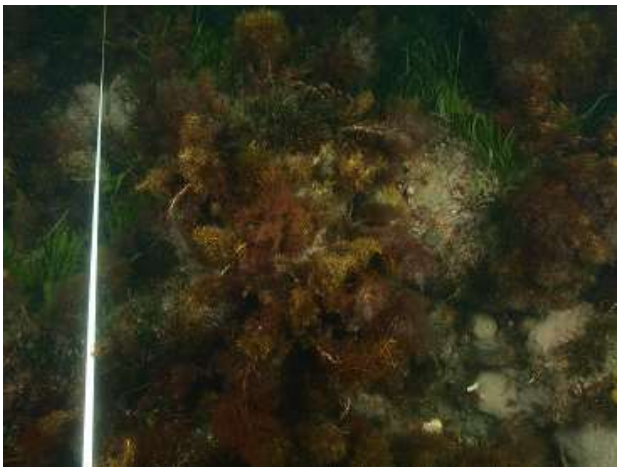
The reef then drops down a gently inclined rocky slope into 2-3 metres. While rockier than other sections of the reef, the gentle profile of this part of the reef provides few large rocks or rocky ridges that might shelter animals from the swell. The seaweed in this area is quite dense but no handfish were found here during the study. Native urchins *Heliocidaris Ethyrogramma* are common on the rocky edges of this weedy area.

The reef then slopes gently down and flattens forming a 10 metre wide reef edge in 4-5M, covered in some small boulders often of 1 metre in diameter. This area is covered in short Caulerpa and sargassum after winter, changing to a bushy red algae in summer. This is the area where handfish are usually found. The vegetated reef slope is only approx. 75M wide from north to south and has been bounded on the southern side by an urchin barren, which showed signs of recovery in 2016.

The reef is fringed by moderately coarse sand. On the nearby sediment flats the sand gradually becomes siltier as the depth increases. Out to sea in 6-9 metres the sediments support a band of seagrass interspersed with *pyura stolonifera* sea squirts.

In the 9-12m area there is a vast sediment plain stretching across the bay and out to sea, dotted with *pyura stolonifera* sea squirts and patchy seaweed. In summer the area is noted for a varied population of large stingrays.

Underwater conditions



The area's visibility during study dives was predominantly in the range 3-5M, indicating that it is in an area of moderate turbidity. The area is shallow and easily agitated by windy weather. Norfolk Bay is also affected by outflows from surrounding rivers and the topography of the area limits water exchange compared with open ocean sites.

The area is moderately exposed to the prevailing westerly weather and can receive a lot of wave energy after winter storms.

In summer the winds become more northerly and the site is more sheltered.

Wind Roses Hobart 3pm Aug-Nov averages since approx. 1958

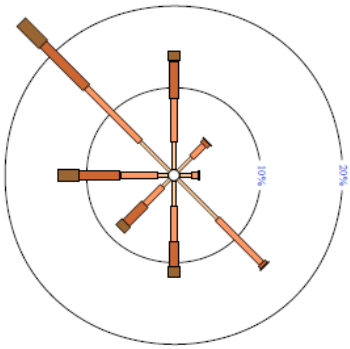


Figure 1 August 3pm Hobart

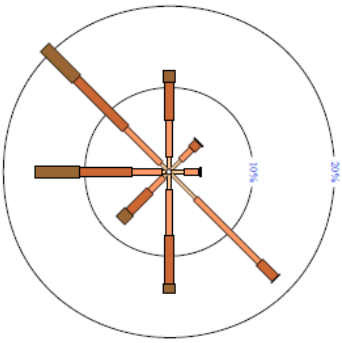


Figure 2 September 3pm Hobart

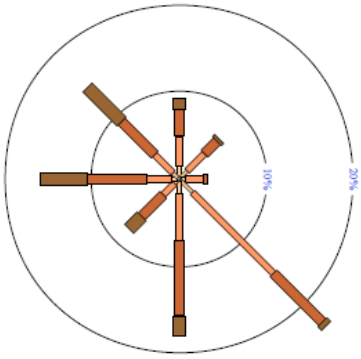


Figure 3 October 3pm Hobart

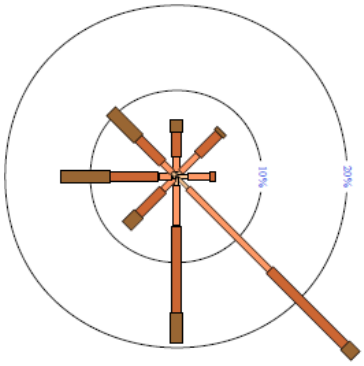


Figure 4 Hobart 3pm Nov

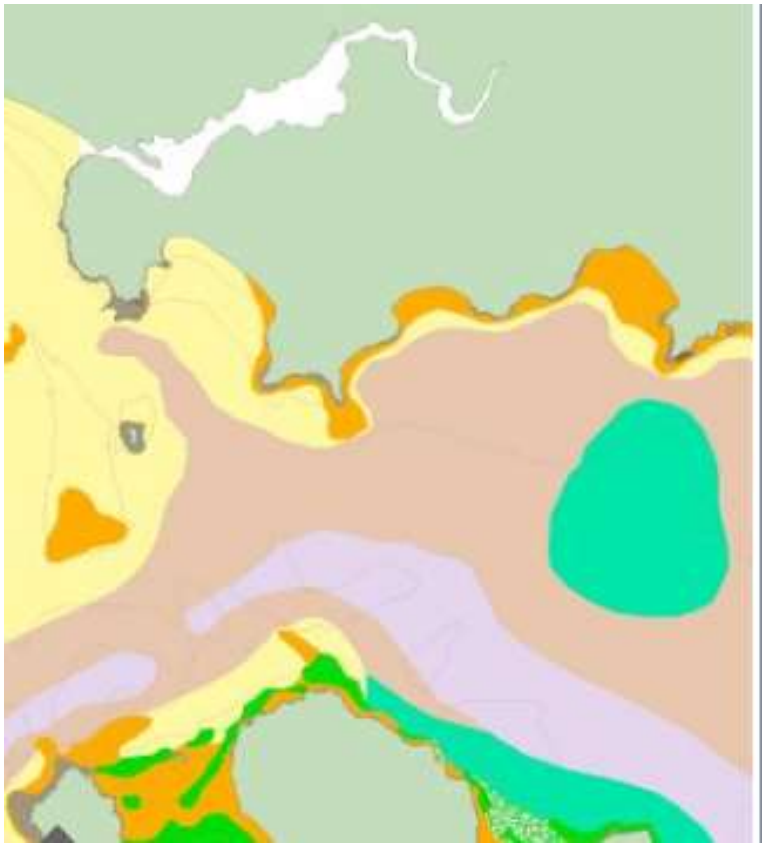
Sightings in adjacent areas

Sightings in the adjacent area include a single fish seen on the reef edge just east of Primrose Point by diver John Butterworth in the late 1990s and an unconfirmed single fish seen in shallow water off Carlton Bluff in around 2008.

Out on the sediments nearby the breeding site, the CSIRO's 1999 study found red handfish in 9.5 to 11 metres depth. Red handfish were measured ranging from 23mm to 71mm in length. This mud was also home to a spotted handfish colony that failed or moved away around 2000 and the red handfish were seen incidentally as part of a spotted handfish survey.

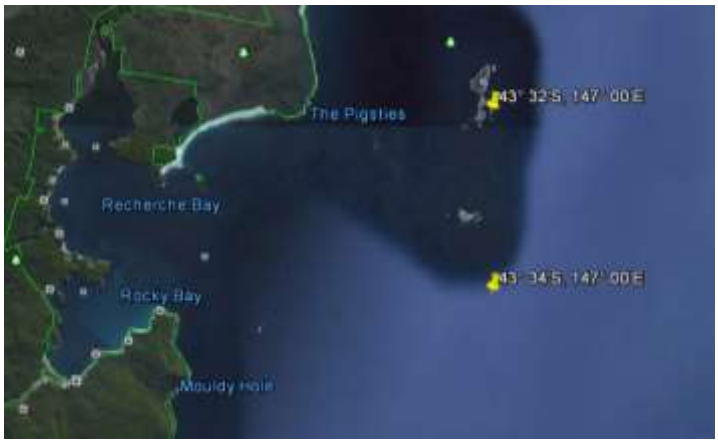
The areas around Primrose Sands contains a number of potentially suitable sites. Interestingly, a site with almost identical site characteristics such as weed composition, geographic orientation, depth, nutrient levels, visibility and wave exposure was located on Primrose Point only 1 km away from the known breeding site, but no handfish were located there. A limited number of similar dives on suitable habitat around the Isle of Caves and Carlton Bluff were also unsuccessful in locating red handfish.

Spotted handfish have been reported in deep water off the northern side of Slopen Island to the south, and off Green Head and these areas warrant further exploration.



Seamap habitat map for the Norfolk Bay area including Primrose Sands

Site B Actaeon Islands, D'Entrecasteaux Channel, SE Tasmania



Previous sightings

The following specimen collections have been made at the Actaeons,

- 60.2 mm, ca. 43° 32'S, 147° 00'E, 8 m, 19 Apr. 1980; [exposed south eastern side of Actaeon Island]
- 61.4 mm, 43° 34'S, 147° 00'E, 5 m, 6 Apr. 1985.[chart reference, exposed South Break]

These specimens were discovered by abalone divers. This area has also been associated with sightings of Ziebells Handfish. These sizes are consistent with one and a half year old sub-adults.

The 1982 book "Coastal Fishes of Tasmania and Bass Strait" includes a Peter Last photo of a red handfish (plate 22) captured off the Actaeons by abalone divers and taken to the Taroona labs of what is now IMAS. The photo cation credits the depth as 4m. This would likely be the 1980 specimen. Interestingly, it is the colour morph also found at Primrose Sands and appears to be male.

The preserved holotype – the 1985 specimen, the Primrose Sands colour morph

Graeme Blight is also known to have photographed a red handfish in a CSIRO tank and credited as from the Actaeons and found in the 1980s. The colour form was very dark red like the Tasman Peninsula colours (I have a suspicion they are actually photos of the 1983 Lagoon Bay samples in the Taroona tank?).

Reef Profile

The sites have not been surveyed, but the depths in this area would mean very exposed reef dominated by Bull kelp with a red algae understory, conditions very unlike Primrose Sands and ordinarily hostile to fragile egg masses.

Underwater conditions

If the locations have been noted correctly this, is a very exposed area of very high wave energy. Visibility is likely to be relatively clear on this open ocean site.

The eastern side is exposed to all weathers with little wind protection from the west offered by these low islands. This area experiences prevailing SW swells from the West Coast, from which small islets and reefs would only provide minimal protection. The north western side of the island chain does receive some shelter from the swell, but in spring it is exposed to the prevailing NW flows. It is still sufficiently sheltered for more delicate seaweed species to grown on the NW side of Actaeon Island. Much of the southern area of the reef is dominated by bull kelp in the shallows.

Adjacent Areas

Recherche Bay is frequently dived and has several sheltered weed gardens that might provide suitable habitat. There are also suitably sheltered weed gardens on the western side of Actaeon Island. Some Ziebell's handfish have been found at the Actaeons, Southport Island and in Recherche Bay. No red handfish have been reported in the locality other than at the exposed areas of the Actaeon reef system.

It is possible that the Actaeons area, particularly any potential sites in the western Actaeons kelp forests have declined. One retired abalone diver (*pers comms 2015 with Mike Jacques*) said that they would see a couple of Ziebell's handfish every year on the edge of the kelp at the Actaeons, but none in the last 10 years, coinciding with a dramatic loss of kelp density in the area.

Site C Lagoon Bay/North Bay area, Forestier Peninsula, SE Tasmania

Previous sightings

These are the collected samples from the area, which are placed offshore of North Bay.

- 67.3 mm, 42° 52'S, 147° 57'E, 10–12 m, Jun. 1987;
- 65.9 mm, 42° 52'S, 147° 57'E, 20 m,1983;

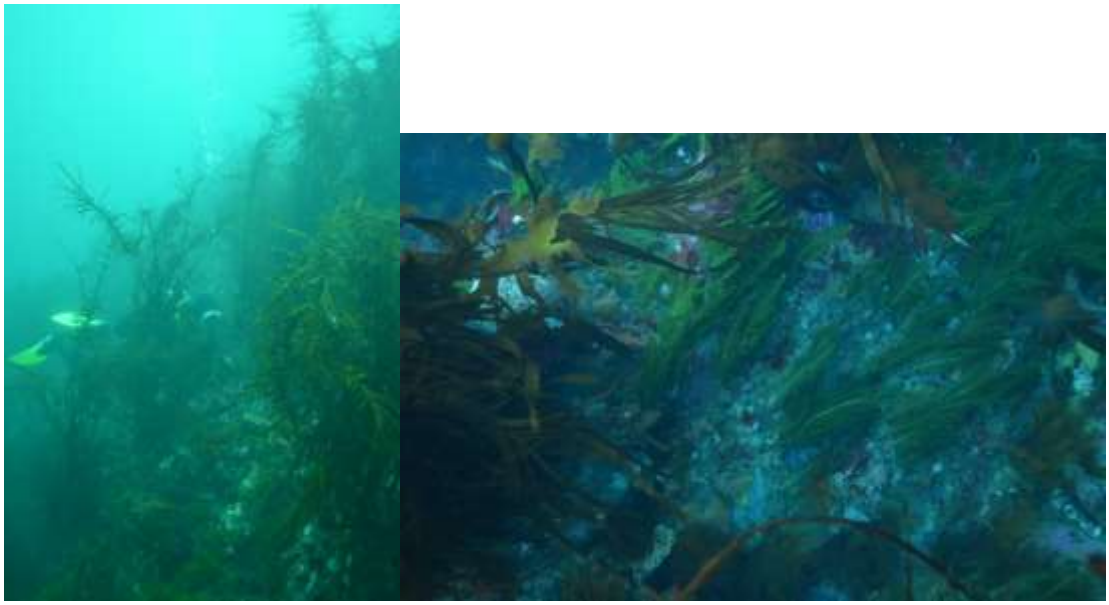
Divers recently performing an extensive urchin research program along the North Bay shore were told to look out for handfish, but none were incidentally sighted.

In addition to the above collected specimens, there was a confirmed sighting in December 2004 in Lagoon Bay, on rocky reef on the southern side of the Kelly Islets, by underwater photographers Sarah Quine and James Parkinson.

Reef Profile

It is presumed the two earlier sightings in North Bay are on rocky reef.

The site at Kelly's Islets is on the southern shoreline on steep sloping reef with narrow ledges that end on sand in 12 metres. It has been redived in September 2016 and the vegetation was as indicated in the photo below,



Underwater conditions

This is an open ocean area with clear visibility and only moderate exposure except to summer easterly storms. Lagoon Bay itself is particularly sheltered.

North Bay is exposed from the NW to the NE. Lagoon Bay is very sheltered from all but NE winds and swell. Swells are mostly southerly and the sites are well-protected from larger swells. After easterly storms there can be easterly swells.
The North Bay site is along coast very open to northerly storms which are common especially in early spring. This site is moderately exposed. Lagoon Bay is a relatively sheltered site.

Adjacent Areas

Various handfish species were regularly seen all along the eastern coast of Tasman Peninsula. The Lagoon Bay area is moderately regularly visited area by larger craft and was previously popular with cray divers and scenic divers visiting remnant kelp forests in Lagoon Bay. Due to the vast area of the reef it is not surprising that sightings are infrequent, but they suggest a viable handfish population. The loss of a resilient kelp forest in this bay in June 2016 is indicative of broader concerning changes. There have now been no sightings reported in the Lagoon Bay area since 2004.

Site D, off Bridport, Bass Strait, Tasmania,

Previous sightings

The collected samples in the area were

- 28.1 mm, 40° 58'S, 147° 25'E, 15 Oct. 1950.

No further records or anecdotal reports have since been received but suggest the red handfish's potential habitat is more widespread than just SE Tasmania. The sighting represents a one year old juvenile that is possibly close to a breeding habitat.

Reef Profile

A Warty Handfish was collected near here on the same day, possibly in the same trawl. The collections were made close to Southern Cross Reef which is recorded at 40.950000762 147.429992675. This reef is the major rocky outcrop on this otherwise flat sandy seabed. Depths on this area of seabed were likely in the 20M zone, although the reef itself dries at low water. This reef is fairly frequently visited by recreational divers, but no further sightings have been made.

Underwater conditions

This is an area of clear open ocean water. With moderate exposure levels.

This area is very exposed to all wind and swell except from the south and receives strong winds. A low headland offers very limited shelter from the west. The direction of the swell through Bass Strait is generally westerly, but it can be reversed by strong easterly storms.

The wind conditions prevailing in Bass Strait are a story of almost constant westerly winds and storms, broken by only occasional easterly conditions. This would make Southern Cross Reef highly exposed with impoverished algal life on the western side, with possibly more delicate seaweed assemblages in deeper areas in sheltered parts of the eastern reef. This site is perhaps twice as exposed as SE Tasmanian sites. In terms of swell, perhaps only the Actaeon Islands are as rough.

Figure 5 September 3PM Burnie

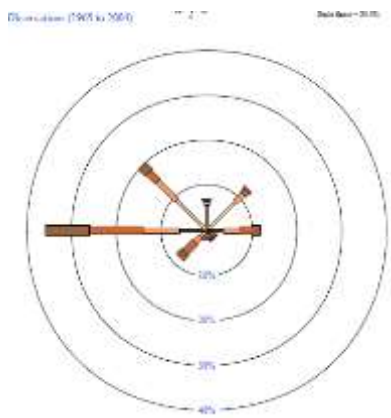


Figure 6 august 3pm Burnie

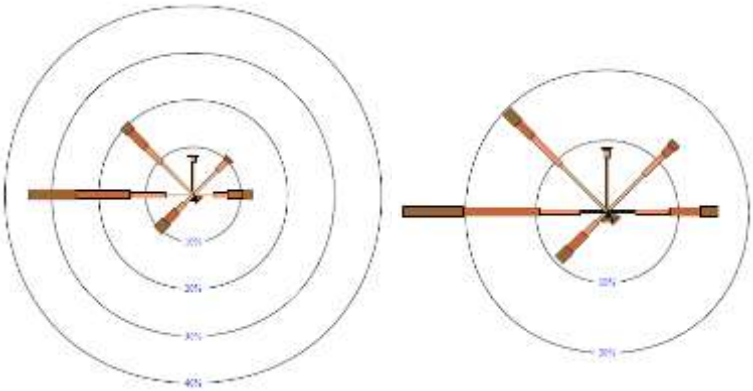


Figure 7 October 3PM Burnie

Adjacent Areas

There have been no further relevant sightings in the area even though Southern Cross reef is a relatively small area that is popular with recreational divers. As this area is within a locality that is actively trawled for scallops, the population may not be viable any longer.

Site E Port Arthur

Previous sightings

Richardson (1842) referred to a reddish handfish collected by amateur naturalist, Mr Thomas Lempriere near the penal colony of Port Arthur, but the exact location was not given. It appears that multiple specimens were collected, probably in shallow water using dip nets.

There have been two reported observations from the Port Arthur area since the 1980's (Gowlett-Holmes, pers comm., cited in Last & Gledhill 2009). Reef Life Survey reports one of these sightings as being in April 2002.

Reef Life Survey noted an April 2002 sighting report in Port Arthur, but with no other particulars.

A credible but unconfirmed sighting report was also made in approximately 2012 and much later reported to the CSIRO. This was at Stinking Bay in the shallow weed close to the entrance to Long Bay.

Reef Profile

The Long Bay/Stinking Bay area was surveyed in Spring 2014 and was also found to be heavily damaged by an urchin barren except in very shallow water. There is a small amount of remnant reef in the back of Stinking Bay. The potential search area is significantly larger than Primrose Sands and no sightings were made.

The area around the shipyard appears muddy and unsuitable with poor water exchange and limited habitat. At Frying Pan Point the seaweed, including Caulerpa, was very dense due to strong light penetration. No handfish were found. It should be noted that the weed was dense despite the Frying Pan Point area being effectively cleared by a native urchin barren in approximately 1991 (M.Jacques pers comms).

Stinking Bay near Long Bay 2014-15

Underwater conditions

These vary from exposed clear water sites at the mouth of Port Arthur to more sheltered areas of limited water exchange in the northern end of the harbour.

The harbour is oriented north- south, with shelter from westerly winds on the west side and easterly winds on the east side. In late Spring, the switch to SE winds is likely to occasionally batter some of the usually sheltered sites on the NW end of the harbour. The eastern and southern cliffs are very exposed.

Adjacent areas

During the study an attempt was made to identify sites similar to Primrose Sands that would be reached by foot, or by small rowboat for a person with limited leisure time, like Lempriere. Sites most likely included Port Arthur shipyard (where there may have been a wooden jetty or slip rails to stand on) but it proved unsuitable.

Reef Life Survey conducted searches of the Port Arthur historic site area jetty and Stinking Bay in 2015, without success.

It should be note though, that locating red handfish is a 'hit and miss' affair and these areas were only sample searched by a limited number of divers. In clearer water sites the algal biomass is significantly larger, creating 'a needle in a haystack' issue for divers seeking such a small fish. This was particularly noted in the very clear 'oceanic' waters of the western side of the Isle of the Dead that were dominated by large brown macroalgae canopy cover.

Further research into Lempriere's activities at Port Arthur may be useful, in identifying his favourite sampling spots.

Site E – Fortescue Bay

Previous sightings

This site was found by John Bryan in 1985 "in bay halfway to Lanterns from boat ramp where the kelp forest used to be". This is the prominent rock on the south side of the bay known as White Rock.

Photo:Jon Bryan

A further record says Hugh Peterson found a red handfish in Fortescue Bay in 1999 and also stated "with the species being sighted in the Fortescue Bay area up until 2001 (Valentine, Pederson, per comm.)". (quoted in Edgar GJ, et al (2015) "Systematic Surveying of Two Threatened Handfish Species". Report for the Department of the Environment.

Reef Profile

The area needs to be redived and surveyed.

Underwater conditions

The area is moderately exposed to NE storms in summer. The kelp forest previously recorded at the rock by Edyvane (2003), has long since disappeared.

Adjacent areas

The Lanterns Area and the northern side of the Thumbs is increasing becoming damaged by invasive NSW black urchins. The Fortescue Bay area has long had very large kelp forests of impressive biomass, but all have since gone. The nearest other red handfish sightings are at Port Arthur or Lagoon Bay.

Site F – Lobster Point

Previous sightings

A red handfish was seen by Dr Neville Barratt off Lobster Point in 2002. The fish were found incidentally during an IMAS reef monitoring study.

The point is 5-10 m high sandstone bluffs and fronted by 80 m wide intertidal rock flats. Accessible along a foot track that follows the crest of the bluffs.

Reef Profile

Apparently flat shallow reef.

Underwater conditions

The discoverer mentioned that the area is often swelly. The reef is a low and shallow weedy reef platform

Adjacent areas

Spotted handfish have been reported in deep water off the northern side of Slopen Island and off Green Head.

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APPENDICES

Appendix 1 Fish Sightings

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1st		2010 late Feb TAFI searched carefully and found none					**2005CSIRO surveyed "in Winter on the mud, no fish**	Mick Barron in wild and in tanks has commented they breed in August estimate in about 2002			**2005CSIRO surveyed "in Late Spring" on the mud, no fish**	2010IndiaFA, 2010JeminaM
2nd			2014 SurferJoeM60mm, EyepatchF60mm, BluefinM70mm							2016 3 UK sighted 1FE	2013 Blueblade male 2013 Tippex male 2013 Banana FA 2013 male possible Jemina	2010IndiaFA 2010EmmaFA 2010 Head injury/Juanita M confused with Mark 80mm
3rd												
4th							2010No sightings 1996CSIRO 8 located (10 seen that year), captured **2 gravid females** 80mm&69m				**1996CSIRO sights two more egg masses and collects an egg mass** **2012gabbi70mmFE** 2012Jemina80mmFA 2012WhitetailFE 2012Flea40mm 2012Laura-Maye70mm	

							m and 2 juv fish 50mm & 68mm				2012Dickie?M70mm **2012TrudiFE**	
5th												2010IndiaFA 2010EmmaFA 2010Jemina
6th										**2012renFE** 2012HeadinjuryM 2012YellowsoxM 2012GabbiFE		2010Martha FA 2010CandiceFA 2010Jemina
7th									**1996 CSIRO captive spawns**		**2010Martha FE 2010Emma FE,**	
8th					2012Ren80mmFA 2012AlisonFA 80mm 2012GraceFA 80mm 2012AmyFA80mm		2012Trudi/Tom M **2007 TSDC searched 4.5x100m line searches on sand, no fish, searched mostly on northern side**					
9th									**1996 CSIRO captive spawns**			
10th									**2010Emma 70mm FG, 2010Martha 70mm FE, 2010India 80mm FE,**			
11th												
12th										**12-14 Oct1999CSIRO found 2 fish offshore on the mud in 7-9M, found in a year when there were many spotteds**		
13th								2012Jemina? M 2012**Whitetail**		2012gabbi70mmFE 2012Jemina80mmFA 2012WhitetailFE		

								2012Liz		201280mmEricM 2012Tigger50mm 2012Flea40mm 2012Laura-Maye70mm 2012headinjuryM 2012TrudiFE		
14th									2013 Tassie 60mm FA 2013 Blueblade male 50mm 2013 Tippex male 60mm 2013 Arrow male 70mm		**1996CSIRO collected egg mass hatches**	
15th									**2011Candice FE**	2011 no sightings		
16th											**2005CSIRO found no fish offshore in a year when there were no spotteds either** **2013 fish observed hatching from 2 egg cases, but no fish**	
17th							2010no sightings					
18th												
19th												
20th				2015 Taniaf65 -70mm LouisaF6 5-70mm, Eyepatch F, BluefinM							**2010Martha FE** **2010Emma FE**, 2010Candice 80mmFA,	
21st									2012 Dickie M	2010Jemina M?60mm, 2010Rick juv, **2010Martha FE** **2011CandiceFE** **2011MarthaFE** 2011JeminaM? 2011Headinjury/JuanitaM?		

										2011AdrianM?		
22nd				2012Handfish 80mm					2013 unidentified fish 2013 Tippex male 2013 Banana FA 2013 Flea FA			
23rd							2010no sightings		2016 4 sighted		2010India FA, 2010MarkFA80mm, **2010MarthaFH**	
24th												2010?uncertain xmas new year sighting of some fish
25th							**2011 Search on mud 6-8M no result**		2016 nil sighted	**25/26 Oct2005CSIRO found no fish offshore in a year when there were no spotteds either**		
26th												
27th											**2010EmmaFE** 2010JeminaM? 2010IndiaFA	
28th				**April1999 CSIRO found 9 fish offshore on the mud in 7-8M all mixed sizes 23mm-71mm. In caulerpa with spotteds**						**2012WhitetailFE** 201280mmEricM 2012Tigger50mm 2012Laura-Maye70mmFA 2012headinjuryM 2012TrudiFA 2012Tina FE 70mm		
29th												
30th										**2011CandiceFE** 2011JeminaM **2011MarthaFE** 2011Emma		

31st 2011 no sightings										1996 CSIRO observes first egg mass		NIl

sex, F or M **eggs status** – FG=gravid FE=present, FA=absent, FH=observed hatching or with some eggs and hatched cases , Habitat normal font + reef bold text = **mud searches**

Summary of annual activity

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Little or no activity	Little or no activity	Fish seen inshore and offshore of varying sizes	Little or no activity	Some fish seen	Little or no activity	Some fish seen inshore in mid-july 2012	Mick Barron commented they bred in August 2002, only a few small fish hanging around mid-Aug 2012	2010 gravid fish and eggs seen mid month, 2011 Eggs seen by mid-month	Eggs first seen in first week of month in 2012 and 2016.	Hatching in tanks occurred mid month 1996 and in wild 2010 and 2013. Latest egg sighting 2010 was 27th Nov.	Post breeding fish may linger for 1st week in Dec, then no sightings

Continuity table - Identified individual fish sightings at Primrose Sands

Fish	2010	2011	2012	2013	2014	2015	2016
Emma female	Bred successfully 70mm (on C. cactoides)	Bred successfully (on C.simpliscula)					
Martha female	Bred successfully70mm (on C. longifolia)	Bred successfully (on C.simpliscula)					
India female	Eggs detached 70mm (on thin red algae)						
Candice female(ex Mick)	Sighted 70mm	Bred successfully70mm (lay eggs on red algae)					
Mark female	Sighted 80mm?						
Head Injury (ex Juanita) male	Sighted 70mm	Sighted with fish injury	sighted				
Jemina male	Sighted 60mm	Sighted	Sighted 80mm	Possible sighting			
Unidentifed				Not photographed			
Rick	Juvenile with damaged fin 50mm?						
Adrian male		70mm sighted					

Trudi (ex Tom)			bred unsuccessfully laid eggs on unknown material, eggs washed away 70mm				
Banana female Perhaps Trudi?				Sighted 65-70mm			
handfish M (thought Jemina but not)			Sighted 70mm?				
Ren female			Sighted 65-70mm?				
Alison F			Sighted 65-70mm?				
Grace F			Sighted 65-70mm?				
Amy F			Sighted 65-70mm				
Whitetail female			Bred successfully on C. Simpliscula 70mm?				
Liz F			Sighted 50mm?	Bred successfully (on C. longifolia) 70mm?			
Dickie M			Sighted 70mm				
Gabbi F			70mm Bred successfully (lay eggs on sargassum) healed fish injury				
Eric M			Sighted 65-70mm?				
Yellowsox male			Sighted 65-70mm?				
Tigger			Sighted 50mm				
Laura-May F			Bred successfully 70mm, lay on unknown substrate red algae?				
Tina female			Bred successfully on unknown algae				
Flea female			Sighted 40mm	Sighted 70mm			

Stephanie				Bred successfully on Sargassum 70mm?			
Tippex male				Sighted 65mm			
Blueblade male				70mm sign of fish injury			
Tassie female				Sighted 60mm			
Arrow male				Sighted 70mm			
Surfer Joe					60mm		
Eyepatch F					60mm	RLS dive?	
Bluefin M					70mm	RLS dive?	
Tania F						RLS dive	
Louisa F						RLS dive	
unnamed							
unnamed							
unnamed							
Unnamed F							With eggs

Observation Totals summary	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
TOTAL MALES	3	3	7	4	4?	1	3?
TOTAL FEMALES	5	3	11	5	3	3?	1
Total Fish	8	6	18 (7 with 11 recruits)	9	8	4	4
Juveniles included in totals	1 one year old male 1 two year old male		-approx. 2 male and 1 female one year olds - estimated 4 male and 4 female two year olds (not seen before)	estimated 3 male and 3 female two year olds (not seen before)	1		
TOTAL BRED SUCCESSFULLY	3 (1 failed)	3	5 (1 failed)	2	?	?	1?
No of Dive events on reef breeding area	12	7	9	4	1	rls	4
Total No of dive tanks used approx. dives (45-100min)	25	16	18	7	3	rls	14
Observed seaweed condition in breeding area	good	thinning	Noticeable further decline	Stable to improved	Very poor	good	Improving And expanding

Observation Summary

Despite a decline in survey activity between 2010 and 2016, the results have been fairly consistent. A stable population of 3-4 males and 3-5 females have likely persisted at the site. 2-3 females successfully raise a clutch of eggs each year.

The aberration is 2012 where 11 new fish appeared, 8 of a smaller size that were likely to have been hatched in 2010. In this year, only two handfish (Emma and Martha) successfully raised a clutch on Primrose Sands reef. Despite moderately high survey effort during 2011, these fish were not detected as a spike in sightings of 20-50mm year one juveniles. In fact, no new juveniles, or even newly identified year two adults were detected that year. This may indicate that these fish remained cryptic under the rocks. It is more likely that they migrated into the colony from another population, or returned to the colony after migrating away from the colony in early 2011.

Also dived Pt Arthur and Isle of Caves with no success.

2012 Winter – pre breeding

Prior to this point we had presumed that the reef was abandoned prior to the lead up to breeding in Spring. On 22 April, we incidentally noticed a small female that has not been previously identified followed by three others in early May. This was the earliest sighting at that time. In 2011 we had conducted unsuccessful surveys and had basically given up on Summer handfish counts. We had been doing urchins smashing in 2012, and it is interesting that there were no incidental sightings as that is work quite close to the bottom around rock edges. TAFI survey teams has also failed to find fish in February 2010. In 1999, CSIRO had found handfish but out on the adjacent mud.

None of the fish seen in this period were previous sightings and all were of a fairly uniform and probably two year old size and female.

2012 Spring/Breeding

The interesting feature of the later Spring dives is that a large number of mixed sizes and genders appeared, including fish seen in earlier breeding years as well as completely new fish. No fish seen during the autumn/winter were resighted in Spring, although you would expect them to be attracted to the breeding activity. The fish that did lay eggs did so in sparse vegetation where we could have expected to have found at least some of them. They may have been on the reef to the north undetected (divers were also attracted to the 'action' around the breeding site), or they could have been already out on the sediment.

2013 'follow on'

It should also be noted that this population 'boom' was not reflected in a subsequent jump in sightings of 70-80mm adults in 2013. Misidentification and mortality could explain the lack of continuity with 2013 sightings (only one year one 2012 juvenile "Flea", could be matched with a year two 2013 adult). Migration away from the colony of this 'excess' population is also likely and it is interesting that the 2013 results appeared more like a 'return to normal' in terms of average population numbers.

2014

The idea was to see if our prior notion that handfish were not about in the warmer months would hold up. I was anticipating no handfish, or maybe only a few 50mm juveniles. Prior earliest sighting (May) were of generally smaller 50 & 60mm fish. It was very useful dive as three handfish were seen, two 60mm (male and female) plus a 70mm male. This contradicts the idea they only use the reef seasonally and then mostly smaller age classes.

Subsequent work that year was on assessing the adjacent mud flats rather than counts and measuring in the reef. We also tried to locate additional colonies in other locations.

2015/16 was merely presence/absence monitoring and should not be used to draw statistical comparisons. We also continued with investigating other sites. Most dives were carried out by other groups with little prior experience of finding red handfish.