

An assemblage of the host anemone *Heteractis magnifica* in the northern Red Sea, and distribution of the resident anemonefish

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The *Heteractis magnifica* assemblage at the tip of the Sinai Peninsula was examined. The actinian size, location, and number of resident anemonefishes were recorded. The anemones were found at depths down to approximately 40 m and the sizes of clustering *H. magnifica* and clusters were positively correlated with depth. The shallow waters of the anemone assemblage contained few mainly small, solitary actinians. There seemed to be a tendency for solitary actinians to cluster once they reached a certain size-range. The resident anemonefishes *Amphiprion bicinctus* and *Dascyllus trimaculatus* were present in very large numbers (approximately 250 and 1800 respectively) and the *A. bicinctus* home range size was positively correlated with depth.

INTRODUCTION

Ten species of tropical giant sea anemones (Families: Actiniidae, Stichodactylidae, Thalassianthidae) are hosts worldwide to 28 species of anemonefishes (Family: Pomacentridae) (Dunn, 1981; Fautin & Allen, 1992).

In the south Sinai region, the northern Red Sea, the *Heteractis magnifica* (Quoy & Gaimard, 1833) occur mainly in relatively large assemblages. One such assemblage is found at the southernmost point of the Sinai Peninsula, where it is situated on a reef 100 m south-west of the Ras Mohammed rock formation. It consists of massive aggregations of the host anemone *H. magnifica* and consequently also the local anemonefishes *Amphiprion bicinctus* (Rüppell, 1828) and *Dascyllus trimaculatus* (Rüppell, 1829).

Large aggregations are not uncommon especially for the host anemone *Entacmaea quadricolor* (Rüppell & Leuckhart) (e.g. Mariscal, 1970; Moyer & Nakanozo, 1978; Dunn, 1981; Richardson et al., 1997; H. Debelius, personal communication; D.G. Fautin, personal communication). While the symbiosis between the anemonefishes and their tropical host anemones has been studied extensively (e.g. Allen, 1972; Fautin & Allen, 1992), and although a number of *H. magnifica* assemblages worldwide have been very briefly mentioned in reports dealing with other issues (Eibl-Eibesfeldt, 1965; Mariscal, 1970; Allen & Mariscal, 1971; Allen, 1972; Dunn, 1981; Debelius, 2001, personal communication; D.G. Fautin, personal communication), only one *H. magnifica* assemblage has been described in detail quantitatively (Fricke, 1979).

No detailed quantitative studies exist for any *H. magnifica* assemblages in the Red Sea: generally quantitative studies of the distribution of tropical giant host sea anemones are severely lacking (D.G. Fautin, personal communication; N.E. Chadwick-Furman, personal communication).

The aim of this study was a mapping and descriptive analysis of the Ras Mohammed *H. magnifica* assemblage and its resident *A. bicinctus* and *D. trimaculatus*.

MATERIALS AND METHODS

During April to June 2002 the assemblage of *Heteractis magnifica* was mapped by SCUBA diving surveys. The anemone assemblage is located (27°43.3'N 34°15.0'E) at the southern tip of the Sinai Peninsula. In addition, other reefs in the vicinity of this anemone assemblage were surveyed as a reference for the distribution and abundance of *H. magnifica* in the area.

The Ras Mohammed anemone assemblage occupies a relatively small area (100×75 m) and consists exclusively of the host anemone *H. magnifica*. For each anemone, the approximate location and depth was measured using a dive computer. With a tape-measure, the long and short axial lengths of the tentacle crown were recorded. Sizes were calculated as (long axial length×short axial length× π)/4 (Hirose, 1985).

Giant tropical sea anemones size may vary over time of day (Fricke, 1979). However, our observations were all conducted in the midday hours from 1000–1500 and we did not observe a significant difference in size.

The anemones were designated as solitary or clustering (Allen, 1972). A cluster, presumably derived via asexual reproduction (Dunn, 1981) would consist of two or more anemones situated so close that column and tentacles of the different actinians constantly touched each other. Anemones were designated as solitary when not in constant contact with another actinian.

The number of resident anemonefish and their home range sizes were recorded. The *Amphiprion bicinctus* were identified as dominant, sub-dominant or juveniles. The fish

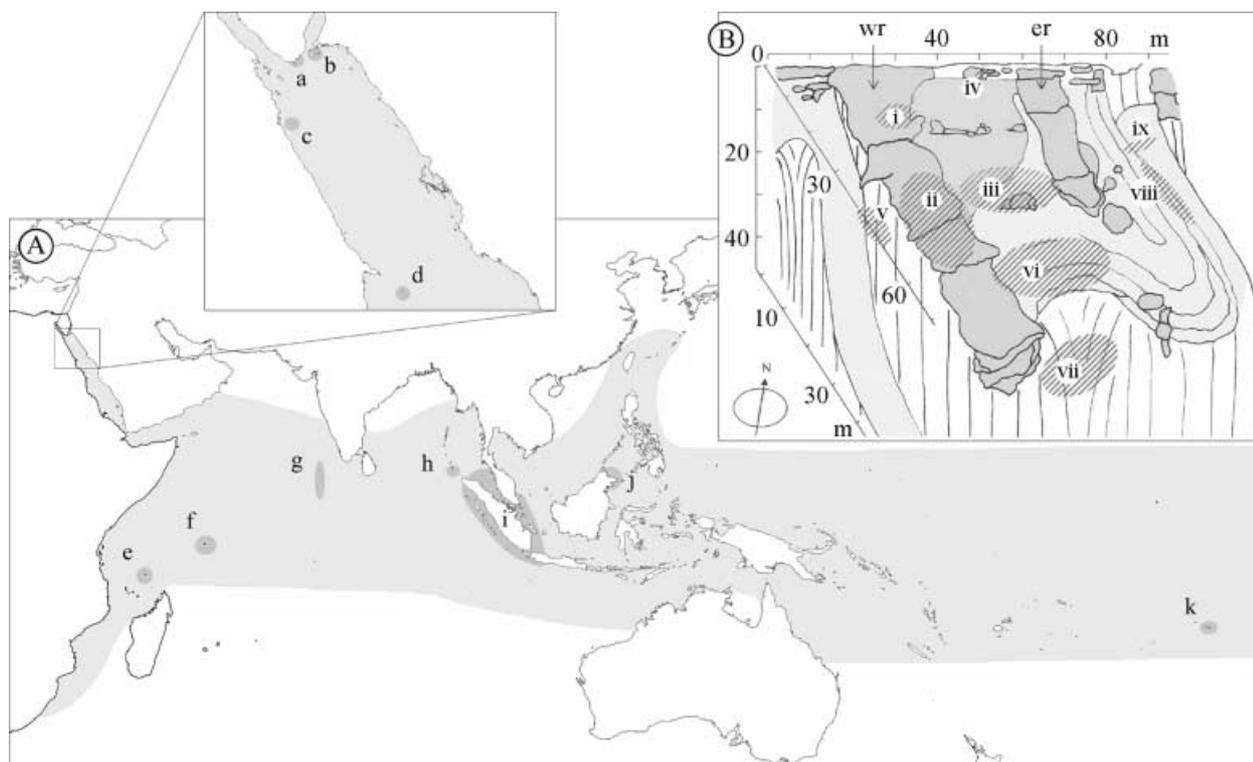


Figure 1. (A) Distribution of *Heteractis magnifica* and clusters of *H. magnifica*. Light grey shade indicates the distribution of *H. magnifica* (Fautin & Allen, 1992), the darker grey indicates reported areas with clusters of *H. magnifica*: a, Ras Mohammed and Ras Ghazlani (present study); b, at the green light beacon at a fringing reef by local diveguides named 'the blue lagoon' at the Island of Tiran; an assemblage similar to the present study (*H. Debelius*, personal communication); c, at a reef off Safaga Bay; an assemblage similar to the present study (Debelius, 2001, personal communication); d, Rocky Island; an assemblage probably similar to the present study (*H. Debelius*, personal communication); e, Aldabra Atoll; shallow carpet-clusters of 309 actinians (approximately 80 m²) (Fricke, 1979); f, Seychelle Islands; usually in clusters of 3–5 actinians (Mariscal, 1970); g, Maldives Islands; usually in clusters of 4–6 actinians (Allen & Mariscal, 1971; Dunn, 1981); h, off the north coast of Great Nicobar Island; an area of dense fields of actinians (Eibl-Eibsfeldt, 1965); i, east coast of Malaysia and western Indonesia; small clustering actinians. Very large beds of clusters in the Strait of Malacca (Dunn 1981; D.G. Fautin, personal communication); j, west coast of Malaysia; large clustering actinians (Dunn, 1981); k, Tahiti; a large area (approximately 500×150 m) of clusters (Allen, 1972; Dunn, 1981); (B) the *H. magnifica* assemblage site in Ras Mohammed National Park. Dark grey areas consisted mainly of coral outcrops or rock. Light grey areas consisted mainly of coral sand with occasional coral outcrops. Hatched areas (i–ix) indicate the different areas where *H. magnifica* were distributed. wr, western ridge; er, eastern ridge.

identified as juvenile were <2.5 cm standard length (SL) with a body/fin-proportion markedly different from larger specimens (Fautin & Allen, 1992). One *A. bicinctus* per home range would typically be markedly larger and darker coloured than the rest. This specimen was denoted α -female (5–9 cm SL) (Fricke, 1979; Fautin & Allen, 1992). The rest were denoted as sub-dominant (2.5–6 cm SL). If one of these was larger than the others it would be classified as a β -male (Moyer & Nakanozo, 1978).

The dominant and sub-dominant would typically centre their activity in the larger anemone or cluster with frequent detours to nearby solitary anemones. The extents of their detours were interpreted as home range boundaries.

Dascyllus trimaculatus were observed in sizes up to 5 cm SL. We did not differentiate the *D. trimaculatus* in juveniles and adults. However, specimens smaller than 1.5 cm SL were excluded from the analysis.

Counting error was assessed to 5% for *H. magnifica* and *A. bicinctus*, and 15% for *D. trimaculatus* since the latter were estimated when present in very large numbers. Anemonefishes were recorded for approximately 80% of the anemones.

RESULTS

The anemone assemblage is located on a plateau (Figure 1B) approximately 100×75 m down to approximately 20 m depth. It begins at a depth of ~2 m beneath a short vertical coral wall, and from there drops down to 7–9 m at a slope of 30–45°. From this depth to approximately 20 m, the plateau is nearly horizontal at a slope of approximately 5–15°. At 20 m of depth there is a rather well defined edge to a vertical wall. The drop-off plunges to a depth of 500–1000 m.

The plateau is covered by a mixture of coral sand and boulders. Coral outcrops form a ridge at the western border of the plateau and another further to the east. Between the two ridges at 6–10 m depth the plateau consists mainly of coral outcrops. The plateau at 9–20 m depth and east of the eastern ridge consists of a relatively homogenous mix of coral sand and outcrops, about 30 cm in diameter.

The *Heteractis magnifica* were distributed in groups covering various areas of the reef (areas i–ix in Figure 1B). A total of 190 anemones were measured, of which 108 were solitary and 82 were clustering actinians distributed on 34 clusters.

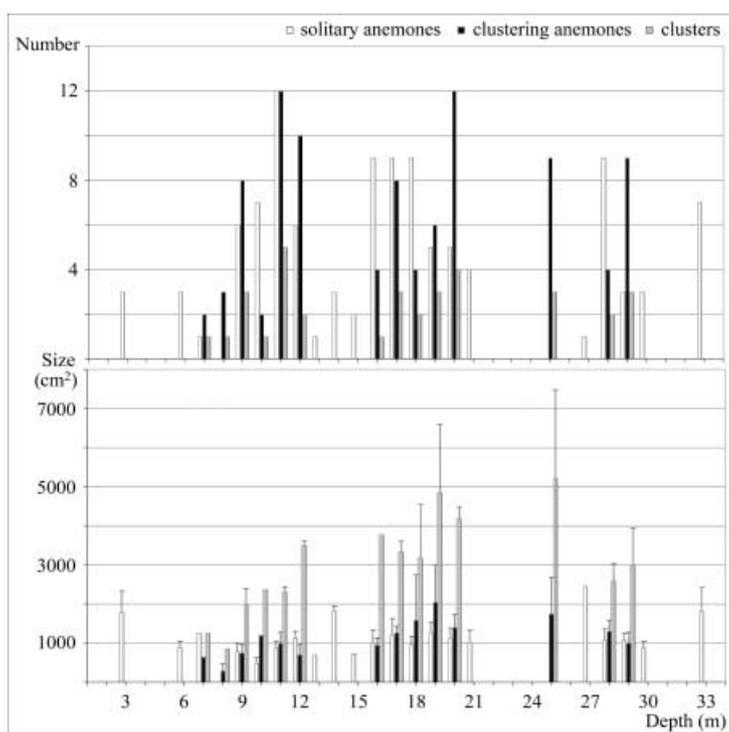


Figure 2. Number and mean size of anemones at the Ras Mohammed anemone assemblage in relation to depth. Standard deviation bars are indicated where two or more actinians or clusters are included in the mean. The distribution of the solitary and the clustering actinians is significantly different regarding mean sizes ($P=0.046$) but not regarding numbers ($P=5.7$) (Student's t -test for a two-tailed, two-sample of unequal variance, $\alpha=5\%$). Pearson's correlation coefficient for number/mean size: solitary actinians=0.06/0.27, clustering actinians=0.25/0.60, clusters=0.28/0.60. Number of clustering anemones per cluster is not correlated with depth (Pearson's correlation coefficient <0.01).

The anemones were distributed from 3–33 m of depth (Figure 2). One actinian near area v (Figure 1B) was situated at an estimated depth of 40 m. For safety reasons this specimen was observed from a distance and was not included in the analysis. Anemones at the top 9 m of depth were relatively small and sparse. Though, at 3 m there was one very large solitary anemone exposed to heavy surge induced currents. The anemones were abundant from 9–20 m with a gap from 13–15 m coinciding with the more sandy nature of the central part of the plateau at that depth. Furthermore there were no anemones from 22–24 m depth. Neither the number of solitary actinians, clustering actinians nor clusters were correlated with depth (Pearson's correlation coefficients: solitary=0.06, clustering=0.25, clusters=0.28). Most solitary anemones were situated within 1–3 m of other actinians.

The total size of the recorded anemones was ~ 23 m² of which 53% were solitary actinians and 47% clustering. The depth-distributions of solitary versus clustering actinians were significantly different with regards to mean size (Figure 2; Student's t -test for two-tailed, two-sample of unequal variance, $P=0.046$). The mean sizes of clusters and clustering actinians were positively correlated with depth (Figure 2; Pearson's correlation coefficients: solitary=0.27, clustering=0.60, clusters=0.60).

There was no significant difference between the mean sizes of solitary and clustering actinians (Student's t -test for two-tailed, two-sample of unequal variance, $P=5.6$). The mean size of solitary actinians without clusters present at the same depth-transect was significantly larger than the mean size of solitary actinians in depth-

transects with clusters present (Student's t -test for two-tailed two-sample of unequal variance, $P=0.03$).

The total number of recorded *Amphiprion bicinctus* was 243; 91 were dominant and 152 sub-dominant. The total number of recorded *Dascyllus trimaculatus* was 1745. The number of *A. bicinctus* was not correlated with depth and the number of *D. trimaculatus* only slightly so (Pearson's correlation coefficient=0.05 and 0.34 respectively). A fish home range could consist of any combination of solitary and clustering actinians. Usually it consisted of a cluster and some nearby solitary anemones. Typically home ranges of dominant and sub-dominant *A. bicinctus* covered the same area.

The home ranges of *A. bicinctus* and *D. trimaculatus* were often overlapping as the group of *D. trimaculatus* would swim from one *A. bicinctus* home range to another. The *D. trimaculatus* home ranges had less defined borders than those of *A. bicinctus*. In areas with many host anemones close to one another the groups of *D. trimaculatus* could become very large with one large shared home range (e.g. parts of areas ii, iii and vi in Figure 1B).

Both dominant and sub-dominant *A. bicinctus* home range sizes were correlated with depth (Pearson's correlation coefficient for home ranges: dominant=0.73, sub-dominant=0.63). The *D. trimaculatus* home range mean size was only slightly correlated with depth (Pearson's correlation coefficient=0.49). All *A. bicinctus* home ranges above 9 m of depth were under 3000 cm² large, and none had more than five resident *A. bicinctus*. Otherwise the mean number of *A. bicinctus* per home range was not correlated with home range size or with depth.

At the Ras Ghazlani reef (a few kilometres north-east of the anemone assemblage at Ras Mohammed) we observed three small clusters of *H. magnifica*, each cluster consisting of 2–3 actinians, at a depth of 10 m. Symbiotic *A. bicinctus* and *D. trimaculatus* were present, the latter in schools of 10–30 specimens per cluster. At most other reefs in the area, the most common host anemones were *Entacmaea quadricolor* and sometimes *H. crispa* (Ehrenberg). According to Chadwick-Furman (personal communication) *H. magnifica* have not been observed in the Eilat area.

DISCUSSION

This is the first detailed study of a Red Sea *Heteractis magnifica* assemblage. Usually *H. magnifica* are only found above 20 m of depth (Dunn, 1981). However, the anemone assemblage was found to a depth of 40 m. Perhaps this is because of the very clear water almost devoid of terrestrial and freshwater input. Simultaneously the location of this anemone assemblage renders it subject to several different, sometimes strong currents. The major currents pass in the surface waters up the Gulf of Suez and the Gulf of Aqaba resulting in upwelling of nutrition-rich waters from the deep waters of the Gulf of Aqaba. These currents pass by the anemone assemblage (H. Samy, personal communication). The nutrition-rich water is a trait shared with an *H. magnifica* assemblage at the Aldabra Atoll (Figure 1A) observed by Fricke (1979). The Aldabra assemblage was however situated in very shallow water (main part at 0.5 m depth at ebb tide).

The home range size was positively correlated with the depth, possibly the food availability for the anemonefish was higher in more shallow water? There seemed to be a threshold home range size (3000 cm²) above which the number of resident *Amphiprion bicinctus* could be considerably larger without being further correlated with the home range size.

Heteractis magnifica is distributed from the eastern Pacific to the western Indian Ocean and the Red Sea. It reproduces asexually only in the rim areas of its distribution. This distribution seems also to apply to *H. magnifica* assemblages (Dunn, 1981) (Figure 1A). Thus the origin of the large aggregations of *H. magnifica* is probably the asexual reproduction rather than settling of young sexually reproduced anemone polyps. The distribution pattern of *H. magnifica* makes it less likely to be a subspecies division (D.G. Fautin, personal communication) and genetic sequencing does not suggest a difference between solitary central and clustering rim specimens (Fautin & Smith, 1997).

That solitary actinians were larger at depths without clusters than at depths with clusters may indicate that when solitary actinians in the area reach a certain size-range they 'bud' to form clusters. This may also explain why the mean size of solitary actinians was not correlated with depth, as opposed to clusters (Figure 2).

One contribution to the existence of assemblages may be the relatively large shoals of *Dascyllus trimaculatus* present at the assemblage. Recently, Israeli experiments have shown that the giant sea anemone *Entacmaea quadricolor* is benefiting from its mutualistic symbiosis with the fish, and its growth rate is significantly hampered, if the anemonefish are removed from the anemone (N.E. Chadwick-Furman, personal communication). Might the large *D. trimaculatus* shoals increase the assemblage in a mutualistic positive

feedback between anemone and fish as in *Amphiprion* spp. (Schmitt & Holbrook, 2003)? This hypothesis could be tested by nutrient measurements at the assemblage. Also to be tested are measurements of light levels, POM and DOM. Do the abundance of anemones and anemonefish result in unusual odour plumes? Since anemonefish depend on olfactory cues to detect their host at settlement (e.g. Arvedlund & Nielsen, 1996; Brolund et al., 2003), might one expect altered settlement patterns of anemonefish on anemone assemblages?

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REFERENCES

- Allen, G.R., 1972. *The anemonefishes, their classification and biology*, 1st edn. Neptune City: TFH Publications.
- Allen, G.R. & Mariscal, R.N., 1971. A redescription of *Amphiprion nigripes* Regan, a valid species of anemonefish (family Pomacentridae) from the Indian Ocean. *Fieldiana, Zoology*, **58**, 91–101.
- Arvedlund, M. & Nielsen, L.E., 1996. Do the anemonefish *A. ocellaris* (Pisces: Pomacentridae) imprint themselves to their host sea anemone *Heteractis magnifica* (Anthozoa: Actiniidae)? *Ethology*, **102**, 197–211.
- Brolund, T.M., Nielsen, L.E. & Arvedlund, M., 2003. Do juvenile *Amphiprion ocellaris* Cuvier (Pisces: Pomacentridae) recognize conspecifics by chemical or visual cues? *Journal of the Marine Biological Association of the United Kingdom*, **83**, 1127–1136.
- Debelius, H., 2001. *Red Sea reef guide*. Frankfurt: IKAN Unterwasserarchiv.
- Dunn, D.F., 1981. The clownfish sea anemones. *Transactions of the American Philosophical Society*, **71**, 2–115.
- Eibl-Eibesfeldt, I., 1965. *Land of a thousand atolls*. London: MacGibbon & Kee.
- Fautin, D.G. & Allen, G.R., 1992. *Field guide to anemonefishes and their host sea anemones*. Perth: Western Australian Museum.
- Fautin, D.G. & Smith, D.R., 1997. Clonality as a taxonomic character of actinian species. *Proceedings of the 8th International Coral Reef Symposium*, **2**, 1609–1612.
- Fricke, H.W., 1979. Mating system, resource defence and sex change in the anemonefish *Amphiprion akallopisos*. *Zeitschrift für Tierpsychologie*, **50**, 313–326.
- Hirose, Y., 1985. Habitat, distribution and abundance of coral reef sea-anemones (Actiniidae and Stichodactylidae) in Sesoko Island, Okinawa, with notes on expansion and contraction behavior. *Galaxea*, **4**, 113–127.
- Mariscal, R.N., 1970. A field and laboratory study of the symbiotic behavior of fishes and sea anemones from the tropical Indo-Pacific. *University of California Publications in Zoology*, **91**, 1–33.
- Moyer, J.T. & Nakanozo, A., 1978. Protandrous hermaphroditism in six species of the anemonefish genus *Amphiprion* in Japan. *Japanese Journal of Ichthyology*, **25**, 101–106.
- Richardson, D.L., Harriott, V.J. & Harrison, P.L., 1997. Distribution and abundance of giant sea anemones (Actinaria) in subtropical eastern Australian waters. *Marine and Freshwater Research*, **48**, 59–66.
- Schmitt, R.J. & Holbrook, S.J., 2003. Mutualism can mediate competition and promote coexistence. *Ecology Letters*, **6**, 898–902.

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