CATRINA (2012), 7 (1): 33 - 40

Territoriality of *Acanthurus sohal* on reefs in Ras Mohamed National Park, Red Sea

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ABSTRACT

Remarkable variation was observed for substrate composition distribution between both inside and outside territories of the surgeon fish *Acanthurus sohal* on reefs of Ras Mohamed National Park, South Sinai, and Egypt. Eight genera of hard corals were recorded; *Acropora, Favites, Pocillipora* and *Stylophora* were the dominant and the widespread genera inside the *A. sohal* territory. On other hand, the *Acropora, Pocillipora, Stylophora* and *Porites* were the dominant and the widespread genera outside the *A. sohal* territory. Five soft coral genera; *Sinularia, Sarcophyton, Xenia, Dendrophyllia* and *Nephthyia* were recorded inside and outside the territories of *A. sohal*. The difference was very clear in algal composition between inside and outside territory. Filamentous algae were dominant inside the territory, while it was not dominant outside the territory. Three groups of associated fauna (Mollusca, echinoderms and sponges) were recorded in the study area outside the territory, while two groups (Mollusca and sponges) were recorded inside the territories. Dead component of substrate (old reef, sand, rubbles and others) showed dominance outside the territory more than inside. The percentage covers of algae, especially filamentous algae, had the highest values inside territory. The total territory areas of *A. sohal* varied between 12.8 m^2 and 17.0 m^2, by an average 15.2 m^2 in the whole study area. There was a significant positive correlated relationship between surgeon fish *A. sohal* territory size and the complexity of substrate inside the territory

Key words: Acanthuridae,Territory behaviour, herbivores, reef fishes, South Sinai, Red Sea, Egypt.

INTRODUCTION

Territorial fishes actively patrol their territories, not necessarily in a regular pattern or in a periodic fashion, but often enough so that all parts are visited within a relatively short period of time. Such behaviour can reduce the density of intruders within a territory. Long-term defence of feeding territories is common among coral reef fishes, especially those eat benthic algae. The level of territoriality varies greatly among the family and species, ranging from weak home-ranging to strong territorial behaviour. Observational (Myrberg and Thresher, 1974; Alwany *et al.*, 2005), experimental (Sale, 1976; Robertson *et al*., 1976), and comparative (Barlow, 1974; Reese, 1975) studies have indicated the possibilities for complex and ecologically important territorial behaviour in fishes.

Many studies of tropical herbivorous fish with territorial behaviour have been conducted in order to understand these relationships. Most of these studies were conducted with marine species or with species that use these environments at some stages of their life cycle (Letourneur, 2000; Ceccarelli *et al*., 2001; Meadows, 2001; Mumby & Wabnitz, 2002; Alwany *et al.,* 2005; Jones, 2005; Stradmeyer *et al.,* 2008). Territoriality among coral reef fishes in Acanthuridae is known (Robertson and Polunin, 1981; Choat and Bellwood, 1985; Craig, 1996; Alwany *et al.,* 2005), similarly other groups such as Pomacentridae (Doherty, 1983; Wilson and Bellwood, 1997; Ceccarelli *et al.,* 2011, 2005, 2011) and Parodontidae (Silva *et al.*, 2009). A number of different factors can lead animals to establish territories, such as the defence of feeding, breeding or refuge sites (Karino, 1998). The behavioural patterns in the defence of these territories may exert a strong effect on the stability and regulation of the population density (Davies and Houston, 1984; Adams, 2001).

The Acanthuridae (surgeonfishes) comprise a common circumtropical family of advanced teleosts which exhibit considerable interspecific variation in general ecology and social behaviour. In many reef ecosystems, surgeonfishes are the dominant vertebrate herbivores (Montgomery *et al.*, 1980; Hixon, 1986; Lewis, 1986) and, therefore, a key component to understanding energy and nutrient flow. The family Acanthuridae includes six genera and 80 species of marine fishes commonly known as surgeonfishes. This group is distributed in tropical and subtropical seas around the world, being absent only from the Mediterranean. The genus *Acanthurus* is a common surgeonfish that occurs in the Red Sea, which represented by three species: *A. sohal, A. nigrofuscus* and *A. gahhm* (Randall, 2002). Their defense of algal-covered territories, particularly against roving herbivores, has been well documented in certain seas (Vine, 1974; Alwany *et al*., 2005). This study examines the territoriality and habitat used by territorial herbivores on the outer reef flat on Ras Mohammed National Park fringing reefs, Southern Sinai, Egypt. Emphasis was placed on how these species organize their territorial defense and habitat used.

MATERIALS AND METHODS

Study area

Ras Mohammed area lies off the southern tip of the Sinai Peninsula. It was declared a national park in 1983 and it is among the most famous diving sites in the Red Sea. It is flanked to the east by the Gulf of Aqaba and to the west by the Gulf of Suez. The area of Ras Mohammed measures about 171 km^2. The reef contains more than 150 different species of corals and over one thousand species of fishes. The shallow water here makes it possible to observe an individual fish over long periods by snorkelling. Three sites that represent the

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Figure (1): Map of northern Red Sea shows Ras Mohammed National Park and the three selected sites.

different reef flat habitats of Ras Mohammed reefs (Fig. 1) were chosen to observe the territorial behaviour of the surgeonfish.

Acanthurus sohal

A. sohal also established territories along the fore reef crest (outer reef flat), extending shoreward towards the reef crest and flats. As nearly as could be determined, the territories of all these individuals included a stretch of reef crest, practically necessary because the crest and even the surface of the reef edge became exposed mostly at low tides. The resident surgeonfish moves over the crest into deeper water at low tide, returning as soon as possible when the tide rises. The reef crest margins of the territories of *A. sohal* dwelling the reef flats seemed to be clearly recognized by the fish, but the shoreward boundaries on the flats sometimes were less clearly determined.

Study territoriality

Both observational and experimental methods to study territoriality were adopted. The simplest method was to sketch territories in pencil on a roughened Perspex board. Each study site was conducted in daytime, with the locations of individual fish on the reef flat being recorded. The transect was 4 m long for both inside and outside the studied territory. The observation time necessary to define a territory varied with fish activity and territory size (Ebersole, 1980; Roberts, 1985, 1986). In present study, the determination of *A. sohal* territories took 20-30 minutes. Observations were made by hovering 2-3 m away from fish location to minimize disturbance.

Complexity and rugosity

Rugosity is a simple measurement of the surface roughness that has been used routinely by coral reef biologists. It is calculated by holding a rope of known length taut above the substrate. A chain that is attached at one end to the rope is draped across the substrate contours. The complexity is the ratio of the chain length (A) to the rope length (B) and calculated as complexity = A/B.

Substrate composition

Transect width was estimated visually and time used to estimate the length of the transect, so as to avoid the disturbance to the fishes that occurs when a line is laid. On average an observer swimming at moderate steady move take about 10 minutes to cover 4 m, the data from visual census was used to calculate species abundance as in Bouchon-Narvaro (1986). Substrate cover at each site was determined according to the method of Loya (1978) and Porter and Meier (1992) by using 4 m line intercept transect placed randomly with respect to substrate. At each site three replicate transect were placed within the area. Substrate beneath the line was classified into hard coral, soft coral, algae, associated fauna, dead components and others. Species mean number and standard deviation was calculated for each site for reef edge.

Data analysis:

The data were analysed statistically using the software packages PRIMER (V 5.0) and SPSS (V 12). Species richness was expressed by considering the number of species (D), and species diversity and homogeneity were determined using the Shannon-Wiener diversity index (H') and the evenness index (J') (Pielou, 1966). One-way ANOVA was carried out with SPSS program. When necessary, abundance data were square root transformed to produce normality and homogeneity of variance.

RESULTS

Diversity of substrate composition inside and outside the territories

Remarkable variation was observed for substrate composition distribution between both inside and outside territories of *Acanthurus sohal* (Table 1).

Several hard coral genera were recorded from the study sites in both inside and outside territory of *A. sohal*. genera were recorded; *Acropora*, *Favites*,

Table (1): different substrate compositing percentage inside and outside *Acanthurus sohal* territory.

S. Composition	Inside territory	Outside territory	*P*
Hard corals			
Acropora	7.0±1.9	13.1±3.4	0.056
Favites	3.0±2.1	3.1±1.2	0.950
Pocillipora	5.1±3.7	5.3±4.3	0.957
Stylophora	4.3±1.9	8.0±1.2	0.044
Montipora	0.6±0.1	1.7±0.5	0.021
Fungia	1.9±1.8	1.5±1.1	0.767
Millepora	1.6±2.0	2.7±0.5	0.439
Porites	1.2±0.9	4.0±1.2	0.030
Soft corals			
Sinularia	0.1±0.2	2.6±1.6	0.062
Xenia	0.03±0.1	0.5±0.7	0.279
Dendrophyllia	0.1±0.2	0.2±0.2	0.581
Nephthyia	0.1±0.2	0.9±0.5	0.089
Sarcophyton	0	1.9±1.2	0.055
Algae			
Filamentous algae	65.5±2.0	5.2±1.2	0.000
Calcarious algae	0.05±0.1	4.2±1.5	0.010
Fleshy algae	4.3±0.7	5.2±2.2	0.553
Crustose algae	1.2±1.5	0.7±1.2	0.652
Associated fauna			
Molluscs	1.1±0.6	12.9±1.9	0.001
Echinodermes	0	10.8±0.8	0.000
Sponges	0.3±0.1	0.1±0.1	0.067
Dead components			
Old reef	0.8±0.1	3.5±1.0	0.010
Sand	0.4±0.2	1.3±0.6	0.066
Rubble	0.1±0.1	2.9±0.6	0.001
Others	1.1±0.1	7.8±1.2	0.001

Millepora and *Porites*. *Acropora, Favites, Pocillipora* and *Stylophora* were the dominant and widespread genera inside the *A. sohal* territory. On other hand, *Acropora, Pocillipora, Stylophora* and *Porites* were the dominant and widespread genera outside the *A. sohal* territory. One-way ANOVA results indicated that no significant differences of hard corals percentage cover between inside and outside territory. Four soft coral genera were recorded from the study sites inside and outside territory of *A. sohal*. These are *Sinularia, Xenia, Dendrophyllia* and *Nephthyia.* While the genus *Sarcophyton* was recorded only at outside territory of *A. sohal*. One-way ANOVA results indicated that no significant differences of soft corals percentage cover between inside and outside territory of *A. sohal*.

The algae are the main food item of *Acanthurus sohal*. So, the difference was very clear in algal composition between inside and outside territory. Four categories of algae (filamentous, calcarious, fleshy and crustose algae) were recorded inside and outside the territory of *A. sohal*. Filamentous algae were dominated inside territory, while it not dominated outside the territory (Table 1). One-way ANOVA results indicated that the covers of filamentous algae have high significant difference between inside and outside territory, where the other types of algae do not show any significant differences.

Three groups of associated fauna; Mollusca, echinoderms and sponges were recorded in the study area outside the territory, while two groups; Mollusca and sponges were recorded inside the territory of *Acanthurus sohal*. One-way ANOVA results indicated that the Mollusca and echinoderms show significant difference between inside and outside territory, while sponges have no significant difference. Dead component of substrate (old reef, sand, rubbles and others) showed dominance outside the territory more than inside the territory of *A. sohal*. One-way ANOVA results showed that the old reef and rubbles significant difference between inside and outside territory, where the sand has no significant difference.

Percentage covers of substrate composition

Inside territories:

The percentage covers of different substrate composition varied inside territory of *Acanthurus sohal*. The percentage covers of algae, especially filamentous algae, had the highest values inside territory (all algae types were 71.0 % as in Figure 2 and filamentous algae is 65.5 % as in Table 1). In general, the hard coral was represented by 25.0 %; *Acropora* and *Pocillipora* dominated; represented by 7.0 % and 5.1 %, respecttively. The dead components were represented by 2.0 %. The other taxa did not exceed 1 % of the total substrate composition inside territories (Fig. 2).

Outside territories:

Figure 2 shows the percentage covers of different substrate composition outside territory of *Acanthurus sohal*, which was quite completely different from the pattern inside the territory.

The hard coral and associated fauna dominated and was represented by 63.0 % of the total substrate composition (represented by 39.0 % and 24.0 %, respectively). The dead components, algae and soft corals were represented by 16.0 %, 15.0 % and 6.0 %, respectively.

Relationship between territory size and complexity

The total territory areas of surgeon fish *Acanthurus sohal* varied between 12.8 m^2 in site 1 and 17.0 m^2 in site 2 (Table 2), by average value about 15.2 m^2 in the whole study area at Ras Mohamed National Park Reefs. The average complexity of the study area was 1.36 inside surgeon fish *A. sohal* territories. Linear regression equations were calculated to investigate the relationships between territory size of *A. sohal* and complexity of the substrate inside the territory on Ras Mohamed National Park Reefs. There are significant positive correlated relationship of surgeon fish territory with complexity of substrate inside the territory ($y = 8.0123x + 2.7496$; $R^2 = 6337$) of surgeon fish *A. sohal* (Fig. 3).

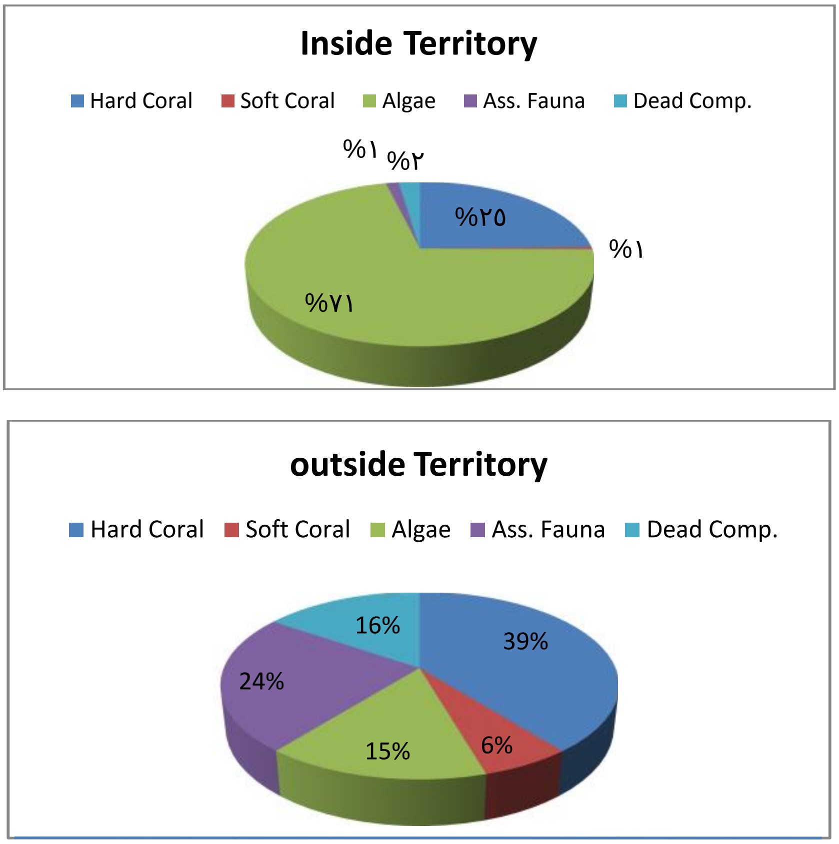

Figure (2): The percentage cover of substrate components inside and outside *Acanthurus sohal* territories.

Table (2): Different territory parameters investigated in three studied sites

Territory Parameter	Study area		
	Site 1	Site 2	Site 3
A	2.7±0.4	3.6±1	3.9±0.4
P	3.8±0.5	3.1±0.6	2.5±0.7
R	6.2±3.8	9.4±7.9	7.1±6.3
L	4.6±3.2	6.5±5.6	5.1±4.3
Total Territory area	12.8±0.8	17.0±3.4	15.9±2.2
Complexity	1.4±0.2	1.4±0.3	1.3±0.3

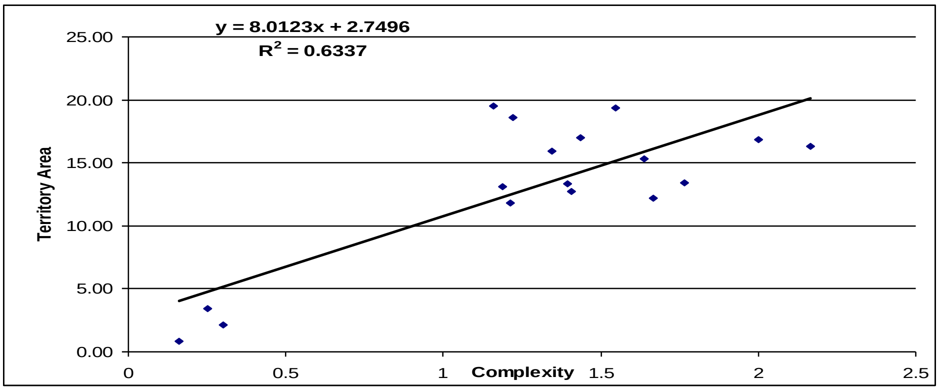

Figure (3): The linear regression relationship between territory area and complexity for *Acanthurus sohal.*

DISCUSSION

Fish territoriality is a key element of coral reef ecology. Most data on this topic are available from Indo-Pacific and Caribbean reefs with a focus on damselfishes. The recognition that the Red Sea represents a separate fish ecological region and the increasing importance of these reefs for the tourist industry underlines the need for examining territoriality there. The famous Ras Mohammed National Park provides an ideal location to conduct this research due to its highly developed reefs and rich fish fauna. Our results emphasize the important role that herbivorous fishes plays on reef algal communities. They point to reduced grazing as a primary factor creating change in the algal community composition. It is evident that *Acanthurus sohal* manipulates the algal community within its territories, creating a balance among various species and between the algal and coral communities.

Despite the high density of farmers on the reef crest and the high proportion of space they occupy (~ 88%), foragers had a greater overall impact on the benthic algal assemblages than farmers (Ceccarelli *et al*., 2005). Our results emphasize the important role *Acanthurus sohal* as a farmer (territory holder) on the reef crest in the Red Sea. The high percentage covers of algae inside the *A. sohal* territory may be due to the effects of farmers that could be attributed to reduce grazing pressure of foragers from their territories on the reef crest. This in agrees with previous studies where differences inside and outside territories have been attributed to the ability of farmers to reduce grazing pressure by foragers (Sammarco and Williams, 1982; Hixon and Brostoff, 1983; Gleason 1996; Hixon and Brostoff, 1996).

Our study adds to the increasing realization that different kinds of herbivores fishes have different functional influence on coral reefs (Steneck, 1988, Bellwood and Choat, 1990; McClanahan *et al.,* 1994). The results support the prevailing views that foragers have a major impact on coral reefs, and in contrast, farmers cultivate selected algae. However, the farmers we investigated do not appear to have a strong influence of habitat structure by reducing disturbance by foragers. Feeding by large herbivorous fishes is usually responsible for reducing algal biomass (Steneck, 1988; Bellwood and Choat, 1990; McCook, 1996; Pennings, 1996; McCook and Price, 1997; Williams *et al.,* 2001; Paddack *et al*., 2006) and, in some cases, enhancing coral cover (Burkepile and Hay, 2008). The role of grazing pressure by herbivores usually results in the facilitation or acceleration of succession to proceed towards a relatively mature community - one dominated by fleshy macro algae, calcified and encrusting algae (Sousa and Connell, 1992; Zanini *et al*., 2006) or in the diversion of succession to an alternative community not otherwise found in un-grazed systems (Hixon and Brostoff, 1996; Littler *et al*., 2006). Our results prove that the surgeon fish *Acanthurus sohal* allow for some corals and algae to grow inside territory more than the other outside.

Alwany *et al*., (2005) reported that *Acanthurus sohal* spends considerable time (51.3%) swimming and patrolling the borders of its territory and feeding comprises 33.7%. One explanation for this distribution of activity is that the territory holder, as an algae feeder, must defend its territory against other algae-feeding intruders. This has also been postulated for *A. sohal* by Vine (1974) in relation to parrotfishes. This interpretation is supported by the fact that the surgeonfish spends only about 6% of its time sheltering. Moreover, much of this time of sheltering is conducted outside rather than within the fish's own territory. This short sheltering time further indicates that the primary function of the territory is to defend food resources (Warner and Hoffman, 1980; Tricas, 1989a). On the other hand, Vine (1974) also reported that *A. sohal* swims over large areas of the reef, often in loosely formed schools. The author concludes that this behaviour allows the surgeonfishes to enter and feed in the territories of other species in Red Sea reefs. Schooling behaviour of intruders may make territory defense more difficult (Robertson *et al*., 1976). It was also observed the latter behaviour, but additional studies will have to be conducted in order to the better understand of how this behaviour fits into the strict territoriality described above. Our current interpretation is that low tide conditions force these individuals to temporarily leave their territories and assume a more atypical, nomadic behaviour.

Specifically, this surgeonfish, as an algal feeder, defends its territory against other fishes that feed on algae. More than 65% of those species that elicited agonism and mostly other Acanthuridae as well as members of the families Scaridae and Pomacentridae – feed preferentially on benthic algae. These results confirm Ebersole's (1977) observations that surgeonfishes and parrotfishes most consistently elicit agonism (in the pomacentrid *Stegastes leucostictus*).

Costs of defending optimal sites are common in territorial animals. So, the present study used simple linear regression to analyze the relationship between territory size and substrate complexity inside territory. This is the first case of size-dependent residency on distinct substrate complexity by territorial adult surgeon fish *A. sohal*.

ACKNOWLEDGEMENTS

The authors thank Dr. Saad Zakaria Head of Department of Marine Science for his suggestions and encouragement in planning this study. This work has been done with the assistance of the Department of Marine Science, Suez Canal University, Ismailia, Egypt.

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التمنطق لسمكة *أكانثورس سوحل* على الشعاب المرجانية فى محمية رأس محمد الوطنية، البحر الأحمر

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الملخـــص العربـــي

لوحظ إختلاف إستثنائى لتوزيع المحتويات القاعية بين داخل وخارج مناطق النفوذ لسمكة *أكانثورس سوحل* على الشعاب المرجانية فى محمية رأس محمد الوطنية، بجنوب سيناء، مصر. سجلت ثمان أجناس للشعاب المرجانية الصلبة، حيث كان كل من: *اكروبورا ، فافايتس، باسيليبورا، و الاستيلوبورا* الاكثر شيوعاً وإنتشاراً داخل منطقة النفوذ لسمكة *أكانثورس سوحل*. من ناحية أخرى كانت *الأكروبورا، باسيليبورا، إستيلوبورا والبورايتس* سائدة ومنتشرة فى خارج منطقة نفوذ لسمكة *أكانثورس سوحل*. كذلك سجلت خمس أجناس من الشعاب المرجانيه اللينة (*سينيولاريا، ساركوفايتون، زينيا، ديندروفيليا، ونيفذيا*) فى منطقة الدراسة خارج وداخل مناطق النفوذ لسمكة *أكانثورس سوحل*. الإختلاف كان واضحاً جداً فى توزيع الطحالب داخل وخارج مناطق النفوذ. الطحالب الخيطية كانت سائدة ومنتشرة داخل منطقة النفوذ، فى حين أنها لم تكن سائدة فى خارج منطقة النفوذ. أيضاً سجلت ثلاث مجموعات من الأحياء المرتبطة بمنظومة الشعاب المرجانية (الرخويات، شوكيات الجلد والإسفنج) من مناطق الدراسة فى خارج مناطق النفوذ، فى حين سجلت مجموعتان (الرخويات والإسفنج) فقط فى داخل مناطق النفوذ. كذلك لوحظ بعض المحتويات الميتة القاعية (شعاب قديمة، رمال، صخور، وأخرى) تكون سائدة فى خارج منطقة النفوذ أكبر عنه فى داخل منطقة النفوذ. النسبة المئوية للغطاء الطحلبى، وخاصة الطحالب الخيطية كانت لها أعلى قيمة داخل منطقه النفوذ لسمكة *أكانثورس سوحل*. الدراسة سجلت مساحة لمناطق النفوذ الكلية تتراوح ما بين ١٢.٨ م٢ و ١٧.٠٠ م٢، بمتوسط حوالى ١٥.٢ م٢ لجميع مناطق الدراسة. وأخيراً، وجد علاقة إيجابية قوية ما بين حجم منطقة النفوذ وتعرج أرضية منطقة النفوذ لسمكة *أكانثورس سوحل* داخل مناطق النفوذ المدروسة.

Received July14, 2012
Accepted September 18, 2012