This is an electronic version of an article published in *Marine Biology Research*, 2007; 3: 468–472.
***Marine Biology Research* is available online at http://journalsonline.tandf.co.uk/**

First record of *Alicia mirabilis* (Anthozoa: Actiniaria) from the Aegean Sea and density assessment with distance sampling in a site of high abundance

Stelios Katsanevakis*, Maria Thessalou-Legaki

Department of Zoology-Marine Biology, School of Biology, University of Athens, Panepistimioupolis, 15784 Athens, Greece

Running head: ***Alicia mirabilis* in Aegean Sea**

corresponding author:
e-mail: stelios@katsanevakis.com tel: +30-210-4203508 fax: +30-210-7274604

Abstract

The occurrence of the actiniarian *Alicia mirabilis* in the Aegean Sea is documented for the first time from five sites of Saronikos Gulf. *A. mirabilis* density was assessed in one site (Lychnari bay) with line transects (underwater distance sampling with SCUBA). Density ranged between 0–4.3 ind are^{-1} (1 are = 100 m^2) with a mean of 1.1 ± 0.5 ind are^{-2}. The species was found in a variety of substrates (sandy bottoms, weeds, seagrass beds, rocks, litter) and its distribution was aggregated. Distance sampling was an efficient way to estimate density of *A. mirabillis* and is proposed as a good choice for density estimations of actiniarians and other benthic fauna.

Keywords: *Alicia mirabilis*; density estimation; distance sampling; line transect

Introduction

The actiniarian *Alicia mirabilis* Johnson, 1861 has an Atlanto-Mediterranean distribution that includes the eastern Atlantic, from the Portuguese continental coast to the Canary Islands, the western Atlantic, from Florida and the Bahamas to Brazil (Humann and DeLoach 2002; Zamponi et al. 1998), and the Azores (den Hartog 1995; Wirtz et al. 2003). In the Mediterranean, *A. mirabilis* has been mostly reported from its westernmost part (Rossi 1983; Ocaña et al. 2000), where it seems to be rather rare (Loukmidou et al. 1996); more recently, it was found for the first time in the Adriatic Sea (Kruzic et al. 2002). Although studies on the actiniarian fauna of the Aegean Sea are rather numerous (Doumenc et al. 1985; Chintiroglou and den Hartog 1995; Chintiroglou et al. 1997; Vafidis et al. 1997), *A. mirabilis* has not been reported till now in that part of the Mediterranean.

Actiniarians may play a crucial role in the local biocommunity structure as they are mainly predators, they provide shelter for many species, mainly crustaceans (Excoffon et al. 1999), and under favourable conditions may reach quite high densities. Nevertheless, assessments of the population density of actiniarians are not common (e.g. Chintiroglou et al. 2000; Kelmo et al. 2003). The present paper reports, for the first time, the presence of *Alicia mirabilis* in Saronikos Gulf, Aegean Sea. Its density was assessed in Lychnari, Saronikos Gulf, as a first step towards understanding its importance for the local communities.

Distance sampling (Buckland et al. 2001) is a widely used method for estimating abundance and/or density of biological populations. Distance sampling has been used extensively in terrestrial ecology (mostly for birds and terrestrial mammals) and for marine mammals. Although it is the standard method for abundance estimations of many species, it has only rarely been used for underwater surveys of benthic fauna (e.g. Katsanevakis 2005, 2006, 2007; Pink et al. 2007). The main distance sampling methods are line transects and point transects. A standardized survey is conducted along a series of lines (in line transects) or points (in point transects) searching for the animals of interest. For each animal detected, the distance from the line or point is recorded. A detection function is fitted from the set of recorded distances, which is used to estimate the proportion of animals missed by the survey and hence accurately estimate abundance (Buckland et al. 2001).

Materials and Methods

In situ measurements

In Lychnari bay (Saronicos Gulf, Greece; Fig. 1) the population density of *Alicia mirabilis* was estimated with line transect sampling (Buckland et al. 2001) by SCUBA diving, during June 2006. At each of 3 randomly chosen locations of the bay, a density measurement was conducted in the following depths: 5 m, 10 m, and 15 m. The substrate was sandy in all transects, except for those at the 5-m depth, where it was partly rocky (~ 40%) at locations 1 and 2 and completely rocky at location 3. At each depth, a 200 m line (= *L*) was deployed using a diving reel. The line was kept at a constant depth contour (± 0.5 m) by tracking it with a dive computer (Suunto). All *A. mirabilis* individuals that were detected along the line were recorded. For each individual encountered, the perpendicular distance from the line was measured *in situ* using a 2 m plastic rod bearing marks every 5 cm.

Density estimation from line transects

The detection function *g(y)*, gives the probability of detecting an individual given that it is at distance *y* from the line. Let $\mu = \int_0^\infty g(y)\mathrm{d}y$ be the integral of the detection function from zero to infinite distance from the line; the parameter μ is actually the half-width of the strip extending either side of a transect centerline such that as many objects are detected outside the strip as remain undetected within it (= effective strip half-width). Then, the density of *A. mirabilis* would be estimated by (Buckland et al. 2001):

$$\hat{d} = N(2L\hat{\mu})^{-1} \qquad \text{(Eq. 1)}$$

where *N* is the number of individuals detected and *L* the length of the line transect. The function *g(y)* was estimated from the distance data (ungrouped data, right-truncated at *W* = 2.3 m to exclude outliers) with a semi-parametric approach, according to Buckland et al. (2001), using the software DISTANCE 4.1 (Thomas et al. 2003). Specifically, the detection function was modeled in the general form: $g(y) = key(y)[1 + series(y)] \times \{key(0)[1 + series(0)]\}^{-1}$, where *key(y)* is the key function and *series(y)* is a series expansion used to adjust the key function. The uniform function *key(y)*=1/*W* (0 parameters), the one-parameter half-normal function *key(y)*= $\exp\left(-y^2 / 2\sigma^2\right)$ and the two-parameter hazard-rate function *key(y)*= $1 - \exp\left[-\left(y/\sigma\right)^{-b}\right]$ were considered as key functions; three series expansions were considered: the cosine series $\sum_{j=1}^{m} a_j \cos(j\pi y / W)$, simple polynomials of the form $\sum_{j=1}^{m} a_j \left(y/W\right)^{2j}$, and Hermite polynomials of the form $\sum_{j=2}^{m} a_j H_{2j}(y/\sigma)$, where *W* is the truncation point (distances exceeding *W* were truncated before analysis), σ and a_j are best fit parameters (Buckland et al. 2001).

Six models were considered for the detection function: uniform key with cosine or simple polynomial series expansions, half-normal key with cosine or Hermite polynomial series expansions, and hazard-rate key with cosine or simple polynomial series expansions, as proposed by Buckland et al. (2001).

Model selection was based on the Information Theory approach (Burnham and Anderson 2002). The small-sample, bias-corrected form AIC_c (Hurvich and Tsai 1989) of the Akaike's Information Criterion (AIC) (Akaike 1973; Burnham and Anderson 2002) was used for model selection. The number *j* of parameters in each series expansion was also defined using AIC_c between models of increasing order. The model with the smallest AIC_c value ($AIC_{c,min}$) was selected as the 'best' among the models tested.

To obtain more robust inferences, the final results were based on model averaging rather than on simply the 'best' model (Burnham and Anderson 2002). The AIC_c differences, $\Delta_i = \mathrm{AIC}_{c,i} - \mathrm{AIC}_{c,\min}$, were computed over all candidate models g_i. To quantify the plausibility of each model, given the data and the set of six models, the 'Akaike weight' w_i of each model was calculated, where $w_i = \dfrac{\exp(-0.5\Delta_i)}{\sum_{j=1}^{6}\exp(-0.5\Delta_j)}$.

The 'Akaike weight' is considered as the weight of evidence in favor of model *i* being the actual best model of the available set of models (Akaike 1983; Buckland et al. 1997; Burnham and Anderson 2002).

Model averaged estimates were calculated by the formula:

$$\hat{\bar{\theta}} = \sum_i w_i \hat{\theta}_i \qquad \text{(Eq. 2)}$$

where $\hat{\bar{\theta}}$ denotes a model averaged estimate of parameter θ. The unconditional standard error of θ was estimated as (Burnham and Anderson 2002):

$$\mathrm{se}(\hat{\bar{\theta}}) = \sum_i w_i \left(\mathrm{var}(\hat{\theta}_i \mid g_i) + (\hat{\theta}_i - \hat{\bar{\theta}})^2 \right)^{1/2} \qquad \text{(Eq. 3)}$$

where $\mathrm{var}(\hat{\theta}_i \mid g_i)$ is the variance of θ according to model g_i, conditional on the model.

Using the raw data (counts of individuals in each transect), the variance-to-mean index of dispersion (= I) was used to assess the spatial distribution of the species (Krebs 1998). A value of I = 1 indicates random distribution, I = 0 indicates uniform distribution, and I > 1 stands for aggregated distribution.

Results and discussion

Alicia mirabilis was found in five sites in the inner Saronikos Gulf: Lychnari, Fragolimano, Amoni, Sideronas and Sousaki. It is the first time that the occurrence of *A. mirabilis* is documented in the Aegean Sea. In the first four sites, the species has been observed (by SK) continuously since 2001 while recently it was also detected in the fifth site. Thus, its presence in the area should be considered rather permanent and not occasional, at least for the last six years. As the species is rather large (its height may exceed 40 cm) it is surprising that it has not been reported before from the Aegean Sea, unless it has only recently extended its distribution.

In the nine line transects of Lychnari bay, a total of 71 individuals were detected during the survey. After the right-truncation of distances to exclude outliers, 67 distances were used to model the detection function. The detection models, the estimated parameters and the corresponding AIC_c values are given in Table 1. The best model of the detection function was that with uniform key function and 1st-order cosine series expansion. No adjustment term was selected (according to AIC_c) with the half-normal and with the hazard-rate key functions, thus models g_2 and g_3 were identical as well as models g_5 and g_6 (Table 1). To avoid model redundancy when model-averaging (Burnham and Anderson 2002), the redundant models were excluded from the calculation of the Akaike weights and of the model averaged estimates of the effective strip half-width. Model-averaged estimates of the effective strip half-width $\hat{\bar{\mu}}$ and population density $\hat{\bar{d}}$ as well as the corresponding unconditional standard errors, calculated using Eqs. 2 and 3, are also given in Table 1.

Using Eq. 1, the *A. mirabilis* density was estimated for each transect (Fig. 2). Location 3 showed the lowest density values among locations. The overall mean density (± standard error) of all nine transects, based on model-averaged estimates, was 1.1 ± 0.5 ind are^{-2} (1 are = 100 m^2); the maximum density was found at 10 m depth in location 2 (4.3 ind are^{-2}). The index of dispersion was estimated as I = 12.5 >> 1, indicating a highly aggregated dispersion.

In the five sites of Saronikos Gulf, *A. mirabilis* individuals were observed from 5 to 20 m depth, on a variety of substrates ranging from sandy bottoms, weeds, sea-grass beds of *Cymodocea nodosa* (Ucria) Ascherson, rocks, or even litter. Although *Alicia mirabilis* has been reported as a rare species in the western Mediterranean and had not been reported before from the Aegean Sea (see Introduction for references), relatively high densities were found in the present study.

Significant patchiness was found in the distribution of *A. mirabilis* and densities in adjacent transects varied greatly. Aggregated distribution is very common among sea anemones that reproduce asexually (Schmidt 1970; Shick and Lamb 1977; Gomes et al. 2003), however it is not a proof of asexual reproduction, as many sea anemones that reproduce exclusively sexually can also form large aggregations (Russo et al. 1994). To our knowledge, no information relevant to the asexual or sexual reproduction of *A. mirabilis* exists.

The population density of *A. mirabilis* was estimated with distance sampling by SCUBA diving; this method has not been previously reported for other Actiniaria species. When the detection of all individuals is difficult (as was for *A. mirabilis* due to its similar coloration to the substrate and the fact that it is generally contracted during the day and active during the night), a distance sampling method is typically more efficient than simple strip transect sampling, because densities are corrected with the use of the detection function and also the sample size is larger for the same amount of effort, as all detected individuals may be recorded regardless of their distance from the line (Katsanevakis 2005). Density estimation of benthic fauna is commonly conducted with fishery surveys using dredges or trawls, in which abundance estimation is based on the catch, making appropriate assumptions regarding the catching efficiency of the fishing tool. Compared to fishery surveys, a visual census is advantageous, as the records are not dependent on catching efficiency (Katsanevakis and Verriopoulos 2004); in addition visual census is a non-destructive method, which should be of concern, especially when dealing with rare or protected species or habitats (Katsanevakis 2007).

References

Akaike H. 1973. Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Csàaki F, editors. Proceedings of the Second International Symposium on Information Theory. Budapest, Akademiai Kiado, p 267–81.

Akaike H. 1983. Information measures and model selection. Bulletin of the International Statistical Institute 44:277–90.
Buckland ST, Burnham KP, Augustin NH. 1997. Model selection: an integral part of inference. Biometrics 53:603–18.
Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. London: Oxford University Press. 448 pages.
Burnham KP, Anderson DR. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edn. New York: Springer. 496 pages.
Chintiroglou C, den Hartog JC. 1995. Additional records of Actiniaria (Anthozoa) from Greece. Zoologische Mededelingen Leiden 69:353–64.
Chintiroglou C, Doumenc D, Zamponi M. 1997. Commented list of the Mediterranean Actiniaria and Corallimorpharia (Anthozoa). Acta Adriatica 38:65–70.
Chintiroglou CC, Antoniadou C, Damianidis P. 2000. Spatial dispersion and density of the *Paranemonia vouliagmeniensis* population in Vouliagmeni Lagoon. Journal of the Marine Biological Association of the UK 80:941–42.
den Hartog JC. 1995. The genus *Telmatactis* Gravier, 1916 (Actiniaria: Acontiaria: Isophelliidae) in Greece and the eastern Mediterranean. Zoologische Mededelingen Leiden 69:153–76.
Doumenc D, Chintiroglou C, Koukouras A. 1985. Actinies de la mer Égée: méthodes d'identification, zoogéographie. Bulletin du Muséum National d'Histoire Naturelle, Section A, Zoologie, Biologie et Écologie Animales 7:497–529.
Excoffon AC, Genzano GN, Zamponi MO. 1999. Macrobenthos associated with a population of *Anthothoe chilensis* (Lesson, 1830) (Cnidaria, Actiniaria) in Mar del Plata harbor, Argentina. Ciencias Marinas 25:177–91.
Gomes PB, Zamponi MO, Solé-Cava AM. 2003. Asexual reproduction and molecular systematics of the sea anemone *Anthopleura krebsi* (Actiniaria: Actiniidae). Revista de Biologia Tropical 51:147–54.
Humann P, DeLoach N. 2002. Reef creature identification: Florida, Caribbean, Bahamas. Jacksonville (USA): New World Publications. 448 pages.
Hurvich CM, Tsai CL. 1989. Regression and time series model selection in small samples. Biometrika 76:297–307.
Katsanevakis S. 2005. Abundance and spatial distribution of the Mediterranean scallop, *Pecten jacobaeus*, in a marine lake. Fisheries Research 76:417–29.
Katsanevakis S. 2006. Population ecology of the endangered fan mussel *Pinna nobilis* in a marine lake. Endangered Species Research 1:51–59.
Katsanevakis S. 2007. Density surface modelling with line transect sampling as a tool for abundance estimation of marine benthic species: the *Pinna nobilis* example in a marine lake. Marine Biology, 152:77–85.
Katsanevakis S, Verriopoulos G. 2004. Abundance of *Octopus vulgaris* on soft sediment. Scientia Marina 68:553–60.
Kelmo F, Attrill MJ, Jones MB. 2003. Effects of the 1997-1998 El Niño on the cnidarian community of a high turbidity coral reef system (northern Bahia, Brazil). Coral Reefs 22:541–50.
Krebs CJ. 1998. Ecological Methodology, 2nd edition. New York: Addison Wesley Longman. 624 pages
Kruzic P, Zibrowius H, Pozar-Domac A. 2002. Actiniaria and Scleractinia (Cnidaria, Anthozoa) from the Adriatic Sea (Croatia): first records, confirmed occurrences

and significant range extensions of certain species. Italian Journal of Zoology 69:345–53.

Loukmidou S, Chintiroglou CC, Doumenc D. 1996. Inventaire du Cnidome des Actiniaires et Corallimorphaires de Méditerranée (Cnidaria, Anthozoa). Bios (Macedonia, Greece) 4:63–114.

Ocaña A, Sánchez Tocino L, López-González PJ. 2000. Consideraciones faunísticas y biogeográficas de los anthozoos (Cnidaria: Anthozoa) de la costa de Granada (Mar de Alborán). Zoologica Baetica 11:51–65.

Pink M, Pratt TC, Fox MG. 2007. Use of underwater visual distance sampling for estimating habitat-specific population density. North American Journal of Fisheries Management 27:246–255.

Rossi L. 1983. Anthozoa. In: Riedl, R. editor. Fauna und Flora des Mittelmeeres. Hamburg: Parey, p 183-203.

Russo CAM, Solé-Cava AM, Thorpe JP. 1994. Population structure and genetic variation in two tropical sea anemones (Cnidaria, Actinidae) with different reproductive strategies. Marine Biology 119:267–76.

Schmidt H. 1970. *Anthopleura stellula* (Actiniaria: Actiniidae) and its reproduction by transverse fission. Marine Biology 5:245–55.

Shick JM, Lamb AN. 1977. Asexual reproduction and genetic population structure in the colonizing sea anemone *Haliplanella luciae.* Biology Bulletin 153:604–17.

Thomas L, Laake JL, Strindberg S, Marques FFC, Buckland ST, Borchers DL, Anderson DR, Burnham KP, Hedley SL, Pollard JH, Bishop JRB. 2003. Distance 4.1. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Vafidis D, Koukouras A, Voultsiadou-Koukoura E. 1997. Actiniaria, Corallimorpharia, and Scleractinia (Hexacorallia, Anthozoa) of the Aegean Sea, with a checklist of the Eastern Mediterranean and Black Sea species. Israel Journal of Zoology 43:55–70.

Wirtz P, Ocaña O, Molodtsova T. 2003. Actiniaria and Ceriantharia of the Azores (Cnidaria Anthozoa). Helgoland Marine Research 57:114– 17.

Zamponi MO, Belem MJC, Schlenz E, Acuna H. 1998. Distribution and some ecological aspects of Corallimorpharia and Actiniaria from shallow water of the south Americal Atlantic coasts. Physis (Buenos Aires) Sección A 55:31–45.

Table 1: Summary of the parameterization of the detection models and of the AIC_c, Akaike differences ΔAIC_c, Akaike weights w_i, effective strip half-width μ, and mean density d (point estimation and standard error) of *Alicia mirabilis* in Lychnari bay. The model-averaged estimation of μ and d and the corresponding unconditional standard errors are also given. Models are sorted from best to worst according to AIC_c.

Model No	Model (key+series expansion)	No of parameters: Key	No of parameters: Series expansion	Parameter values	AIC_c	ΔAIC_c	w_i	μ (m)	SE(μ) (m)	d (ind are^{-2})	SE(d) (ind are^{-2})
g_1	uniform+cosine	0	1	0.3587	109.11	0.00	31.6%	1.69	0.20	1.10	0.48
g_2	half-normal+Hermite polynomial	1	0	1.692	109.25	0.13	29.6%	1.75	0.20	1.06	0.46
g_3	half-normal+cosine	1	0	1.692	109.25	0.13					
g_4	uniform + simple polynomial	0	1	-0.6280	109.45	0.34	26.7%	1.82	0.17	1.02	0.44
g_5	hazard-rate+cosine	2	0	1.204 1.000	111.04	1.92	12.1%	1.58	0.36	1.18	0.56
g_6	hazard-rate+simple polynomial	2	0	1.204 1.000	111.04	1.92					
							Model-Averaged	1.73	0.22	1.08	0.48

SE, standard error; 1 are = 100 m^2

Figures

Fig.1: Sites of occurrence of *A. mirabilis* in Saronikos Gulf during the present study. Population density assessment was conducted in Lychnari.

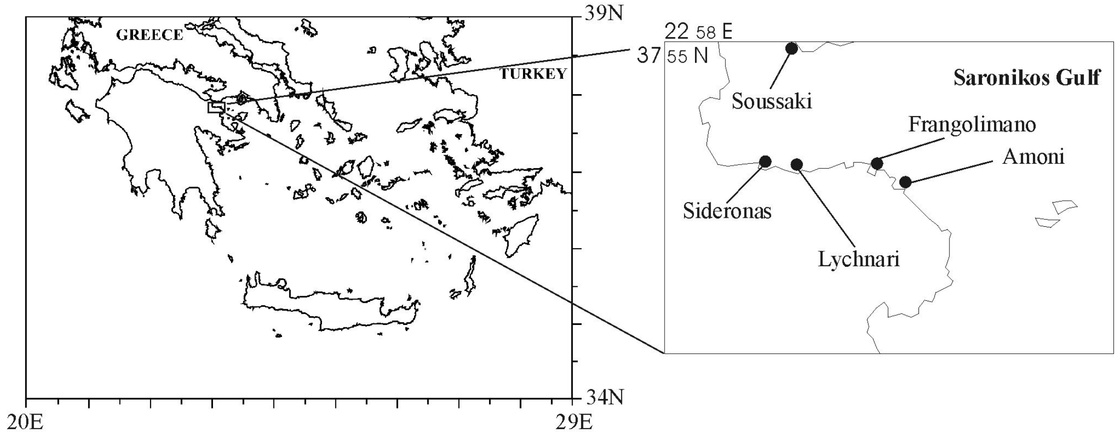

Fig.2: *A. mirabilis* mean density (with the corresponding 95% confidence intervals) in nine line transects (3 locations x 3 depths) in Lychnari bay, using model-averaged estimates for the detection function. The figures above each bar indicate the number of detected individuals in the specific line transect. 1 are = 100 m^2.