

Akihisa Hattori · Miyako Kobayashi

Incorporating fine-scale seascape composition in an assessment of habitat quality for the giant sea anemone *Stichodactyla gigantea* in a coral reef shore zone

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Abstract Habitat loss due to land reclamation often occurs in sandy coral reef shore zones. The giant sea anemone *Stichodactyla gigantea*, which harbors the false clown anemonefish *Amphiprion ocellaris*, both of which are potentially flagship species, inhabit these places. To assess habitat quality for *S. gigantea*, we examined correlative associations between the number and the body size of *S. gigantea* and the amount of habitat types in fine-scale seascape composition quantified from an enlarged section of a high-resolution (1/2,500) color aerial photograph of the shallow shore zone of Shiraho Reef, Ishigaki Island, Japan. This study confirmed that anemones were most abundant at the edges of dense seagrass beds characterized by shallow sandy bottoms, rock beds, and sparse seagrass beds, while they were less abundant in coral patch reefs. However, anemones inhabiting coral patch reefs were significantly larger and their rate of disappearance over 3 years was lower than those inhabiting other habitats. This suggests that coral patch reefs may be more suitable habitats supporting larger animals and greater persistence of *S. gigantea*. The visual census techniques applied here, combined with aerial photography and image-analysis software, may be useful as a simple analytical tool for local assessment of suitable habitats for relatively small-bodied marine fauna in shallow-water seascapes.

Keywords Coral reefs · Seagrasses · Clownfish · Habitat patches · Image analysis · Seascape structure

A. Hattori (✉)
Faculty of Liberal Arts and Education, Shiga University,
2-5-1 Hiratsu, Otsu, Shiga 520-0862, Japan
E-mail: hattori@edu.shiga-u.ac.jp
Tel.: +81-77-5377852
Fax: +81-77-5377852

M. Kobayashi
Nature Conservation Educators Association Sakishima,
Shiraho, Ishigaki, Okinawa 907-0242, Japan

Introduction

A heterogeneous environment often enhances species diversity and population abundance of a species (Tilman and Kareiva 1997; Turner et al. 2001; Pullin 2002). Marine subtidal shore zones often possess complex seascapes (Robbins and Bell 1994; Mumby and Harborne 2006). For instance, a fringing coral reef, which has developed in tropical or subtropical coastal waters, is usually characterized by a complex mosaic of habitat types (e.g., patch reefs and seagrass beds, etc.). Information on seascape composition (i.e., areas and diversity of habitat types) and configuration of habitat types are useful for an assessment of habitat quality for marine animals (Irlandi 1994; Pittman et al. 2004; Grober-Dunsmore et al. 2007).

A coral reef shore zone is an essential component of a coral reef ecosystem and harbors many reef animals, although their diversity and abundance are fewer than those of other habitats such as outer reef slopes (Lowe-McConnell 1987). In Fanning Island, for example, 38 fish species are found in small patch reefs of the turbid lagoon near the sandy shoreline and 19 fishes inhabit a tide pool, while 64 species are recorded in limestone benches of the outer reef flats (Chave and Eckert 1974). As sandy coral reef shore zones are usually very shallow and calm, land reclamation has frequently occurred for the building of piers, parking lots, and roads, etc., and even more extensively for airports, industrial sites, and waterfronts, etc., especially in densely populated islands, such as Okinawa, Japan (Spalding et al. 2001; Japan Coral Reef Society and Ministry of the Environment 2004). Few ecological studies have focused on the habitat quality of sandy coral reef shore zones except for large seagrass beds (e.g., Nagelkerken et al. 2000; Adams et al. 2006; Pittman et al. 2007a, 2007b). At broader scales, the seascape structure of coral reef shore zones may be relatively homogenous in comparison with other reef habitats. However, small patches of coral heads,

rock beds, and seagrass beds, etc., may be found at finer scales.

In describing the local seascape composition and configuration of habitat types, remote sensing techniques and products such as aerial photographs and satellite images have been useful tools: for instance, in quantification of live and dead coral coverage and areas of seagrass beds (Mumby et al. 1995; 2004; Sheppard et al. 1995; Pittman et al. 2004; Purkis and Pasterkamp 2004). However, most remote-sensing techniques cannot cover habitat use by relatively small-bodied animals. To assess the habitat quality in relation to their habitat use, underwater observations are necessary, and small quadrats or belt transects have been used for visual censuses (Luckhurst and Luckhurst 1978; Bell and Galzin 1984; McCormick 1994). Ordinary visual census techniques can precisely describe the habitat or micro-habitat structure in a quadrat. However, those cannot cover seascape composition and the spatial distribution patterns of individuals, especially in low-density species.

Hattori and Kobayashi (2007) developed a simple technique to incorporate the fine-scale seascape composition in a 3-ha field survey, including areas of habitat patches and habitat use by the giant sea anemone (*Entacmaea quadricolor*), which hosts anemonefish (*Amphiprion frenatus*), in shallow back reefs. In their study, they used an enlarged section of a high-resolution color aerial photograph (less than 0.1 m) to produce an accurate seascape map (equivalent to 1/2,500 scale or more). Each individual anemone was precisely located in the field map and image analysis software was used to quantify the surrounding abundance of individual patch types.

In the present study, we examined relationships between fine-scale seascape composition and habitat use by a relatively small-bodied and low-density animal, another giant sea anemone *Stichodactyla gigantea*, which harbors the false clown anemonefish *Amphiprion ocellaris*. The sea anemone is sparsely distributed over shallow sandy coral reef shore zones, although the clownfish *A. ocellaris* is sometimes found in deeper sites with other giant anemones (Dunn 1981; Fautin and Allen 1992; Mitchell 2003). As both *S. gigantea* and *A. ocellaris* are very popular marine ornamentals and require a large stable area for long-term survival (Shuman et al. 2005), they can be flagship species (for definition, see Pullin 2002) for conservation of shallow sandy coral reef shore zones.

According to a theoretical study on the optimum body size of sea anemones (Sebens 1982), the maximum size of their tentacle crown surface area in a particular habitat reflects the suitability of that habitat. As sea anemones catch small prey on the surface of the tentacle crown, a larger surface area of tentacle crown facilitates the capture of more prey. However, the cost in energy of maintaining the body increases in proportion to the body volume (Sebens 1982). Therefore, we can assume that *S. gigantea* having larger crown surface areas will be found more frequently in a habitat

type with more prey and lower levels of physiological stress (Hattori 2006).

The aim of the present study is to understand the relationships between fine-scale seascape composition and habitat use by the low-density animal, in order to incorporate the fine-scale seascape composition in an assessment of the habitat quality at a sandy coral reef shore zone. In the present study, we hypothesized that the average body size of *S. gigantea* would be largest in a habitat type where the number of anemones would be most abundant and their disappearance rate would be lowest. The null hypotheses we tested are as follows: (1) they are randomly distributed, (2) there is no difference in their body sizes between habitat types, (3) there is no difference in their disappearance rates between habitat types, (4) their body sizes are not correlated with their inhabiting water depths, and (5) their density in a quadrat is not correlated with the total area of a particular habitat type. Actually, their distribution might be random because they are often found in both sandy bottoms and hard substratum of shallow coral reefs (Dunn 1981; Fautin and Allen 1992; Mitchell 2003). Although the present study site was very shallow (≤ 1.4 m deep), water depth might influence their body sizes and distribution patterns. To test the hypotheses, we measured the tentacle crown surface areas and the inhabiting water depths of all individuals of *S. gigantea*, and patrolled the study site over 3 years, monitoring all individuals to determine disappearance rates and recruitment rates in relation to habitat types. As the boundaries of several habitat patches such as rock beds and sandy bottoms were often unclear in the field, we applied the posterization function of image analysis software to discern the boundaries between several habitat patches: we used the simplified aerial photograph as a blank map.

Materials and methods

The field study was conducted between September 2003 and 2006 in Shiraho Reef, Ishigaki Island (24°22'N, 124°15'E), Okinawa, Japan (Kobayashi and Hattori 2006; Hattori and Kobayashi 2007; Tamura et al. 2007). We used a large-sized aerial photograph (92 × 92 cm²), which was enlarged from the original negative of the aerial color photograph of Shiraho Reef (23 × 23 cm², OKC-94-13, 1/10,000, 95 Ishigaki C15-34, Geographical Survey Institute, Ministry of Land, Infrastructure and Transport, Japan). To record the precise location of individual *S. gigantea* and the surrounding benthic seascape, a section (14.6 × 6.5 cm²) of the large-sized photograph covering the shore zone (Fig. 1a, b, 261.65 × 116.29 m², maximum depth = 1.4 m at spring low tide) was enlarged to a size of 27.3 × 12.1 cm² after converting it to a digitized image (Windows BMP format, 3,465 × 1,540 pixels) with a scanner at a resolution of 600 dpi. Although the aerial photograph was taken in 1995, the outlines and



Fig. 1 **a** Location of the study site (red square $261.65 \times 116.29 \text{ m}^2$) in a shallow coral reef shore zone (0–1.4 m deep) of the back reef moat (0–3 m deep) of Shiraho Reef, Ishigaki Island, Okinawa, Japan (original color aerial photograph: OKC-94-13, 1/10,000, 95 Ishigaki C15-34, Geographical Survey Institute, Ministry of Land, Infrastructure and Transport, Japan). **b** Habitat map [fine-scale seascape map (1/2,500)] and distribution of the giant sea anemone, *Stichodactyla gigantea*, in September 2003 (red circles) and newly found anemones during the 3-year study period (yellow circles). As one anemone divided into three individuals, two of them indicated (white circles) individuals disappeared in the study period (open circles) and one anemone that seemed to have moved were also shown (open circle combined with yellow circle). **c** The habitat categories were simplified using the posterization function of image-analysis software. Squares indicate quadrats 1–36 (from left to right, up to down). The side of a grid is equivalent to 29.1 m

configuration of seagrass patches, bed rocks and patch reefs did not change substantially in the study period. It was partly confirmed by the aerial photographs taken by a remotely operated captive blimp in 2004 (National Institute of Advanced Industrial Science and Technology, Japan, data not shown).

The photographic map was simplified using the posterization function of image-analysis software (Adobe Photoshop CS). Each pixel has three color axes (red, green, and blue) of brightness values from 0 to 255, each axis was divided into three equal parts, and the ‘three grades’ posterization function assigned each axis to one of the three grades as a color value (0, 127, or 255)

according to the brightness value. Consequently, each pixel of the image was simplified into 27 color types ($3 \times 3 \times 3$ color values). The four major color types comprising the largest total area (blue–black, gray, blue and white) were used for analyzing the distribution patterns of the anemones (see “Results”). The simplified map was printed, waterproofed, and used for mapping the sea anemone.

Several seascape elements such as coral heads and dense seagrass beds were recognized in the same color type in the posterized map but could be easily discerned underwater. The boundary of several seascape elements, such as rock beds and sandy bottoms, was often unclear underwater, but could be easily discerned in the map. Accordingly, we determined seven habitat types based on the color types on the map and seascape elements observed underwater (Fig. 1c). (1) patch reefs: blue–black in photograph; small patch reefs or coral heads, (2) dense seagrass beds: blue–black in photograph; sandy bottoms with seagrass beds, (3) sparse seagrass beds: gray in photograph; sandy bottoms with seagrass beds, (4) rock beds: gray in photograph; bedrock or beach rock with sand cover, (5) shallow sandy bottoms: gray in photograph; sandy bottoms without seagrass beds, (6) medium-depth sandy bottoms: white in photograph; sandy bottoms without seagrass beds, and (7) deep sandy bottoms: blue in photograph; sandy bottoms without seagrass beds.

Two snorkelers located all *S. gigantea* on the map documenting the habitat types over 18 h in September 2003, and 7 h again in November 2003. Rocks nearby *S. gigantea* were tagged to confirm their locations. There was no *S. gigantea* without anemonefish. The area covered by the tentacles of each actinia was regarded as an oval and was measured and calculated (long axial length \times short axial length $\times \pi/4$) (Hattori 2002, 2005, 2006). All *S. gigantea* were individually recognized by their locations on the map and body sizes. Distances between several benthic landmarks were measured in the field: a distance of 13.243 pixels on the digitized maps was equivalent to 1 m, and one pixel was much smaller than the smallest patch reef (about 0.7 m in diameter) inhabited by the anemones. Based on the lowest sea level in daytime in September 2003 at 0 m deep (nearly equal to mean sea level of Tokyo Bay, the lowest sea level and the highest sea level from MSLTB in September 2003 was -0.6 and 1.59 m, respectively) the water depths at the sites to which anemones attached were measured to the nearest 1 cm using a tape measure while snorkeling. The snorkelers re-sighted all anemones on the maps whilst searching for new anemones in the entire study site in March and September 2004, 2005, and 2006 for 10 h each in each month.

The study site was divided into 36 grids (Fig. 1c, each cell = 385×385 pixels, $29.1 \times 29.1 \text{ m}^2$) to compare the heterogeneity of seascapes and distribution of *S. gigantea*. The total area of each major color type determined from the posterized image of each grid was calculated on a computer with a public domain program (Image J

1.33, see Rasband, W.S. Image J, US National Institutes of Health, Bethesda, MD, USA, <http://rsb.info.nih.gov/ij/>, 1997–2007). Because of the low density of anemones, the 36 grids were unified into nine contiguous virtual transects (each transect = $29.1 \times 116.4 \text{ m}^2$) to re-analyze their habitat use.

In order to know whether the spatial distribution of *S. gigantea* is random, Morisita index (I_δ) was calculated as follows:

$$I_\delta = n \left(\sum_{i=1}^n x_i(x_i - 1) \right) / (N(N - 1)),$$

where n is the total number of grid, x_i is the number of anemones in the grid i , and N is the total number of anemones (random distribution, $I_\delta = 1$; contagious or cluster distribution, $I_\delta > 1$, Morisita 1959; Shimada et al. 2005). Null hypothesis ($I_\delta = 1$) was tested with F -value, which was calculated as below (Shimada et al. 2005):

$$F = (I_\delta(N - 1) + n - N) / (n - 1).$$

For other null hypotheses mentioned in the Introduction, parametric statistical tests [t -test, analysis of variance (ANOVA), Pearson correlation coefficient and stepwise regression analysis] were applied to the data set when the distribution did not differ significantly from the standardized form of normal distribution (Chi-square test), otherwise non-parametric procedures were applied (Mann-Whitney's U -test and Spearman rank correlation coefficient). Multiple comparison (Bonferroni/Dunn post-hoc test) was conducted after a significant difference was found in ANOVA.

Results

Spatial distribution of *S. gigantea*

At the beginning of the study period, there were 44 anemones (Fig. 1b) in the study site. Their density was very low (0.14 anemones per 100 m^2), but the average nearest-neighbor distance was $11.1 \text{ m} \pm 10.1 \text{ SD}$ (median = 6.9, range = 43–1.5, $N = 44$). The contagious or cluster distribution was detected (Fig. 2a, Morisita index, $I_\delta = 1.82$, $F = 2.01$, $P < 0.01$).

Habitat type and body size of *S. gigantea*

Although the average body size of *S. gigantea* was slightly larger than the median, their size-frequency distribution did not differ significantly from the standardized form of normal distribution (Fig. 3a, Chi-square test, $\chi^2 = 5.27$, $P > 0.05$, $N = 44$, average size = $815.1 \text{ cm}^2 \pm 374.9 \text{ SD}$, median = 766.2 cm^2 , range = 1,882–214). While no *S. gigantea* were present in the dense seagrass beds, there were two anemones in

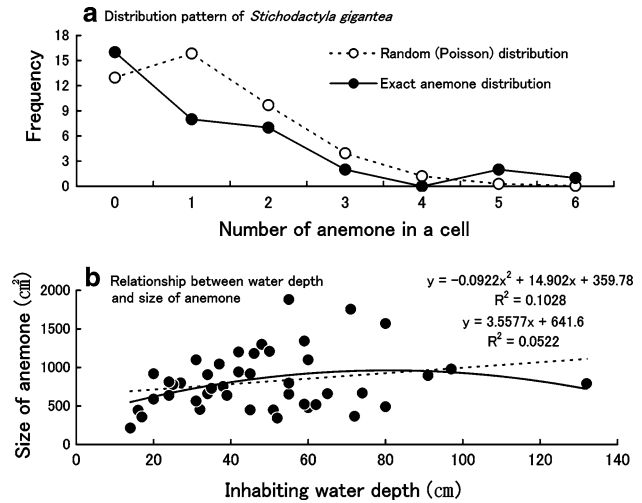


Fig. 2 a Spatial distribution pattern of 44 individuals of the giant sea anemone among 36 quadrats or grids of the study site. Random (Poisson) distribution patterns of 44 individuals among 36 quadrats are also shown. b Relationship between the body size of the anemone and inhabiting water depth. Non-significant regression line and curve are also shown

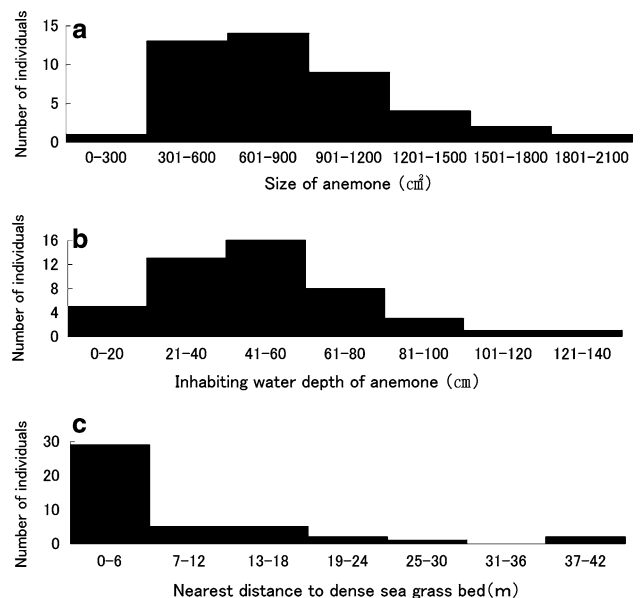


Fig. 3 a Size-frequency distribution of the giant sea anemone. b Depth-frequency distribution of the anemone. c Distance-frequency distribution (to the nearest dense seagrass bed) of the anemone

the sparse seagrass beds (Fig. 4). While no anemones were found in the deep sandy bottoms, 14, 12, and three anemones inhabited the shallow sandy bottoms, the rock beds, and the medium-depth sandy bottoms, respectively. There were 13 individuals on the patch reefs: they were all attached to the edges of the patch reefs. There was a significant difference in the average body size of *S. gigantea* between the five habitat types (Fig. 4a, ANOVA, $F = 3.46$, $P = 0.02$). Individuals inhabiting

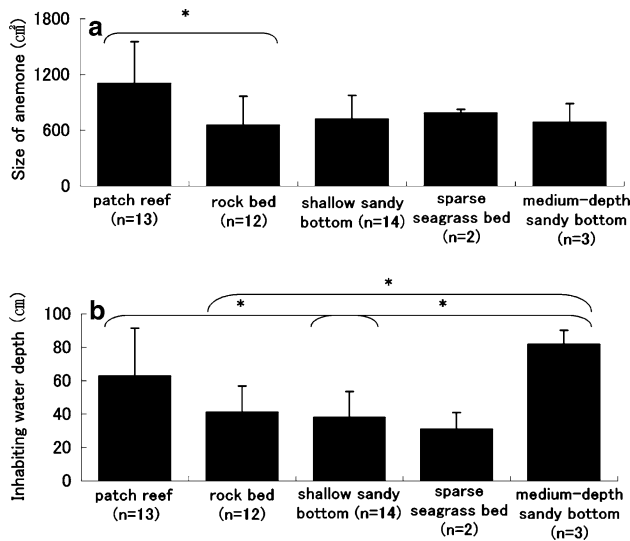


Fig. 4 **a** Comparison of the average size (+SD) of giant sea anemone among five habitat types. **b** Comparison of the average water depth (+SD) of the giant sea anemone among five habitat types. Results of multiple comparison test (Bonferroni/Dunn) are shown (* means $P < 0.05$)

the patch reefs were significantly larger than those inhabiting the rock beds (Bonferroni/Dunn test, $P < 0.05$), but there were no significant differences in the size between the rock beds, the shallow sandy bottoms, the sparse seagrass beds, and the medium-depth sandy bottoms (Bonferroni/Dunn test, $P > 0.05$).

Habitat type, disappearance rate, and settlement of *S. gigantea*

At the end of the study, 43 anemones existed: nine had disappeared, six had been newly found, and one actinia had divided into three small individuals. One individual (565 cm^2) seemed to have moved about 3 m. All 13 anemones that had inhabited the patch reefs at the outset remained, whereas one of 12 anemones that inhabited the rock beds and eight of 19 anemones that inhabited the sandy bottoms including the sparse seagrass beds had disappeared by the end of the study. There was a significant difference in the disappearance rate of *S. gigantea* between the patch reefs and other habitat types (0/13 vs. 9/31, Fisher's exact probability test, $P = 0.0284$). Nine actiniae that had a nearest neighbor within a 4-m radius inhabited the shallow sandy bottoms or the rock beds. The six newly found anemones also inhabited the shallow sandy bottoms or the rock beds. The anemone that had divided into three individuals inhabited the rock beds. The average size of *S. gigantea* that had disappeared during the period ($566.7 \text{ cm}^2 \pm 255.3 \text{ SD}$, $N = 9$) was slightly smaller than that of *S. gigantea* which remained ($879.0 \text{ cm}^2 \pm 376.6 \text{ SD}$, $N = 35$); there was a significant difference between them (t -test, $t = 2.34$, $P = 0.024$). The 6

individuals that had been newly found ($386.4 \text{ cm}^2 \pm 216.5 \text{ SD}$, range = 687–141, $N = 6$) were significantly smaller than the 44 individuals measured at the beginning of the study (t -test, $t = 2.72$, $P = 0.009$).

Water depth and body size of *S. gigantea*

The water-depth frequency distribution of anemones did not differ significantly from the standardized form of normal distribution (Fig. 3b, $N = 44$, average depth = $48.8 \text{ cm} \pm 24.1 \text{ SD}$, range = 132–14). There was no significant correlation between their body sizes and inhabiting water depths (Fig. 2b, $r = 0.228$, $P = 0.135$, $N = 44$): polynomial regression analysis could not reveal any significant regression curves. There was a significant difference in the average water depths of *S. gigantea* among the five habitat types (Fig. 4b, ANOVA, $F = 5.33$, $P = 0.002$). However, there were no significant differences in the water depths between the rock beds, the shallow sandy bottoms and the sparse seagrass beds (Bonferroni/Dunn post hoc test, $P > 0.05$), while anemones on the patch reefs and on the medium-depth sandy bottoms inhabited deeper than those on the shallow sandy bottoms (Bonferroni/Dunn post hoc test, $P < 0.05$).

Habitat area and density of *S. gigantea*

In the posterized photograph, 28 anemones (63.6% of all individuals) were found in the gray patches (36.7% of the study site, 0.25 individuals/100 m^2), 13 (29.5%) in the blue–black patches (7.9%, 0.54 individuals/100 m^2) and three (6.8%) in the white patches (14.1%, 0.07 individuals/100 m^2) (Fig. 1c). About 93.2% of all observed *S. gigantea* inhabited the gray patches or the blue–black patches (44.6% of the study site). The ratio of the four major color types of habitat, blue–black, gray, blue and white, varied in the quadrat 1–36 (Fig. 5). The number of *S. gigantea* in a grid was not significantly correlated with the total area of the gray patches ($r_s = 0.064$, $P = 0.703$, $N = 36$), the blue patches ($r_s = 0.103$, $P = 0.538$, $N = 36$) and the white patches ($r_s = 0.014$, $P = 0.932$, $N = 36$). However, it was weakly correlated with the total areas of the blue–black patches ($r_s = 0.404$, $P = 0.016$, $N = 36$). A slightly higher correlation was found between the number of anemones in a grid and the product of the total areas of the blue–black patches and the gray patches ($r_s = 0.481$, $P = 0.004$, $N = 36$). Putting four contiguous cells in a column together in a virtual belt transect ($29.1 \times 116.4 \text{ m}^2$), a highly significant correlation was found between the number of anemones and the product of the total areas of the blue–black patches and the gray patches ($r = 0.783$, $P = 0.012$, $N = 9$). It was weakly correlated with the total area of the blue–black patches ($r_s = 0.700$, $P = 0.047$, $n = 9$) but was not correlated with the gray patches ($r_s = 0.565$, $P = 0.109$, $n = 9$).

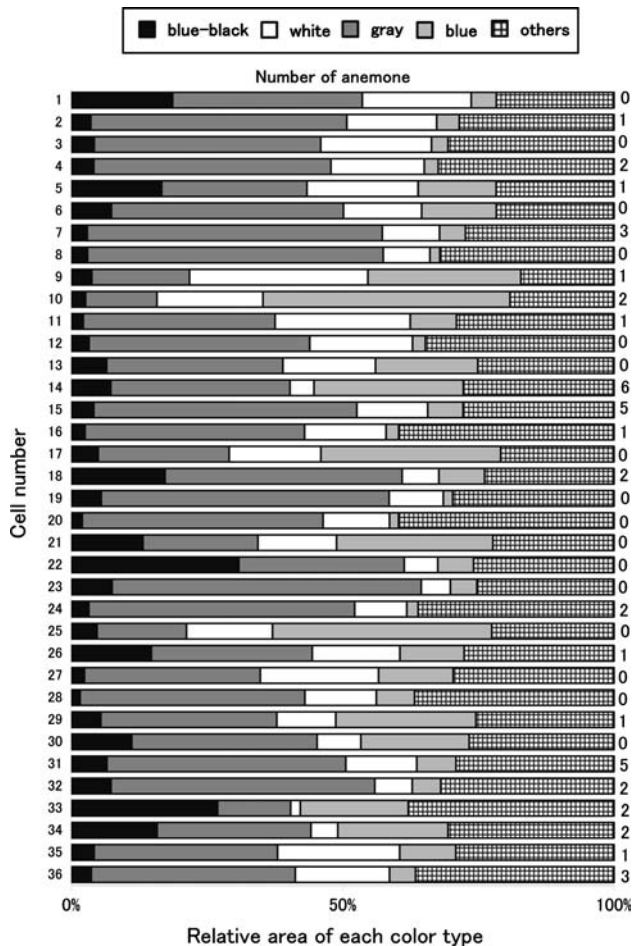


Fig. 5 Relative areas (%) of simplified habitat categories in each grid and total number of anemone

Influence of habitat proximity on *S. gigantea*

Anemones were abundant nearby the dense seagrass beds (Fig. 2c, median = 4.5 m, range = 39.6–0.74, $N = 44$): the frequency distribution of the nearest distance anemone to the dense seagrass beds differed largely from the standardized form of normal distribution (Chi-square test, $\chi^2 = 5.27$, $P < 0.0001$, $N = 44$). The size of an anemone was weakly but positively correlated with the nearest distance to the dense seagrass beds ($r_s = 0.428$, $P = 0.005$, $N = 44$). The six newly found anemones also inhabited nearby the dense seagrass beds (median = 2.6 m, range = 12–1, $N = 6$): there was no significant difference in the distance to the nearest dense seagrass beds between the six anemones and others (Mann-Whitney's U -test, $U = 94$, $P = 0.256$).

Discussion

The present study demonstrates that by using a posterized high-resolution aerial photograph as a fine-scale seascape map we can recognize the habitat types of

which boundaries are often unclear in a field survey. For example, although we did not have the actual isobathic data of the study site, we could still recognize the shallow sandy bottoms and medium-depth sandy bottoms in the field. Anemones were frequently found in the former habitat type and their inhabiting water depth was actually shallower than the latter habitat type. Furthermore, we could thoroughly examine the spatial distribution pattern of the relatively low-density species in the entire study site of 3 ha. *S. gigantea* was widely distributed over the shallow sandy shore zone including both soft and hard substratum less than 1.4 m deep, but the distribution pattern was not random (Fig. 2a). Anemones were abundant ($N = 28$, 63.6% of all individuals) at the edges of dense seagrass beds, characterized by shallow sandy bottoms, rock beds, and sparse seagrass beds (the gray patches in the posterized seascape map, Fig. 1c), and less abundant in patch reefs ($N = 13$).

We predicted that the average body size of anemones would be largest in the most suitable habitat. Following the optimum body size theory of Sebens (1982), our results indicate that the patch reefs are most suitable habitat type for *S. gigantea*. In addition, the sizes of anemones were not relevant to the water depth in the present study site (Fig. 2b). Although the inhabiting water depths of *S. gigantea* in the patch reefs and the medium-depth sandy bottoms were slightly larger than other anemones, individuals in the latter habitat were as small as those in the other shallow habitats. The disappearance rate of anemones was significantly lower in the patch reefs than that in other habitat types. This finding supports the notion that patch reefs are the most suitable habitat. All individuals inhabiting the patch reefs did not move or disappear throughout the 3-year period, whereas all the anemones that disappeared or moved had inhabited the sandy bottom or rock beds. Because the sandy bottoms consisted of sand and the rock beds were slightly covered by sand, the sand surface may be involved in the anemones disappearance or movement.

Contrary to our predictions, however, *S. gigantea* was less abundant in the suitable habitat: anemones were more abundant in the edges of the dense seagrass beds, and their size was weakly but positively correlated with the nearest distance to the dense seagrass beds. Newly found anemones that inhabited the shallow sandy bottoms or rock beds nearby the dense seagrass beds were significantly smaller than other anemones. This implies that they were newly settled juveniles. The anemones may be frequently settled on the less suitable habitat nearby the dense seagrass beds. A similar phenomenon is observed in another giant sea anemone *Heteractis crispa*, which inhabits shallow reef edges in a fringing coral reef (Hattori 2006): individuals are more abundant in shallow reefs (<0.5 m deep), where few large individuals are found, and larger individuals are found in deeper habitats (<4 m deep) of the reef edges, where few small individuals are found. Hattori (2006) suggests that anemones in the deep habitats, which are suitable

for their growth, suffer from high predation pressures when juveniles, while those in the shallow habitats, which provide with refuges consisting of corals, suffer from higher levels of physiological stress such as higher water temperature. For *S. gigantea*, in this study, individuals on the patch reefs inhabited slightly deeper than those on the shallow sandy bottoms nearby the dense seagrass beds. Predators such as fish often prefer patch reefs to shallow seagrass beds, which are well known as nursery habitat for juveniles (Nagelkerken et al. 2000; Adams et al. 2006; Pittman et al. 2007a, 2007b). High predation pressure for small anemones in the patch reefs that were suitable for their growth may account for the unique distribution pattern of *S. gigantea*. Alternatively, the wider area of the shallow edges may have been major targets for passive drifting settlers because the edges of the dense seagrass beds were 36.7% of the study site, while the patch reefs were much less than 7.9%. Giant sea anemones can reproduce sexually and asexually (Dunn 1981; Fautin and Allen 1992). One actinia in the rock beds was actually found to have divided into three. High density and small sizes of *S. gigantea* in the edges of the seagrass beds might have been caused by asexual reproduction. Further study is needed to reveal their recruitment process and reproduction.

It is noted that the major habitats of *S. gigantea* could be adequately detected using posterization techniques on the aerial photograph. All the individuals but three (93.2%) were found in either the gray or the blue-black patches on the photograph (44.6% of the study site). In addition, the number of *S. gigantea* in a virtual belt transect was highly correlated with the product of the total area of gray and blue-black patches. Although the gray patches were nearly identical to the edges of dense seagrass beds, the number of *S. gigantea* in a grid was not correlated with the total area of gray patches alone. Probably, their low population density could not have represented a significant correlation in this study. Their population density in the blue-black patches (0.54/100 m²) was slightly higher than that of the gray patches (0.25/100 m²), but two habitat types (dense seagrass beds and patch reefs) were included in the blue-black patches, whereas they were only in the patch reefs. Thus, the area of the major habitat types of *S. gigantea* were recognized as a combination of the two color types in the posterized photograph. As posterization techniques are non-deterministic and not directly transferable to other regions, we cannot apply this methodology to compare habitat qualities widely between sites over two or more aerial photographs. However, the simplified seascape categories can be used to compare local sites' habitat quality on fine scales, if the target sites are within the same photograph (the shoreline in the photograph of this study was about 2.8 km).

Although landscape ecology is applicable to fine scales (Turner et al. 2001), few marine applications exist at these spatial scales (but see Irlandi 1994; Irlandi et al. 1995; Pittman et al. 2004). Fine-scale seascape composition can influence the local abundance of small-bodied

species. For instance, configurations of small patches of seagrass beds (<100 m²) influence the survivorship of bivalves (Irlandi et al. 1995). In addition, many marine animals use several habitat types to complete their life cycle, which requires investigators to incorporate seascape structure into studies of species-environment relationships (Pittman and McAlpine 2003). More seascape approaches are necessary that examine the linkages between species distributions and environmental heterogeneity at multiple spatial scales (Pittman et al. 2004). While *S. gigantea* inhabits a shallow shore zone in a broad scale, it appeared to respond structural features of specific habitat types at fine scale. Without using GIS and advanced remote-sensing techniques, we developed a landscape ecology approach to examine several of the key environmental determinants that influence the distribution of a sessile marine organism. The visual census techniques applied in the present study, using enlarged aerial photographs and image analysis software, may be widely used as a simple analytical tool in fine scales for local assessment of suitable habitats for relatively small-bodied and low-density marine fauna in shallow water seascape.

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