Fisheries Scientific Committee

Proposed determination

McCulloch's anemonefish
Amphiprion mccullochi

Assessment outcome: CRITICALLY ENDANGERED
Category: A2abc+A3bc+A4abc , B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv)

The Fisheries Scientific Committee, established under Part 7A of the *Fisheries Management Act 1994* (the Act), has assessed *Amphiprion mccullochi* (**McCulloch's anemonefish)** under the Common Assessment Method and has determined that it is eligible to be listed as a **CRITICALLY ENDANGERED SPECIES** Part 1 of Schedule 4 of the Act.

The Fisheries Scientific Committee, with reference to the criteria relevant to this species, prescribed by Part 16 of the Fisheries Management (General) Regulation 2019 (the Regulation) has assessed and determined that:

- The listing of CRITICALLY ENDANGERED is provided for by Part 7A, Division 2 of the FM Act.
- The assessment has been determined in accordance with the national Common Assessment Method (CAM), which provides a nationally consistent approach to the assessing and listing of threatened species in Australia.
- The assessment documentation below indicates the eligibility of the species for listing under both FM Act requirements and IUCN criteria as prescribed by the CAM.
- For more information about the CAM, visit https://www.dcceew.gov.au/environment/biodiversity/threatened/cam

Please note that all submissions may be made public unless confidentiality is specifically requested. Only written submissions will be accepted.

Any person may make a written submission which should be forwarded by **email** to fsc@dpi.nsw.gov.au or by **post** to:

Fisheries Scientific Committee
c/- NSW DPI Fisheries

LMB 3020
NOWRA NSW 2541

The proposed determinations can also be viewed at the DPI Fisheries Head Office and District Fisheries Offices in NSW.

This consultation process may coincide with a separate process for listing these species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as part of the Common Assessment Method.

For information about this process visit Comment on listing assessments - DCCEEW

Species information and status

The information contained within this nomination has been provided from the 2022 summary report by Dr. Jean-Paul Hobbs: "Summary report on the conservation status of McCulloch's anemonefish: towards consideration as a threatened species. Report for Lord Howe Island Marine Park."

a) Taxonomy

Conventionally accepted as *Amphiprion mccullochi Whitley* (1929). Order Perciformes, Family Pomacentridae (Damselfishes)

Type data: Holotype AM IA.1962, Lord Howe Island.

Paratype(s) AM I.5392; AM I.5730; AM IA.1967; AM I.5729; AM IA.1964; AM IA.1965; AM IA.1966; AM IA.1963.

b) Cultural and community significance

The population stronghold for the McCulloch's anemonefish occurs in the Lord Howe Island lagoon within the Lord Howe Island Marine Park (LHIMP). Tourism is the primary industry on Lord Howe Island, with most commercial use of the LHIMP directly related to tourism. A LHIMP Visitor and Expenditure Survey found that most tourists to the island undertook a guided tour within the marine park during their visit, and over 90% rated the marine park as very important relative to other aspects of their trip (MPA, 2010). There are three glass-bottom boat companies who take passengers on snorkelling and coral viewing tours on the sheltered waters of the lagoon, and one dive operation. The McCulloch's anemonefish is a major draw card for the tourism industry, many of whom have been involved in community monitoring for this species since 2009 (Hobbs, 2009). The McCulloch's anemonefish was named after Allan Riverstone McCulloch (1885-1925), an iconic ichthyologist and field naturalist with the Australian Museum.

c) Current conservation status

Jurisdiction	State / Territory in which the species is listed	Date listed or assessed (or N/A)	Listing category
National (EPBC Act)	Not listed	Under assessment	Proposed Critically Endangered.
National (Australian Society for Fish Biology)	National	N/A	N/A
State / Territory	New South Wales	Under assessment	Proposed Critically Endangered.

d) Description of species

Adult McCulloch's anemonefish are dark brown to black with a whitish snout (Fig 1). They have one white bar on the cheek that usually does not connect over the top of the head. The caudal peduncle and caudal fin are white. The maximum size for the McCulloch's anemonefish is 120 mm total length (TL). It is only found associated with the sea anemone species *Entacmaea quadricolor* (bubbletip anemone). Like all other anemonefishes, McCulloch's anemonefish lay a clutch of eggs on the substrate next to the host anemone. Initially, eggs are approximately 2-3 mm long and orange-red in colouration. When the eggs are 7–8 days old, they change colour to be transparent with black and silver eyes. The larvae maintain this colouration when they hatch out of the eggs (days 9–12) and while they are in the pelagic environment (pelagic larval duration = 10–12 days). Between days 19–24, the larvae will leave the pelagic environment and settle into an anemone. During the settlement process, the transparent larvae will change colour to become black with three white vertical bars. The face, trailing edge of the pectoral fins, and caudal peduncle are yellow. As the fish grows, it gradually loses its yellow colouration and the two posterior white bars. By 5 cm (TL), the fish usually exhibit the adult colouration.

Figure 1: *Amphiprion mccullochi* (McCulloch's anemonefish) within *Entacmaea quadricolor* (bubbletip anemone) in the Lord Howe Island lagoon © Justin Gilligan.

e) Distribution of species

McCulloch's anemonefish is endemic to Australia, occurring in the lagoon and inshore waters of Lord Howe Island in New South Wales, and within the Ramsar listed Middleton Reef and Elizabeth Reef, in Commonwealth waters (Fautin and Allen, 1992) (Figure 2). Lord Howe Island is a hotspot for endemic species and its high conservation significance has been formally recognised by its inclusion on the UNESCO World Heritage List (1982), as well as the declaration of Marine Parks in State and Commonwealth waters surrounding the island. The Lord Howe Island Marine Park (LHIMP) was declared in 1999 and extends to the edge of NSW waters from the mean high-water mark, covering an area of approximately 48,000 hectares. The Lord Howe Marine Park (Commonwealth Waters) was declared in 2000 and extends beyond NSW waters, to the north encompassing Middleton Reef and Elizabeth Reef. All three remaining subpopulations of McCulloch's anemonefish occur within these marine parks.

McCulloch's anemonefish was originally recorded from four regions (Fautin and Allen, 1992; Choat et al., 2006; ALA 2022); however, it is no longer detected at Norfolk Island with dedicated surveys in March 2012 of 2559 host bubbletip anemones failing to locate any McCulloch's anemonefish (Hobbs unpubl. data). Their absence at Norfolk Island is also supported by reports from other field surveys (H. Paterson pers. comm.; Reef Life Surveys; Francis 2022) and local divers (J. Marges, M. Smith pers. comm, M Scott pers. comm.) (Hobbs, 2022).

McCulloch's anemonefish is present but rare at Middleton and Elizabeth Reefs, and most abundant at Lord Howe Island (Hobbs, 2022). At Elizabeth Reef, across the years 2007, 2011, and 2018, it was only recorded at 1–2 of the 7–10 survey sites. At Middleton Reef across the years 2006, 2007, 2011 and 2018, it was only recorded at 1–4 sites out of 4–24 survey sites (Hobbs, 2022) (Figure 3).

Across the time span of the monitoring program (2009–2021) at Lord Howe Island, the abundance of McCulloch's anemonefish has declined substantially due to the decline in the abundance of host anemones. High levels of anemonefish mortality occur following bleaching events due to rapid habitat loss (mass mortality of anemones). Consequently, McCulloch's anemonefish likely could not maintain a stable abundance during this period of high juvenile and adult mortality.

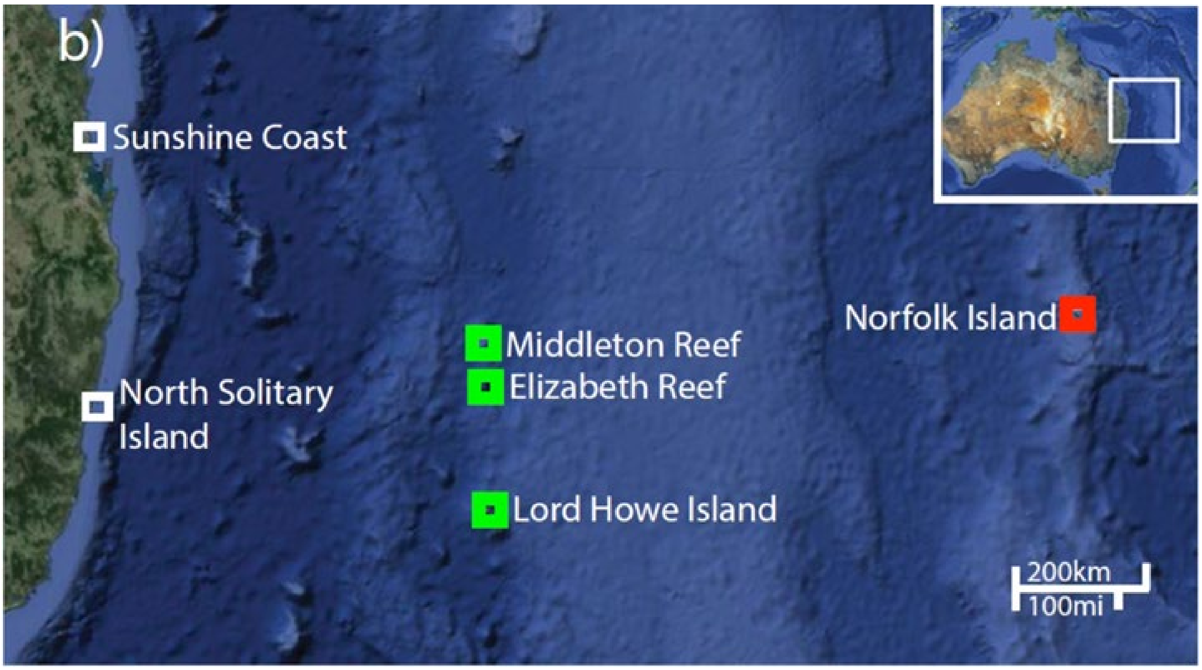

Figure 2: Based on published records, the geographic range of McCulloch's anemonefish encompasses four isolated regions that are offshore from the Australian east coast. The current distribution (green) includes Middleton Reef, Elizabeth Reef and Lord Howe Island. For the purpose of this assessment, Middleton Reef, Elizabeth Reef and Lord Howe Island are considered a single location. McCulloch's anemonefish can no longer be found at Norfolk Island (red). Source: Map adapted from Steinberg et al., 2020.

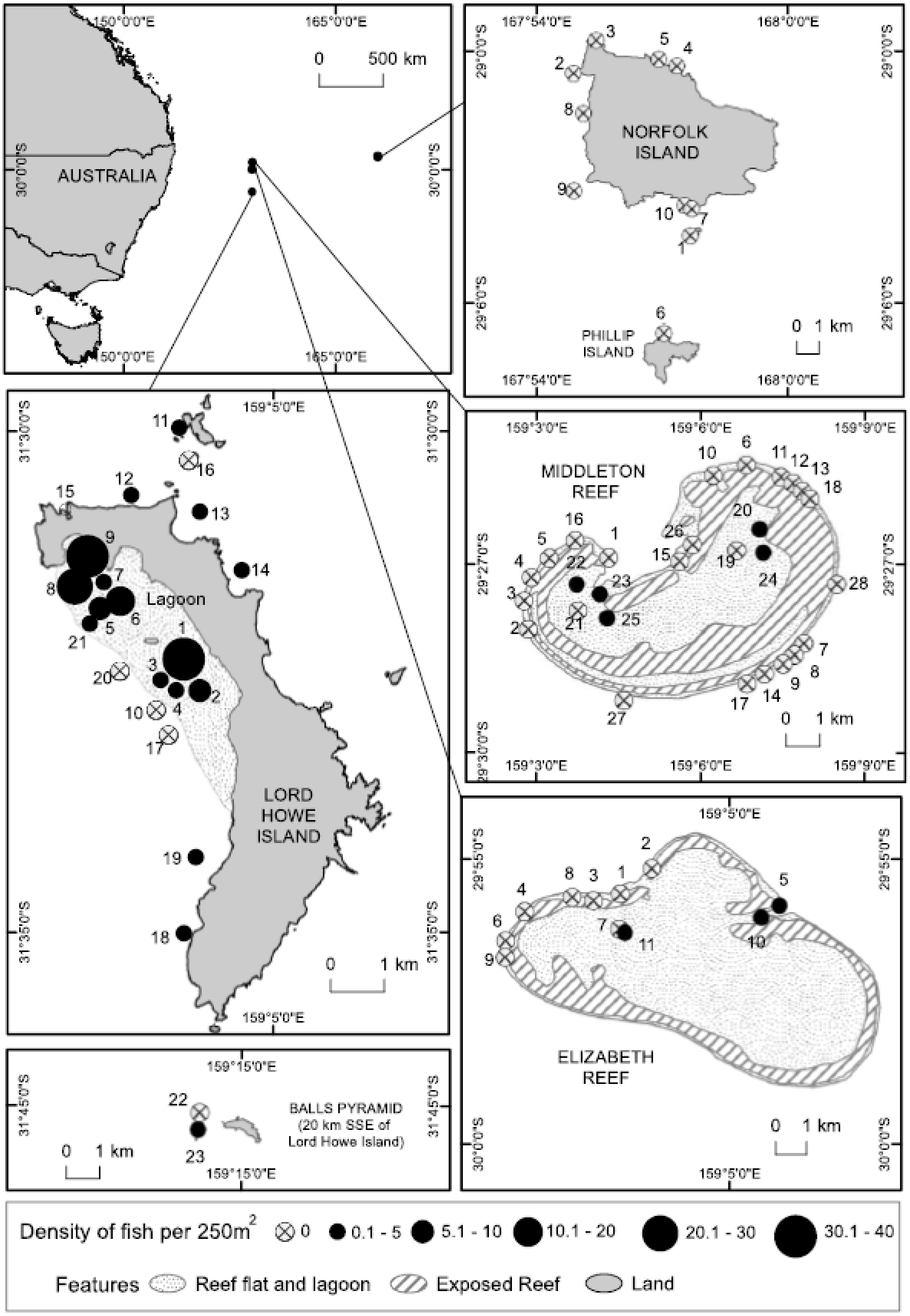

Figure 3: Study sites across the four regions that comprise the geographic range of the endemic species McCulloch's anemonefish. The size of the circle corresponds to the mean density of McCulloch's anemonefish per 250 m² at that site. Figure from Hobbs (2022).

f) Relevant biology/ecology of the species

Anemonefish spawn by laying an egg clutch on the benthic substrate next to their host anemone (Fautin and Allen, 1992). At high latitudes, spawning usually occurs in summer when sea temperatures are elevated (Bell, 1976; Ochi, 1985; Richardson et al., 1997).

Like other reef fishes with a bipartite life cycle, mortality is likely to be highest during the larval stage. There is support for this in McCulloch's anemonefish given the relatively low numbers of new recruits (post-larvae fish) compared to the reproductive output. Demographic data has been obtained from monitoring surveys and research on life histories (Hobbs, 2022). Each breeding pair produces approximately 500–1000 eggs per clutch, and a new clutch is laid around every 8–14 days during the spawning season (November–March). There is one breeding pair per social group, which will produce thousands of eggs during the spawning season, yet each social group will receive about 1–3 new recruits during the season. Although mortality during the juvenile and adult life stages is likely to be much lower than the larval stage, rapid loss of habitat could cause episodes of high levels of mortality.

Given the high reproductive output, there is potential for McCulloch's anemonefish to recover rapidly from low numbers. However, due to the mutualistic relationship and resource limitation, the recovery of McCulloch's anemonefish is likely constrained by the number of host anemones. For example, field surveys at Middleton and Elizabeth Reefs revealed that host anemones are rare, and all are occupied by McCulloch's anemonefish. The low number of anemones would explain why these subpopulations of McCulloch's anemonefish have remained very small from 2006–2018, and not rapidly increased (Hobbs, 2022).

Anemonefish are known to change sex from male to female (protandrous hermaphroditism) (Fautin and Allen, 1992). Given the social and reproductive patterns of McCulloch's anemonefish match those of other anemonefish, it is most likely that it is also a protandrous hermaphrodite (Hobbs, 2022). McCulloch's anemonefish first mature (as males) at 1–2 years of age and can live up to 22 years (Hobbs, 2022). Social groups vary in size (1–19 individuals); however, only the two largest individuals are mature they supress maturation in the smaller ranked individuals (Fautin and Allen, 1992, from Hobbs 2022). Due to the strict social hierarchy and monogamous mating system, the sex ratio of the population is 1:1. Using this size at maturation (56 mm TL), the proportion of adult-sized individuals recorded in transects was 36% (N = 548, across all sites and habitat, 2009–2018). Note that field observations reveal that third-largest fish can be larger than the estimated size at maturity. Many social groups contain fish that are larger than the size at maturity (56 mm TL) but are not part of the breeding pair. These large, non-breeding fish are most likely immature; however, they were included with the mature individuals in the estimate above because they could quickly become reproductive following the death of a dominant mature individual (Hobbs, 2022).

The information on size at maturation was used to measure the decline in the number of mature fish encountered in field surveys. The monitoring data at Lord Howe Island revealed a significant reduction in mature individuals (42% on transects and 81% on tagged colonies) in 10–12 years. The generation time is calculated as 5 or 12 years depending on the method used (see Criterion A), thus, the observed decline in mature individuals has occurred over one to two generations (Hobbs, 2022).

g) Habitat requirements of the species

On coral reefs, many species are reliant on specific microhabitats. Anemonefish are among the most specialised coral reef fishes because of their mutualistic relationship with anemones. Anemonefish can only survive if they inhabit an anemone.

The degree of specialisation varies among the 28 known species of anemonefish, with the most specialised inhabiting only one anemone species, while the most generalised species inhabits up to ten different anemone species. Whilst two potential host anemones have been recorded in its range, McCulloch's anemonefish has been defined as an obligate inhabitant of only bubbletip anemones (Hobbs 2022). Furthermore, the abundance of McCulloch's anemonefish is positively linked to the abundance of bubbletip anemones, thus the population size of McCulloch's anemonefish is constrained by the number of host anemones (Hobbs 2022).

Bubbletip anemones are found on coral reefs throughout the tropical Indo-Pacific. In Australia, its distribution extends south to at least Coffs Harbour on the east coast, and Perth in Western Australia. At Lord Howe Island, the anemone is distributed from the low water mark to 40 m depth and is most common in the lagoon (1–5 m). Bubbletip anemones require a hard, stable structure to attach their foot to. On coral reefs, including at Lord Howe Island, they typically attach to dead coral reef. The bubbletip anemone is heterotrophic and gets its energy from the sun (via endosymbiotic algae) and from capturing plankton. The energetic benefits provided by the endosymbionts are lost during episodes of elevated water temperatures (above 27° C at Lord Howe Island) because the endosymbionts are expelled, and the anemones turn white. Under continued heat stress, beached anemones will shrink and die. Anemones also receive nutrients from the actions and waste of anemonefish. Anemonefish will defend the anemones from predators (e.g. butterflyfish). Consequently, the growth, survival and reproduction of anemones is positively correlated with the number and size of resident anemonefishes (Frisch et al., 2016).

Although bubbletip anemones were present at Middleton and Elizabeth Reefs, they were so rare that none were recorded in transects in any year of field surveys (2006, 2007, 2011, 2018). Across all the sites surveyed at Lord Howe Island in 2009, anemones covered approximately 0.1% of the benthos. However, in the 2019 and 2021 surveys at Lord Howe Island, no anemones were encountered in any line intercept transects. Collectively, these results show that host anemones are a rare habitat throughout the geographic range of McCulloch's anemonefish (Hobbs, 2022).

To determine if the abundance of McCulloch's anemonefish is linked to the abundance of its host anemone, replicate belt transects (50 x 5 m) were required to survey anemones across a much larger area of the reef per site. These surveys by Hobbs et al (2009) revealed a strong positive relationship between the abundance of McCulloch's anemonefish and its host anemone at the site ($R^2 = 0.96$, $p < 0.001$, $n = 23$) and replicate level ($R^2 = 0.99$, $p < 0.001$, $n = 108$). Furthermore, long-term monitoring of tagged colonies showed that declines in the abundance of McCulloch's anemonefish mirrored declines in anemone abundance (Hobbs 2022). Given that McCulloch's anemonefish cannot survive without its host anemone, and its distribution and abundance is dependent on that of its host anemone, it can be concluded that the bubbletip anemone is the sole critical habitat for this fish.

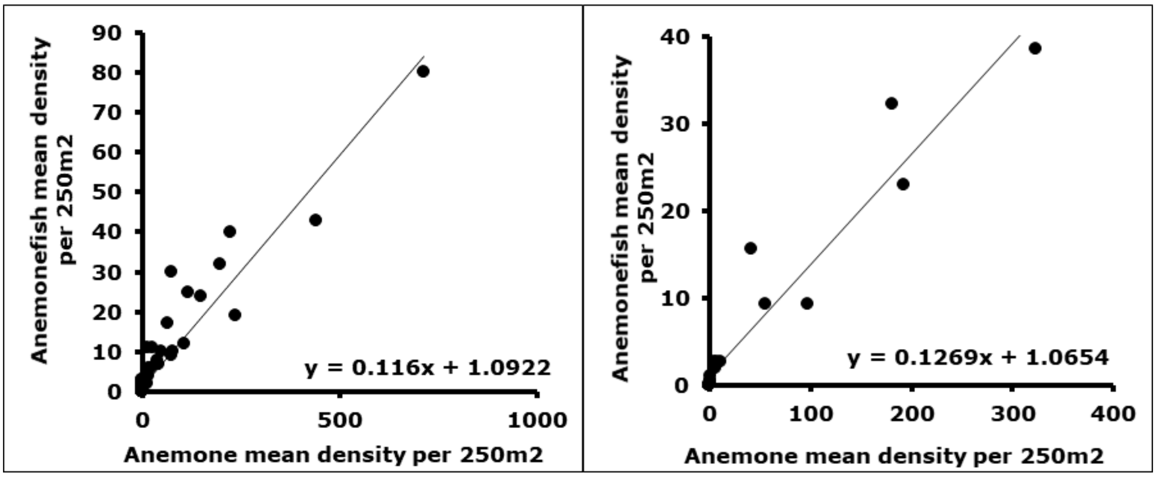

Figure 4. The relationship between the mean density per 250 m^2 of McCulloch's anemonefish and its host anemone (bubbletip - *E. quadricolor*) at: (a) the replicate level (n = 108) and (b) site level (n = 23) around Lord Howe Island. Data from Hobbs et al., 2009.

At the same Lord Howe Island monitoring sites for McCulloch's anemonefish, the two survey techniques revealed a 54–64% reduction in host bubbletip anemones. Surveys reveal a strong positive and linear relationship between the abundance of McCulloch's anemonefish and its host anemone. This indicates that total population size of McCulloch's anemonefish is constrained by the number of host anemones. This relationship has been demonstrated in other anemonefish species and is due to resource limitation. The strength of the relationship is not surprising given McCulloch's anemonefish is an obligate inhabitant of one species of host anemone. Reductions in habitat diversity do not apply to McCulloch's anemonefish because it only inhabits one species of anemone. Thus, declines in the sole critical habitat provide an accurate and reliable measure for estimating reductions in population size of McCulloch's anemonefish.

h) Threats and level of risk to the species
Assessment of threatening processes (under clause 238 of the Fisheries Management (General) Regulation 2019)

Climate change

Climate change is an observed threat that has already negatively affected McCulloch's anemonefish and this threat is expected to increase in the near future. Human caused climate change has been listed as a key threatening process under the NSW *Fisheries Management Act 1994* and has the ability to adversely affect threatened species populations and ecological communities. Furthermore, the loss of habitat caused by anthropogenic emissions of greenhouse gases is also listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Coral bleaching has been documented around Lord Howe Island in 1998, 2010, 2011, and 2019 (Harasti et al., 2022). McCulloch's anemonefish critical habitat (host anemone) are close relatives to corals and will also bleach and die during episodes of elevated sea temperature (Hill and Scott, 2012; Hobbs et al., 2013).

McCulloch's anemonefish critical habitat (host anemone) is directly threatened by increasing sea temperatures associated with anthropogenic climate change. It has been demonstrated that increased sea temperatures cause bleaching and mortality of anemones (Hobbs et al. 2013), which has resulted in rapid declines in abundance of McCulloch's anemonefish and local extinction of other anemonefishes (Hattori, 2002). Laboratory experiments have shown the relationship between anemones and their endosymbiotic algae is highly sensitive to increases in sea temperature, with bleaching occurring when temperatures rise 1 °C above the summer maximum (Hill and Scott 2012; Hill et al., 2014) which is considered to be approximately 26 °C for Lord Howe Island. During severe thermal stress, bleaching leads to anemone mortality (Hill and Scott 2012; Hill et al., 2014). Seawater temperatures above 27° C cause bleaching in host anemones (*E. quadricolor*) at Lord Howe Island (Harrison et al., 2011). Bleaching events are predicted to increase in frequency and severity (Hoegh-Guldberg, 1999; IPCC, 2021), as evidenced by four events on the Great Barrier Reef in the last six years. Modelling predicts bleaching events will occur every 2 years by 2030 (King et al. 2017; Hughes et al., 2018).

Of particular concern is that waters in the Lord Howe Island region are warming faster than elsewhere due to climate change effects on the East Australian Current (Ridgway 2007; Hobday and Pecl 2013; Robinson et al. 2015). Importantly, of the four bleaching events previously recorded at Lord Howe Island, the greatest impact was in the lagoon (Harrison et al., 2011; Moriarty et al., 2019; Dalton et al., 2020), which is the last remaining stronghold for the McCulloch's anemonefish subpopulation at Lord Howe Island. Of greater concern are the subpopulations at Elizabeth Reef and Middleton Reef, which are extremely small and confined to shallow lagoonal areas. These subpopulations are at high risk of significant declines or local extinction within 1 to 2 generations. Therefore, the predicted increase in severity and frequency of bleaching events will cause a continuing decline in the distribution, abundance, habitat, and number of subpopulations of McCulloch's anemonefish.

Habitat degradation

Any disturbance to the Lord Howe Island lagoon could threaten McCulloch's anemonefish. Any disturbance that may result in anemone mortality, such as localised water pollution from diffuse source runoff or maritime source pollution, eutrophication resulting from groundwater contamination (Davis, 2022) which can exacerbate the impacts of climate change and disease (Page et. al., 2023), and anchor damage, may also be considered a threat. Furthermore, any modifications to the natural hydrology and water or sediment flow regime within the lagoon may also result in unfavourable conditions for McCulloch's anemonefish or its anemone habitat and pose a threat to the Lord Howe Island subpopulation.

Illegal harvest

Overfishing is a potential threat because it has caused significant declines in populations of anemones and anemonefishes elsewhere (Shuman et al., 2005). Collections for the aquarium trade impact wild populations by removal of anemonefishes and/or their critical habitat (host anemones). McCulloch's anemonefish is already in the aquarium trade, following the permitted collection of five breeding pairs from the LHIMP in 2005 (https://marsh-reef.org/index.php?threads/time-wasters-to-ride-out-ike-amphiprion-mccullochi-story.19439/). Its rarity commands a high price, and this could encourage further collections. However, the entire geographic range of McCulloch's anemonefish occurs within a Commonwealth and State marine park and collection of this fish, or its host anemones, requires permission from management agencies. Given this management protection, and the remoteness of the marine parks, the threat of aquarium trade collections is considered to be much lower than the environmental threats the species faces.

i) Eligibility against criteria

Reason for assessment

This assessment incorporates monitoring results investigating the vulnerability of the McCulloch's anemonefish from a report prepared for the LHIMP. Hobbs (2022) examined the geographic range, abundance, and specialisation in McCulloch's anemonefish to ascertain its risk of extinction. The geographic range of McCulloch's anemonefish is very small and originally encompassed four subpopulations. One subpopulation (Norfolk Island) has gone extinct. Of the three remaining subpopulations, the Elizabeth and Middleton Reefs subpopulations are very small and on the brink of extinction. The last remaining stronghold for this species is in the lagoon at Lord Howe Island. However, the abundance of McCulloch's anemonefish at Lord Howe Island has declined by more than 50% in the past decade due to habitat loss. Given the small geographic range of the McCulloch's anemonefish, high degree of habitat specialisation and low abundance, McCulloch's anemonefish faces a high risk of extinction.

Field surveys reveal McCulloch's anemonefish is an extreme habitat specialist that only survives by inhabiting one species of bubbletip anemone: *Entacmaea quadricolor*. The distribution and abundance of McCulloch's anemonefish is determined by that of its host anemone. This anemone has declined in recent times from stress (bleaching) and mortality caused by episodes of elevated sea temperatures. As the climate changes, the frequency and severity of these bleaching events is predicted to increase. Therefore, McCulloch's anemonefish has a high risk of extinction because it specialises on a habitat in decline, and its small geographic range and low abundance are also declining.

To determine whether McCulloch's anemonefish warrants listing as a Threatened Species, biological and ecological data were collated to compare against the IUCN Red List criteria below. The data revealed that McCulloch's anemonefish meets the criteria for listing as a Critically Endangered species. This is based on its small and declining geographic range, the threat the species faces across is range from impacts such as rising sea surface temperatures, and the decline in subpopulations number and size.

Assessment of the species reduction in abundance, geographic distribution or genetic diversity (under clause 271 of the Fisheries Management (General) Regulation 2019)

In 2015, the NSW Government signed an Intergovernmental Memorandum of Understanding on the Agreement on a Common Assessment Method for listing of threatened species and threatened ecological communities (the CAM). The CAM provides a nationally consistent approach to assessing and listing threatened species in Australia, using the IUCN Red List Categories and Criteria (Version 3.1). To ensure that this Proposed Final Determination meets the requirements under the CAM, an assessment against the IUCN Red List Categories and Criteria (Version 3.1) has been included. This assessment also reflects the requirements for listing species provided under clause 271 of the Fisheries Management (General) Regulation 2019. For more information on the CAM please visit http://www.environment.gov.au/biodiversity/threatened/cam

This assessment uses the criteria set out in the EPBC Regulations. The thresholds used correspond with those in the IUCN Red List criteria except where noted in criterion 4, subcriterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent listing assessments through the Common Assessment Method (CAM).

Table 1 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria. The definition of each of the parameters follows the Guidelines for Using the IUCN Red List Categories and Criteria.

Table 1 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	-	-	-	The number of mature individuals in the three remaining subpopulations of McCulloch's anemonefish is unknown.
Trend	Contracting due to climate impacts on host anemones. The cause of the reduction (habitat loss due to increasing sea temperatures) has not ceased and is not reversible in the near future.			One subpopulation (Norfolk Island) has gone extinct. Of the three remaining subpopulations, two are very small (Elizabeth and Middleton Reefs) and on the brink of extinction. Repeat surveys at Lord Howe Island lagoonal sites has revealed a 55% decline in the total number of McCulloch's anemonefish from 2009 to 2021 (Hobbs, 2022).
Generation time (years)	5	5	12	The duration for three generations is estimated as 15 years based on an estimated generation of five years calculated by taking the average age from a sample of 37 adult fish (i.e., the average age of parents of the current cohort). Age was determined from otoliths and maturation was determined by histological examination of gonads. Using the other estimation method of generation length = (longevity + age at maturity)/2 results in an estimated generation length of 12 years. Irrespective of the method used to estimate generate length, the Lord Howe Island subpopulation of McCulloch's anemonefish has declined by more than 50% in less than three generations (Hobbs, 2022)
Extent of occurrence	2,907 km^2			GeoCat estimate based on former geographic range including Norfolk Island - 119,442.677 km^2 (Hobbs, 2022)
Trend	Contracting .			Contracting due to climate impacts on host anemones and small population size.

<table>
<tr><th>Metric</th><th>Estimate used in the assessment</th><th>Minimum plausible value</th><th>Maximum plausible value</th><th>Justification</th></tr>
<tr><td>Area of Occupancy</td><td>48 km2</td><td>48 km²</td><td>184 km²</td><td>48 km² (GeoCAT; Bachman et al. 2011).
As defined by the IUCN "Area of occupancy is defined as the area within its 'extent of occurrence', which is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats." Thus, the AOO excludes unsuitable and unoccupied habitat. Given that McCulloch's anemonefish only inhabits anemones, there is only very specific areas that can be occupied by this taxon.</td></tr>
<tr><td>Trend</td><td colspan="3">Contracting</td><td>GeoCAT estimate based on former geographic range including Norfolk Island - 76 km² (Hobbs, 2022). Contracting due to climate impacts on host anemones and small population size.</td></tr>
<tr><td>Number of subpopulations</td><td>3</td><td></td><td></td><td>Population genetic analyses reveal extremely low levels of contemporary gene flow between the remaining three localities and each subpopulation is predominately maintained by local replenishment (van der Meer et al., 2012). The former geographic range included Norfolk Island.</td></tr>
<tr><td>Trend</td><td colspan="3">Contracting due to climate impacts on host anemones and small population size.</td><td></td></tr>
<tr><td>Basis of assessment of subpopulation number</td><td colspan="4">McCulloch's anemonefish only occurs at three isolated localities. Extensive surveys have revealed they no longer occur at Norfolk Island (Hobbs, 2022). Molecular research shows the three remaining localities support three genetically distinct subpopulations (van der Meer et al., 2012).</td></tr>
<tr><td>No. locations</td><td>1</td><td>1</td><td></td><td>Lord Howe Island, Elizabeth Reef, and Middleton Reef are combined to be one location.</td></tr>
<tr><td>Trend</td><td colspan="3">Contracting</td><td>McCulloch's anemonefish has previously been recorded from Norfolk Island, but is now considered extinct at Norfolk (Hobbs, 2022)</td></tr>
<tr><td>Basis of assessment of location number</td><td colspan="4">The main threat to the McCulloch's anemonefish is rising sea surface temperatures. Elizabeth and Middleton Reefs and Lord Howe Island are located along the Lord Howe seamount chain with Lord Howe Island located approximately 150 km south of the reefs. Given the close proximity of Elizabeth and Middleton Reefs to Lord Howe Island, and that sea surface temperatures at both locations being influenced directly by the East Australian Current, for this assessment they are combined as the one location as the influence of rising sea surface temperature would similarly affect both Elizabeth and Middleton reefs and Lord Howe Island.</td></tr>
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Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Fragmentation	McCulloch's anemonefish is present but rare at Elizabeth and Middleton Reefs. Across the surveyed years at Elizabeth Reef (2007, 2011, 2018), it was only recorded at 1–2 of the 7–10 survey sites. Similarly, across survey years at Middleton Reef (2006, 2007, 2011, 2018) it was only recorded at 1–4 sites out of 4–24 survey sites. At Lord Howe Island, it has been recorded in the lagoon and on the outer reef all around the island and at Balls Pyramid (Hobbs, 2022). Population genetic analyses reveal low levels of contemporary gene flow between the subpopulations, which are predominately maintained by local replenishment (van der Meer et al., 2012). There is some evidence to that indicates fragmentation is occurring within the Lord Howe Island sub-population with very little contemporary gene flow between the lagoon and outer reef (van der Meer et al 2012). There is no evidence of fragmentation in sub-populations at Elizabeth and Middleton reefs			
Fluctuations	Population fluctuations have not been recorded for McCulloch's anemonefish.			

Criterion 1 Population size reduction

Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered **Very severe reduction**	**Endangered** **Severe reduction**	**Vulnerable** **Substantial reduction**
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3, A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [*(a) cannot be used for A3*]

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

Based on any of the following

(a) direct observation [except A3]
(b) an index of abundance appropriate to the taxon
(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
(d) actual or potential levels of exploitation
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Criterion 1 evidence

Eligible under Criterion 1: A2abc+A3bc+A4abc for listing as Critically Endangered

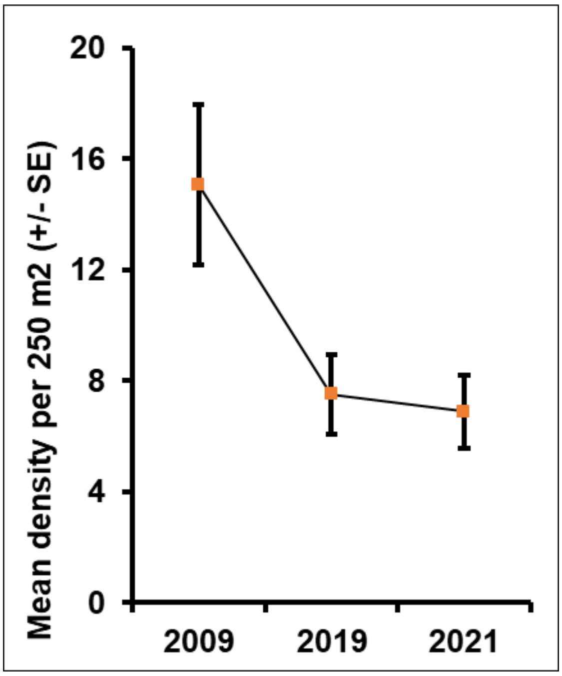
McCulloch's anemonefish is inferred to be extinct at Norfolk Island because it is no longer found there despite extensive surveys by various observers over the past 20 years. The original size of the Norfolk Island subpopulation is unknown, the last record of this species was in the 1970's and may have been a vagrant (G. Allen. pers. comm.) A monitoring program in the Lord Howe Island lagoon (the last remaining stronghold for McCulloch's anemonefish), revealed a 55% reduction in abundance from 2009 to 2021 with the trend showing a continuing decline (Fig. 5, 6). This trend was detected using 50 x 5 m belt transects and was also seen in the data from tagged colonies where the total number of McCulloch's anemonefish declined 52% (Figure 8). Both estimates include all individuals, and analyses of mature individuals also revealed a significant reduction (42% on transects and 81% on tagged colonies). Overall, this population decline is considered large, and the cause of the decline (climate change induced habitat loss) is not clearly reversible. Population trends are unknown for the deeper (5–25 m) areas around Lord Howe Island, and at Elizabeth and Middleton Reefs. However, the abundance of McCulloch's anemonefish is already extremely low in these places and depths (see Figs. 4, 5) and at risk of extinction within 1–2 generations. They rarely occur in Underwater Visual Census surveys, and this precludes any meaningful analyses of temporal trends in population size (Hoey et al, 2018).

The duration for three generations is estimated as 15 years. A generation length of five years was calculated by taking the average age from a sample of 37 adult fish (i.e., the average age of parents of the current cohort). Age was determined from otoliths and maturation was determined by histological examination of gonads (Hobbs, 2022). Using the pre-disturbance estimation method of generation length = (longevity + age at maturity)/2, results in an estimated generation length of 12 years. Irrespective of the method used to estimate generate length, the Lord Howe Island population of McCulloch's anemonefish has declined 55% in less than three generations. The cause of the reduction (habitat loss due to increasing sea temperatures) has not ceased and is not reversible in the near future. Collectively, this indicates McCulloch's anemonefish meets criteria A2a for listing as Endangered.

In addition to direct observation of a reduction in population size, there has been a decline in geographic distribution and habitat quality (Criteria A2c). The geographic distribution of McCulloch's anemonefish has reduced from four regions (Norfolk Island, Lord Howe Island, Elizabeth reef and Middleton reef) to three, as it is no longer found at Norfolk Island. Inferring changes in population size based on changes in geographic distribution requires calculating the reduction in the extent of occurrence (EOO) and area of occupancy (AOO). **Using GeoCat, the reduction in EOO is estimated at 97.57% (Figs. 9,10), which meets the threshold for Critically Endangered (A2c > 80% reduction).** Using GeoCat, the reduction in AOO is 36.84%, which would meet the threshold for Vulnerable (A2c >30% reduction). The absence of data on habitat use by McCulloch's anemonefish at Norfolk Island prevents accurate estimation of the former area of occupancy (AOO) at this location. However, an estimation could be achieved using data on the current distribution of host anemones at Norfolk Island (0 to at least 25 m depth), and data on the current distribution of McCulloch's anemonefish at Lord Howe Island (0–45 m depth, however, most common in the Lord Howe Island Lagoon from 0–5 m).

McCulloch's anemonefish cannot survive without its host anemone. This obligate dependence means that declines in anemone abundance, which can be used as an index of abundance (Criteria A2b), equal loss of anemonefish. Monitoring surveys (transects) at Lord Howe Island showed a 54% decline in bubbletip anemones (from 2009–2021), was matched by a 55% decline in anemonefish abundance. A second survey technique (tagged colonies) revealed a 64% decline in anemones (2011–2021) was linked to a 52% decline in anemonefish (Figs. 5, 6). Field surveys reveal a strong positive and linear relationship between the abundance of McCulloch's anemonefish and bubbletip anemones (Fig. 6). This relationship has been demonstrated in other anemonefish species and is due to resource limitation. This indicates that population size of McCulloch's anemonefish is constrained by the number of host anemones. Reductions in habitat diversity do not apply to McCulloch's anemonefish because it only inhabits one species of anemone. Thus, declines in the sole critical habitat (*E. quadricolor*) provide an accurate and reliable measure for estimating reductions in population size of McCulloch's anemonefish (as demonstrated in Figs. 5, 6).

McCulloch's anemonefish meets the criteria (A3c) for Critically Endangered based on a suspected reduction in the population size by more than 90% in three generations. There has already been a large reduction in population size in the past 10 years, and the cause for this decline (habitat loss (anemones) due to elevated sea temperatures) is predicted to increase. Given that a marine heatwave is currently being experienced in the region in 2023, it is likely there will be immediate impacts on anemones because of rising sea surface temperatures. It is projected and suspected that the ongoing decline in both anemonefish and its host anemone will continue, and that increased marine heatwaves will expedite the decline.



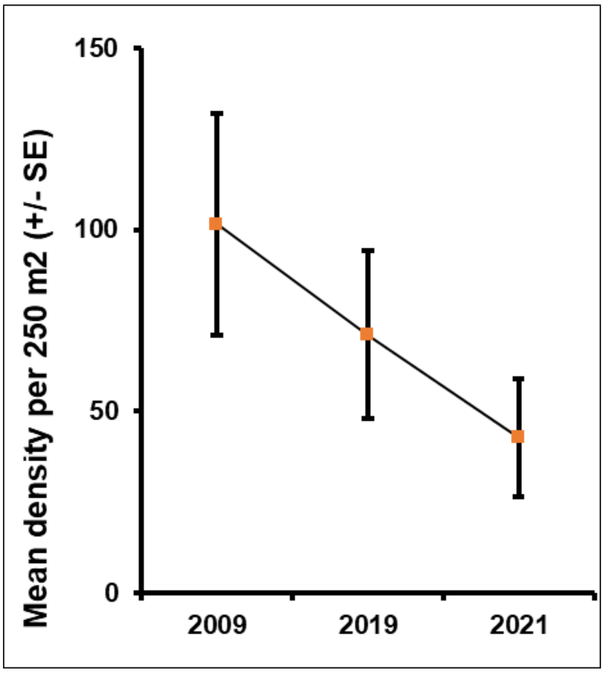


Figure 5: The mean density per 250 m2 (+/-SE) of McCulloch's anemonefish (left) and host anemones (bubbletip – *E. quadricolor*) (right) at lagoon sites (n = 9) in the Lord Howe Island lagoon from 2009–2021.

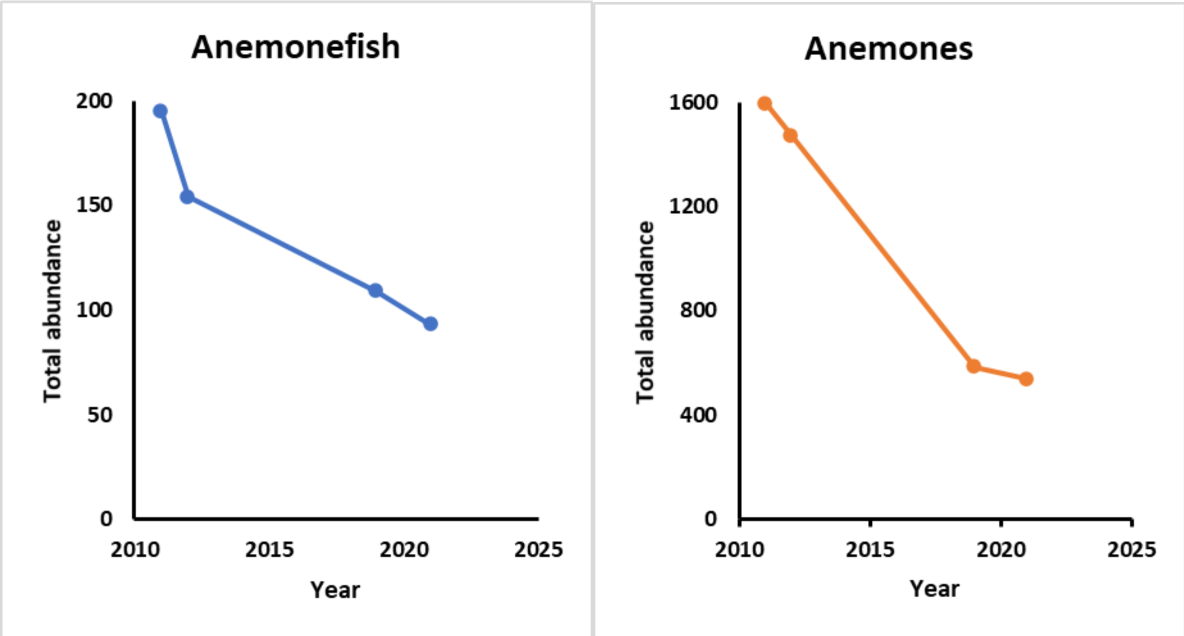


Figure 6: The total number of McCulloch's anemonefish and host anemones (bubbletip anemone, *E. quadricolor*) in tagged colonies (n = 10) in the Lord Howe Island lagoon from 2011–2021.

The Committee considers that McCulloch's anemonefish and the host anemone has undergone a very severe reduction in numbers over three generations (15 years for this assessment), declines of over 50% from 2009–2021 have been observed in the Lord Howe Island lagoon, the species is now extinct at Norfolk Island, subpopulation declines are inferred to continue at the remaining localities a reduction in EOO of ~ 97.57%, and the reduction has not ceased, the cause has not ceased. Therefore, the species has met the relevant elements of Criterion 1 (A2bc) to make it eligible for listing as Critically Endangered.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

		Critically Endangered Very restricted	**Endangered Restricted**	**Vulnerable Limited**
B1.	Extent of occurrence (EOO)	**< 100 km²**	**< 5,000 km²**	**< 20,000 km²**
B2.	Area of occupancy (AOO)	**< 10 km²**	**< 500 km²**	**< 2,000 km²**
AND at least 2 of the following 3 conditions:				
(a)	Severely fragmented OR Number of locations	**= 1**	**≤ 5**	**≤ 10**
(b)	Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Criterion 2 evidence

Eligible under Criterion 2: B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv) for listing as Critically Endangered

Based on its geographic range, McCulloch's anemonefish meets the criteria for Endangered because it meets the threshold of an EOO <5,000 km² and an AOO <500 km². GeoCat was applied to determine a current EOO of 2,907km² and AOO of 48 km² (Fig. 7). This EOO and AOO differs significantly if the species was not considered extinct at Norfolk Island (Fig. 7, 8).

As defined by the IUCN "Area of occupancy is defined as the area within its 'extent of occurrence', which is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats." Thus, the AOO excludes unsuitable and unoccupied habitat. Given that McCulloch's anemonefish only inhabits anemones, there is only very specific areas that can be occupied by this taxon.

McCulloch's anemonefish also meets two other conditions (a,b) that are required under Criteria B. It only occurs at one location (Elizabeth/Middleton Reefs and Lord Howe Island combined) and thus it meets the threshold (n=1) for Critically Endangered under condition (a). Molecular research shows that each McCulloch's anemonefish at Elizabeth reef, Middleton reef and Lord Howe Island represents three genetically distinct subpopulations (van der Meer et al., 2012). McCulloch's anemonefish meets condition (b) because a continuing decline has been observed for i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; and (iv) number of locations or subpopulations. These observed declines of over 50% from 2009–2021 in the Lord Howe Island lagoon, and the extinction from one region (Norfolk Island), are projected to continue because the subpopulations are extremely small at Middleton and Elizabeth Reefs, and the cause of the decline (habitat loss due to elevated sea temperatures) will continue.

The Committee considers that the species' Extent Of Occurrence (EOO = 2,907 km^2) and Area Of Occupancy (AOO = 48 km^2) is restricted, it now only occurs at one location and continuing decline has been observed in the extent of occurrence, area of occupancy, and the area, extent and quality of habitat and the number of locations. Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as Critically Endangered.

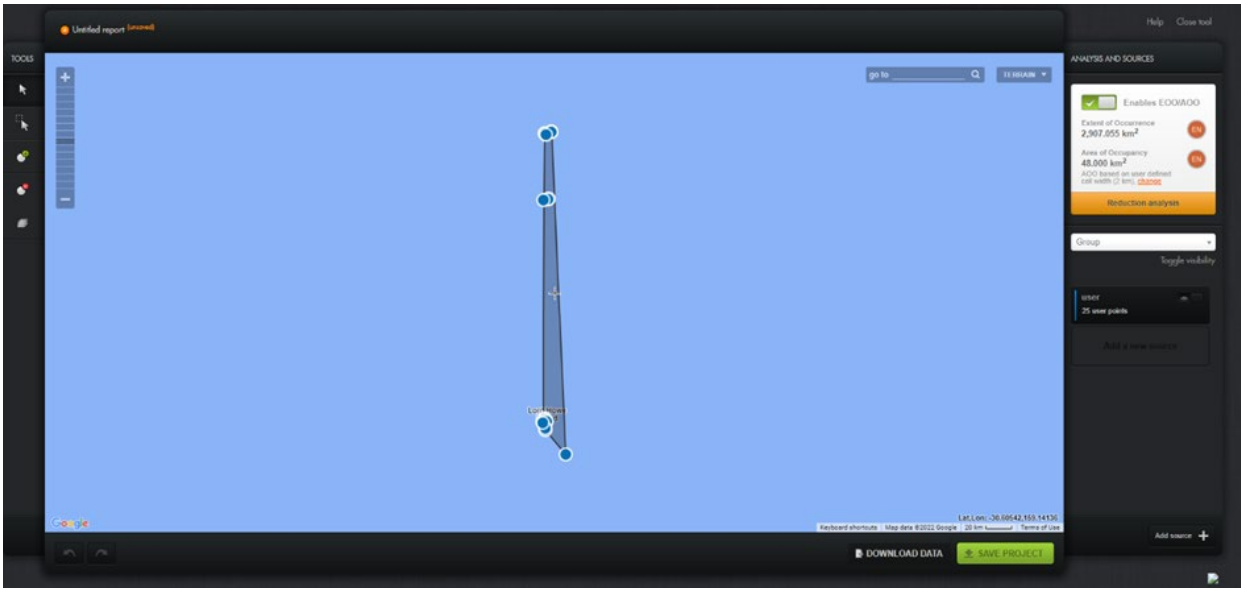


Figure 7: GeoCat map and estimated Extent of Occurrence (2,907.055 km^2) and Area of Occupancy (48 km^2) for McCulloch's anemonefish based on its current geographic range (i.e., excluding Norfolk Island).

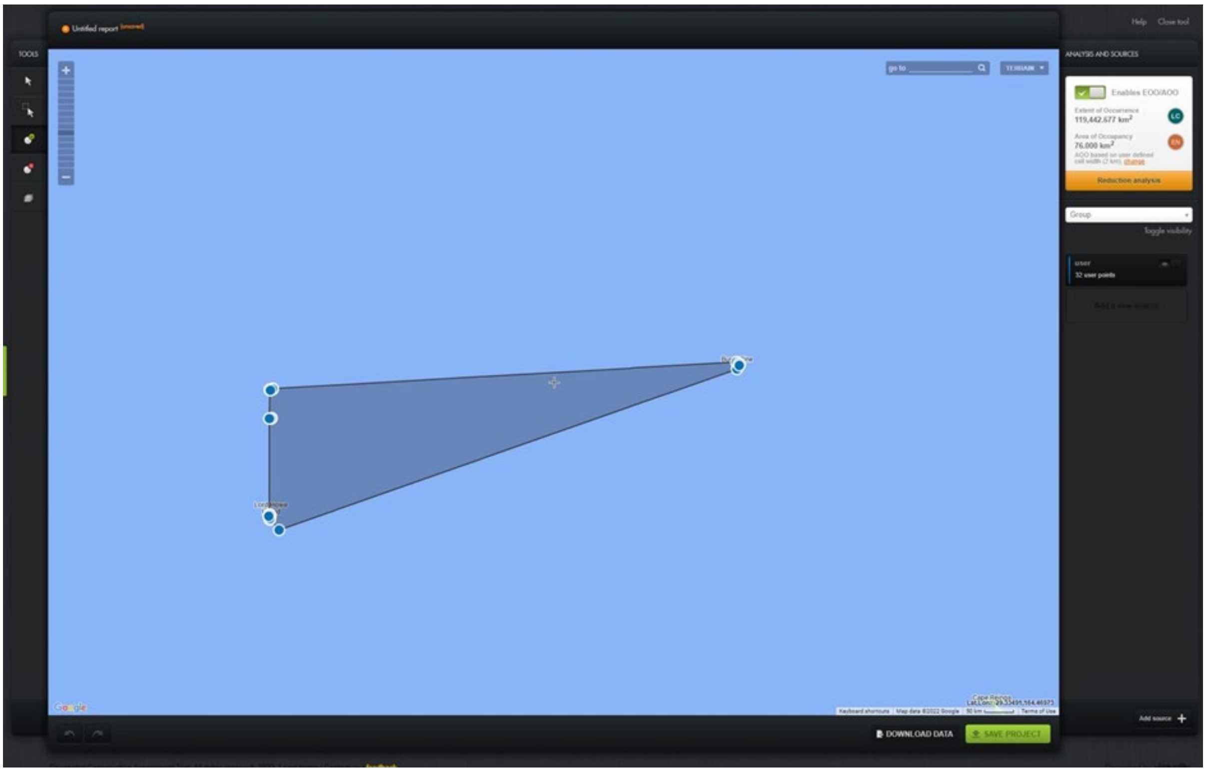


Figure 8: GeoCat map and estimated Extent of Occurrence (119,442.677 km^2) and Area of Occupancy (76 km^2) for McCulloch's anemonefish based on its former geographic range (i.e., including Norfolk Island).

Criterion 3 Population size and decline

	Critically Endangered **Very low**	**Endangered** **Low**	**Vulnerable** **Limited**
Estimated number of mature individuals	**< 250**	**< 2,500**	**< 10,000**
AND either (C1) or (C2) is true			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	**Very high rate** **25% in 3 years or 1 generation** **(whichever is longer)**	**High rate** **20% in 5 years or 2 generation** **(whichever is longer)**	**Substantial rate** **10% in 10 years or 3 generations** **(whichever is longer)**
C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	**≤ 50**	**≤ 250**	**≤ 1,000**
(a) (ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals			

Criterion 3 evidence

Insufficient data to determine eligibility

It is difficult to estimate the total number of mature individuals. The Committee considers that there is insufficient information on number of mature individuals in the subpopulations to determine the eligibility of the species for listing in any category under this criterion.

Criterion 4 Very small or restricted population

	Critically Endangered **Extremely low**	**Endangered** **Very Low**	**Vulnerable** **Low**
D. Number of mature individuals	< 50	< 250	< 1,000
D2.[1] *Only applies to the Vulnerable category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time			D2. Typically: area of occupancy < 20 km^2 or number of locations ≤ 5

[1] The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2. This information will not be considered by the Committee in making its recommendation of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the *common assessment method*.

Criterion 4 evidence

Eligible under Criterion 4: D2 for listing as Vulnerable.

The Committee considers that as the number of locations is ≤5 (only 1 location), and there is a plausible future threat (i.e. rising sea surface temperatures, marine heatwaves) that could drive the species to Critically Endangered or Extinct in a very short time. Therefore, the species has met the relevant elements of Criterion 4 to make it eligible for listing as Vulnerable D2.

Criterion 5 Quantitative analysis

	Critically Endangered **Immediate future**	**Endangered** **Near future**	**Vulnerable** **Medium-term future**
Indicating the probability of extinction in the wild to be:	**≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)**	**≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)**	**≥ 10% in 100 years**

Criterion 5 evidence

Insufficient data to determine eligibility

Population viability analysis has not been undertaken. Therefore, there is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

j) Additional information

i) Fisheries Scientific Committee Management Recommendations for McCulloch's anemonefish

Current and recommended management and research actions

The three remaining subpopulations of McCulloch's anemonefish occur with State and Commonwealth marine parks, the current and recommended management actions will benefit the conservation of the species:

- The continued implementation of comprehensive and adequate no-take areas within the remaining distribution of the McCulloch's anemonefish is recommended to ensure effective ecosystem function and resilience against climate change.
- Lord Howe Island Marine Park management actions should be implemented to conserve and enhance remaining McCulloch's anemonefish habitat.
- Continued implementation of management actions to address the threat of anchoring impacts on remaining habitat.
- Continued emergency response implementation to reduce the threat of oil and chemical spill impacts on McCulloch's anemonefish populations.
- Prohibition of aquarium fish collection throughout the distribution of the McCulloch's anemonefish (including commercial collection) to address the impact of this threat and reduce the chance of McCulloch's anemonefish being targeted by the illegal trade.
- The export of aquarium fish from Lord Howe Island should be prohibited to further reduce the risk of McCulloch's anemonefish being targeted by the illegal trade.
- Management actions to protect the host anemone from collection or removal should be implemented in the future.
- Targeted education and advisory initiatives to increase public appreciation and awareness of the threats and conservation status of the McCulloch's anemonefish.

- Management actions should be implemented to reduce impacts from anthropogenic threats that result in changes to hydrology/ water/sediment flows in nearshore environments, particularly the Lord Howe Island lagoon, that may result in unfavourable conditions for McCulloch's anemonefish or its anemone.
- Any disturbance that may result in anemone mortality, such as localised water pollution from diffuse source runoff or maritime source pollution, eutrophication resulting from groundwater contamination which can exacerbate the impacts of climate change should be identified and addressed through local management actions.
- Effective compliance and enforcement activities in relation to management actions for this species should be implemented as an effective deterrent to illegal activities.
- Emergency response actions for this species should be developed and incorporated into local marine heat wave response planning actions.

The following research priorities for McCulloch's anemonefish are recommended:

- Continued maintenance of monitoring sites for research based on the absence of all or selected extractive activities.
- Continued monitoring of sites to identify local long-term trends on available information to further clarify projections.
- Surveys to assess and map the distribution of McCulloch's anemonefish in key habitats, for example Lord Howe Island lagoon, to establish critical monitoring baselines.
- Update habitat mapping of the Lord Howe Island lagoon to further clarify the distribution of abundance of suitable habitat for the McCulloch's anemonefish to be used in spatial planning.
- Further surveys should be undertaken to map the distribution and abundance of this species at Elizabeth Reef and Middleton Reef.
- Given this species is reliant on host anemones that are subject to bleaching events, recovery and restoration of this critical habitat should be investigated and implemented.
- Research into constraints on the size of the breeding population of McCulloch's anemonefish and whether translocations or captive breeding can be used to increase the breeding population.
- Research focusing on determining the adaptability and resilience of McCulloch's anemonefish to increasing water temperatures is recommended.
- Genetic research on patterns of population replenishment and connectivity between the Lord Howe Island lagoon and waters outside the lagoon should be investigated.

ii) Priorities Action Statement

The NSW Department of Primary Industries Priorities Action Statement (PAS) is a statutory, non-regulatory document addressing each threatened species, population, ecological community and key threatening process (KTP) listed on the schedules of the *Fisheries Management Act 1994*. The PAS provides an agreed list of strategies and actions that will assist to down-grade or de-list species, populations and ecological communities from the threatened species schedules of the *Fisheries Management Act 1994*, as well as actions that will assist to abate or eliminate the impacts of KTPs.

If the species is listed in the Schedules of the FM Act, a PAS will be developed to guide recovery actions.

k) Statement on the standard of scientific evidence and adequacy of survey:

This assessment has been prepared by the Fisheries Scientific Committee in good faith using the highest possible standard of scientific evidence and adequacy of survey. The text is this assessment has been provided from the summary report by Dr. Jean-Paul Hobbs: "Summary report on the conservation status of McCulloch's anemonefish: towards consideration as a threatened species. Report for Lord Howe Island Marine Park."

As prescribed under Section 4 of the Intergovernmental MOU on the CAM, in preparing this documentation the Committee gave consideration to:

(i) the nature of the data, including adequacy of survey (occurrences) and monitoring (to detect change), including factors such as sampling design, effort applied, number of variables considered, proportion of a species' range covered, time period covered etc.;

(ii) the number of data sets relevant to the conclusion;

(iii) the range of uncertainty in the data and degree of consistency between different data sets;

(iv) the source of the data and its credibility; and

(v) the relevance of the data to the particular assessment criterion.

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m) Acknowledgements

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