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Does collecting inhibit the recovery of anemone and anemonefish populations after bleaching?

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Abstract. Anemones and anemonefishes are some of the most popular species targeted by the global marine aquarium trade. In spite of the ease with which they can be aquacultured, most of the trade is supplied by specimens captured from the wild. In the southern inshore section of the Great Barrier Reef (Keppel Islands) populations of *Amphiprion akindynos*, *A. melanopus*, *E. quadriclour* and *H. crispa* have reached alarmingly low levels as a result of bleaching and collecting impacts. This study examines five sites in this region before and after a voluntary suspension of collection by the Marine Aquarium Fish and Coral Fisheries at three of the five sites. The densities of all three species diminished between December 2009 and September 2010 at all but one site. Although there was evidence of an increase in densities since previous surveys conducted by Jones et al (2008) and Frisch et al. (2008), populations were present at low levels compared to other GBR regions. Long-term studies of population changes and species-specific, locally relevant assessment of sustainable yields are urgently needed to inform improved fisheries management and ensure that populations return to a healthy state. However, in light of the predicted future for tropical reefs, it seems inevitable that the trade must shift from wild collection to supply by aquaculture, particularly in the Keppels region.

Key words: anemonefish, anemone, bleaching, aquarium, harvesting.

Introduction

Declines in the health and area of coral reefs that can be correlated with similar declines in associated marine life are now well documented. Reef-dependent fishes are among the growing list of marine organisms diminishing in numbers on reefs impacted by bleaching and floods (Munday 2002; Jones *et al.* 2004; Graham *et al.* 2006; Feary *et al.* 2007; Wilson *et al.* 2009; Saenz-Agudelo *et al.* 2010). Organisms targeted by commercial aquarium collectors are at even greater risk from the same factors that are causing habitat losses due of the compounding effects of harvesting for trade (Thornhill 2012). Anemones (*Actinaria*) and anemonefish (clownfishes) are more vulnerable to over-exploitation than other targeted species because their intriguing relationship and bright coloration make them highly attractive as marine aquarium ornaments. In the Philippines, harvest of anemones and anemonefishes comprises 60% of the total aquarium harvest (Ross 1984; Shuman *et al.* 2006). Where habitat loss has been caused by thermal stress or low salinity, there is now evidence that anemone and anemonefish populations that are also subject to harvesting, have declined in numbers and failed to recover (Frisch, and Hobbs 2008; Jones *et al.* 2008).

Scientists have been concerned about the sustainability of harvesting anemones and anemonefishes from the wild since the 1990's (Edwards, and Shepherd 1992) and in spite of attempts to aquaculture them for the aquarium trade (Dawes 2003; Scott, and Harrison 2007; Scott, and Harrison 2008,2009), most are still caught from the wild (Wabnitz *et al.* 2003). A lack of robust scientific studies to prove that collecting causes populations declines has inhibited management authorities from tougher regulations on the harvest in many regions. Collectors are reticent to reveal collection numbers and locations because of commercial competition, and this makes comparisons between collected and uncollected sites difficult. There is now growing evidence that densities of both anemone and anemonefish are frequently significantly lower in exploited areas than in protected areas (Shuman *et al.* 2006; Planes *et al.* 2009; Scott *et al.* 2011), strongly suggesting that collecting is at least one cause of populations declines.

Considering the predictions of further coral reef degradation over the coming decades (Wilkinson 2008), better management, more targeted restrictions, investment in aquaculture and in some cases the complete cessation of the harvest of anemones and anemonefishes may need to be considered in most regions. Recently, two published studies revealed the positive effects of taking measures to protect local populations. The first was the implementation of a marine reserve that included "no-take" zones in 1991 around North Solitary Island off the coast of Australia which dramatically but differentially increased the abundance of different species of both anemones and anemonefishes (Scott *et al.* 2011), enabling recovery from declines due to over-collection and bleaching. The second example occurred in the Maldives where initially, in 1988, a cap on exports for all allowable coral reef species was implemented (Edwards, and Shepherd 1992). A shift in targeted species resulted in a review of this arrangement in 1992 and the implementation of a comprehensive species-based quota system and the establishment of protected areas in 1995 and 1999 (Saleem, and Islam 2008). In 2008, Saleem and Islam (2008) described the new system as "quite effective", but also suggested a number of changes to improve the efficacy of the management regime.

The protection afforded anemone and anemonefish populations in the Maldives and the North Solitary Islands has confirmed that species-specific quotas and the introduction of protected areas can provide an effective safeguard, potentially improving sustainability. However, there is also evidence that quotas must be based on sound knowledge of species-specific population and behavioral ecology and supported by adequate enforcement and monitoring.

The implementation of a voluntary moratorium on the collection in The Keppel Islands region of the GBR has presented an opportunity to investigate the effects of temporary suspension of fishing pressure. The moratorium, preventing the collection of the anemonefish *Amphiprion melanopus* or the anemone *Entacmaea quadricolour* and the collection of any species at three sites that were previously targeted by collectors, was undertaken by the Queensland Aquarium Fish and Coral Fisheries in response to community concerns about the low densities of anemones following a bleaching event (Anonymous 2009). The moratorium prevented the collection of the anemonefish *Amphiprion melanopus* or the anemone *Entacmaea quadricolour* and the collection of any species at three sites (Passage Rocks, Man and Wife Rocks and Halftide Rocks) that were previously targeted by collectors. The current study investigates the effectiveness of the moratorium and discusses the implications of the results for more effective management of the fishery.

Material and Methods

The study took place in an inshore section of the southern Great Barrier Reef, The Keppels (Fig. 1) between December 2009 and September 2010. Following the initiation of the collecting moratorium in December 2009, surveys of anemones and anemonefish were conducted at five sites including Passage Rocks, Man and Wife Rocks and Halftide Rock, where all collecting was suspended, Shelving Reef which is closed to collecting, and Leeke's Creek which was not part of the moratorium but is not usually targeted by collectors. The first surveys were conducted in December 2009, and the second surveys were conducted in September 2010. Fish and anemone densities were compared those for the same sites in 2007 (Jones *et al.* 2008).

The moratorium specified that collecting was suspended at Passage Rocks, Man and Wife Rocks and Halftide Rocks (Fig. 1). The two other sites in the study were Shelving Reef, which is a Marine Park Public Appreciation area where no collecting occurs, and Leeke's Creek where collecting of species other than *A. melanopus* and *E. quadricolour* is permitted and where collecting was not suspended throughout the moratorium (although no data on collection was available).

Figure 1. Map of the Keppel Islands and locations of anemone and anemonefish surveys conducted during a study of the effects of a moratorium on commercial collecting. Inset shows the location of the Keppels along the Queensland coast in Australia.

Visual census surveys using free swims along 5 m-wide transects were used in place of shorter fixed transects to census the populations of anemones and anemonefish at the five sites (Shuman *et al.* 2006). Transects aligned where possible with those in an earlier study by Jones et al. (2008). A towed GPS recorded the survey track and longitude coordinates (± 1m) were recorded every 10 s. The GPS tracks were later used to estimate the length of each free swim. The number of both adult and juvenile *A. melanopus* and *A. akindynos* and the approximate diameter of *E. quadricolour* colonies was recorded along each transect and each specimen was photographed for later verification of species. Fish densities were calculated by dividing the total number of fish by the area surveyed (track length x 5m) which were then recorded as the number of fish per $100m^2$ reef. The density of *E. quadricolour* was calculated as the diameter of the colony per $100cm^2$ reef. Each survey covered approximately 2.6 km of reef.

Results

Densities of *A. akindynos* decreased ~50-100% at all sites in the study that had specimens in December 2009 (Fig. 1a, Table 1). No specimens were found at Passage Rocks in December 2009 or in September 2010.

Densities of *A. melanopus* (not collected at any sites) decreased 25-100% at all sites except Halftide Rocks where densities increased 37% (Fig. 1b, Table 1). No specimens of *A. melanopus* were found at Passage Rocks following the moratorium in spite of several of this species occurring there in December 2009.

Entacmaea quadricolour was found at all five sites in Dec 2009 and densities decreased 30-75% during the study. No specimens were found at Leeke's Creek in September 2010 in spite of a colony occurring there in December 2009. Leeke's Creek was not part of the moratorium but no data is available to show whether collecting took place in that period.

Species	Site and collection status	Density fish.100m^{-2}	
		Dec-09	Sep-10
Amphiprion akindynos	Halftide Rocks (no collecting)	93.3	0
	Man and Wife Rocks (no collecting)	11.5	0
	Passage Rocks (no collecting)	0	0
	Shelving Reef (no collecting)	610.2	282.5
	Leekes (collecting)	173.9	34.8
Amphiprion melanopus	Halftide Rocks (no collecting)	13.3	18.3
	Man and Wife Rocks (no collecting)	15.4	11.5
	Passage Rocks (no collecting)	46.7	0
	Shelving Reef (no collection)	113	22.6
	Leekes (no collecting)	104.3	104.3
Entacmaea quadricolour	Halftide Rocks (no collecting)	31.8	8
	Man and Wife Rocks (no collecting)	9.2	3.8
	Passage Rocks (no collecting)	6.7	1.7
	Shelving Reef (no collection)	66.7	46.3
	Leekes (no collecting)	137.7	52.2

Table 1. Densities (fish.100m^{-2} reef) of *Amphiprion akindynos, A. melanopus* and *Entacmaea quadricolour* at five sites in the Keppel Islands before, and 9 months after, a moratorium on commercial collecting in December 2009.

Discussion

Densities of *A. akindynos*, *A. melanopus* and *E. quadricolour* diminished in the Keppels between December 2009 and September 2010 (Fig. 2). There was no evidence that the moratorium on collecting influenced the changes. There was evidence of population changes in response to local flooding. The time-frame of this study may be too short and the survey points too infrequent to provide

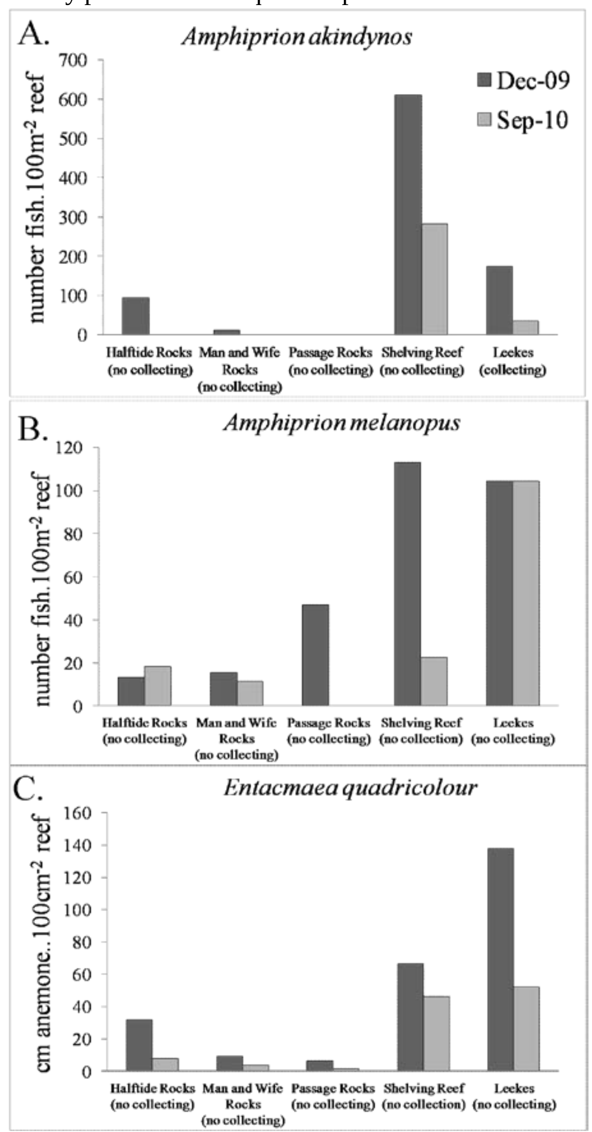

Figure 2. Densities of a. *Amphiprion akindynos*, b. *A. melanopus*, and c. *Entacmaea quadricolour* at five sites in the Keppel Islands before, and 9 months after, a moratorium in December 2009 showing the sites and species that were subject to a voluntary moratorium by commercial collectors or were open to collecting.

robust evidence of either the impact of suspending collecting or of seasonal variations in population densities. Longer-term studies and much more detailed collection data would be required to attribute cause to the observed changes. However, observations can be made about the study results in order to inform future research. The two smallest reefs with the lowest coral cover (Jones *et al.* 2011) of the five study sites, Shelving Reef and Leeke's Creek harboured the highest densities of all three species compared to other sites. Shelving Reef is a small sites close to a major tourism facility and the reef at Leeke's Creek is a small, depurate reef mostly growing on rock that is strongly influenced by sediment and tidal flushing (Fig. 1). Shelving Reef had relatively high densities of both anemones and anemonefish in December 2009 compared to other sites, in spite of having relatively low coral cover (Jones *et al.* 2011). This site is protected from collecting by Great Barrier Reef Marine Park zoning. It is possible that Shelving Reef represents a source of larvae and recruitment to other reefs (Fautin 1992; Planes *et al.* 2009; Scott *et al.* 2011). . Leeke's Creek is not targeted by collectors because of it's depurate nature. A final observation is that, although the densities were, in some cases, higher than those found in this region in 2007 (Jones *et al.* 2008), they are still low compared to other GBR regions such as North Queensland where densities can be as high as ~300 fish $100m^{-2}$. There are also less species present in the Keppels than in other regions.

Commercial harvest of wild populations of anemones and anemonefishes in the Keppel region is unlikely to be sustainable now, or in the near future, in light of the confounding impacts of floods and bleaching. The industry quota system, no-take zones and recently implemented species-specific triggers have been augmented with an industry voluntary code of conduct and a stewardship action plan (Jones 2011). These measures may assist impacted sites immediately during and for three months following a bleaching event but are unlikely to make any significant gains in recovery to what was once a much healthier and more diverse population. Furthermore, there is evidence from the studies in the North Solitary Islands (Scott *et al.* 2011) and the Maldives (Saleem, and Islam 2008) that species-specific rather than overall quotas may be more effective in controlling fishery impacts. This makes sense because species like *E. quadricolour* can reproduce through cloning whereas others, like *Heteractis crispa*, reproduce sexually and therefore repopulate much more slowly than *E. quadricolour*. Collection triggers should reflect these differences. What is also apparent is that fishery closures may need to be considered to take into account seasonal changes in populations and the impacts of disturbance events. However, these measures would only work if the populations of anemones and anemonefishes were already at healthy levels and harvest yields are sustainable, and they are clearly not in the Keppel region.

The current attention on the sustainability of wild fisheries harvest will increase exponentially in the next decade as more reef habitat is lost due to thermal stress and extreme weather events (Rhyne *et al.* 2009) and as the demand for specimens for domestic aquaria increases (Tissot *et al.* 2010). A shift to aquaculture of anemones and anemonefish may help meet the pressures currently facing the industry in Queensland. Although some wild collection may always be necessary to collect brood stock for aquaculture, this should only occur where there are healthy and biodiverse populations and catch levels should be based on robust, locally relevant species-specific assessments of sustainable yield and where there is adequate enforcement and monitoring of these quotas (Ross 1984). In addition, the population connectivity of many of the species that are vulnerable to over-exploitation by the fishery is unknown and may need to be considered in any new management arrangements.

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