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THE ENCRUSTATION OF THE SPIDER CRAB *HYASTENUS HILGENDORFI* IN RELATION TO ITS REPRODUCTIVE BIOLOGY IN THE SUEZ CANAL, EGYPT

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ABSTRACT

The encrustation of the spider crab *Hyastenus hilgendorfi* inhabiting the Suez Canal in relation to its reproductive biology was studied. This species is considered a by-catch in the area of the Suez Canal. It has a negative impact on fishing gear and causes severe damage. Specimens were collected from July 2009 to June 2010. Crabs were sexed and the degree of encrustation was visually assessed. 1054 specimens were collected, of which 569 (54.0%) were males, 363 (34.4%) non-ovigerous and 122 (11.6%) ovigerous females. 23.7% (250) had no encrustation while 76.3% (804) were covered. 49.5% (398) of encrusted individuals were males; 41.0% (330) were non-ovigerous females and 9.5% (76) were ovigerous females. The degree of encrustation varied with carapace width in ovigerous females. Females outnumbered males by 2.9:1 between December and April. Berried females and those with ripe ovaries existed in all seasons except winter. A single reproductive period from June to November was apparent followed by a resting phase between January and March. The size at which 50% of females were mature was 22.4 mm CW. Fecundity was found to be related to carapace width. It is concluded that this crab may engage in podding behavior. The successful establishment of this species in the Suez Canal may be related to its fecundity, short larval life span and effective camouflage against predatory fishes. Suggestions for the reduction of the impact of the bycatch of this species on the traditional fishery of the Canal are discussed.

Keywords: Encrustation, reproductive biology, *Hyastenus hilgendorfi*, Suez Canal.

INTRODUCTION

Spider crabs are distinguished for their habit of masking themselves by placing pieces of foreign substances on their backs and appendages (Wicksten, 1993). Algae, sponges, hydroids, tunicates and other adventitious materials are held in place by the hooked setae that characterize many majid species (Wicksten, 1993; Hartnoll, 1993). Other sessile epibionts, such as cirripeds, bivalves and polychaetes, use majoid carapaces as a substrate for settlement. Finally, mobile organisms, such as amphipods, may live among the attached organisms. The slow movements, absence of burying behavior, and terminal anecdysis contribute to the establishment of a complex and abundant epibiota on many spider crabs (Hartnoll, 1993).

Studies on the reproductive biology of crustaceans provide essential information for understanding their reproductive pattern and strategies. Variations in the sequence of reproductive events are reflected in the diversity of life history pattern necessary for the success of reproduction and growth. Therefore, investigations of these aspects are important factors in determining the reproductive potential of a species (Hartnoll, 1985). Information on the reproductive biology of a species such as sex ratio, size at maturity and seasonality of spawning is particularly important if this species has a fishery potential, however, it is equally important for non commercial species when studying the impact those might have on the fishery production of a region (Falk-Petersen, *et al.* 2010).

The spider crab *Hyastenus hilgendorfi* (Kossmann, 1880) (Brachyura, Epialtidae) exists in the Suez Canal in huge quantities and is highly distributed around the year in its waters. It is a Red Sea species that migrated into the Suez Canal and established itself in this new environment (Por, 1978), building up large populations (Sallam *et al*., 2007). Despite flourishing successfully, this crab has no economic significance: it is inedible and has no commercial value or fishery potential. On the other hand, it has a negative impact on fishing gear as enormous numbers of crabs are entangled in nets and cause severe damage (Sallam *et al*., 2007; Sallam and Wicksten, 2011). Those authors stated that massive occurrence and vast distribution represent a constraint and a threat to successful fishing**.** Masking behavior of *Hyastenus hilgendorfi* inhabiting the Suez Canal has been studied, however, nothing is known about the relation of this behavior to the reproductive biology of the species. This work aims to deal with some characteristics of *H. hilgendorfi* related with its reproductive biology. The relationship between the reproductive aspects of this species and its encrustation will be examined and discussed. Solution to the reduction of the impact that the bycatch of this species has on the artisanal fishery of the Canal will be suggested.

Materials and Methods

Specimens of *Hyastenus hilgendorfi* were monthly collected from July 2009 to June 2010 from Elferdan at km 68 to the south of the Suez Canal. The site was visited in the early morning and crabs were obtained from fishermen's trammel nets with an approximate mesh size of 33.5 mm. They were fixed in 10% formalin in seawater. Fixed samples were sexed and the numbers of individuals in each sex recorded. Carapace width (CW) was measured by means of Vernier calipers and molting stage was determined. The degree of epibiota coverage on the integument was assessed visually. Each individual was placed in one of 5 step scales: 0%, 5-25%, 25-50%, 50-75%, 75-100%. Diving is prohibited in the Suez Canal, so, it was not possible to view these crabs *in situ.*

Identification of epibionts was carried out down to species level as much as possible. Females were dissected and the stage of ovarian maturation was noted according to the color of the ovaries (Chu, 1999). For the estimation of fecundity, egg masses were detached from the pleopodal setae, and the eggs were counted manually with a counter under low power (X10) of a stereomicroscope. Egg developmental stage was determined according to the categories listed in Subramoniam (1982).

RESULTS

Sex ratio:

A total of collected 1054 specimens were collected, of which 569 (54.0%) were males, 363 (34.4%) non-ovigerous and 122 (11.6%) ovigerous females. Females outnumbered males between December and April by 2.9:1 (Figure.1) but males predominated throughout the rest of the year. This variation in sex ratio was significantly different (X2= 6.69, P< 0.05).

Encrustation with epibionts:

All individuals were hard shelled. Of the total sample, 23.7% (250) had no material covering their integuments and 76.3% (804) were covered with epibionts (Table 1). 49.5% (398) of encrusted individuals were males; 41.0% (330) were non-ovigerous females and 9.5% (76) were ovigerous females. The recorded macro-epibionts included the green alga *Ulva rigida* Linnaeus 1753, the sponge *Geodia micropunctata* (Issel, 1869), the tubeworm *Hydroides elegans* (Haswell, 1883), the barnacles *Amphibalanus amphitrite* (Darwin, 1854) and *Balanus eburneus* (Gould, 1841), the bivalve *Brachidontes variabilis* (Krauss, 1848) and the tunicate *Styela plicata* (Lesueur, 1823). The degree of encrustation varied according to seasons between the different categories of individuals (Figure. 2). Ovigerous females disappeared completely during winter while males and non-ovigerous females were presented in different percentages and degrees of encrustation all year round. Non-encrusted males and non-ovigerous females (with 0% cover) were highly abundant in spring, as well as fully encrusted ovigerous females (with 100% cover). Males and non-ovigerous females with full coverage were most common in winter but ovigerous females with 0% cover were most common in summer. The degree of encrustation varied with carapace width in ovigerous females (Figure.3). Individuals with full coverage fell within both the smallest and the largest ranges (14-17mm, 26.1-29mm CW) respectively while those with bare integuments were most common (36.4%) in the smallest size. However, the number of eggs carried by females did not vary significantly with the degree of encrustation on their integuments (F= 1.291, *P*= 0.280) (Table 2).

Incidence of ovigerous females:

Berried females existed during all seasons except winter when they disappeared completely (Figure.4). They showed their maximum occurrence in summer (65.6%) and their minimum in autumn (30.6%). Non-ovigerous females had their maximum occurrence (100%) in winter while their minimal occurrence was observed in summer (34.4%).

Size at sexual maturity:

The 407 females examined ranged from 14.5 to 33.6 mm CW. Of these, 312 were in sexually mature condition. The size at onset of sexual maturity (> 5% mature) was within the 20 mm CW size. The estimated size for 50% sexually mature females was 22.4 mm CW (Figure 5). The smallest detected ovigerous female had a carapace width of 14.1 mm.

Seasonality of spawning:

Figure 6 shows the seasonal variations in the percentage of sexually mature females H. hilgendorfi. Over 90% of the population consisted of mature females during a single reproductive period lasting from June to November. This period of reproductive activity was followed by a well-defined resting phase between January and March. Females' gonad condition varied with seasons (Figure. 7). Those with immature ovaries occurred all year round. They occurred in their maximum percentage (100%) in winter and their minimum in summer (21.7%). Maturing and mature ovaries were observed during autumn and winter only while ovaries in the ripe condition existed in all seasons except winter with their maximum (27.3%) in autumn.

Egg development:

Apparent seasonal variations in the stages of egg development were observed (Figure.8). Eggs at the first stage of development had their minimum in autumn and maximum in spring (27.3%, 44.4%) respectively while those at the last stage (Stage IV) showed their minimum percentage in summer (22.6%) and their maximum in autumn (72.7%).

Fecundity and size of female:

The number of recently extruded eggs carried by ovigerous females ranging in size from 13.0- 27.2 mm CW ranged from 1,059- 7,625. Fecundity showed an increase with increasing carapace width (Figure 9). The relationship is expressed by the power function: Egg number= 1.243 CW 2.6114 (r= 0.678).

Discussion

Hyastenus hilgendorfi was first recorded in the Suez Canal water by Por (1978). This Red Sea species has shown remarkable adaptation to the Canal environment. It was successfully crossed the Canal and reached the Levantine Basin of the Mediterranean (Galil, 2006). This author, established defined species as those that have self-sustaining populations of some duration. The reason for the reproductive success of this species in the Suez Canal habitat is still unknown.

Male *H. hilgendorfi* predominated throughout the seasons except for the months December-April where females outnumbered them by 2.9:1. The same pattern was reported for *Schizophrys dahak* from the Suez Canal (Morsy, 2007). This period of females' predominance is coincided with their resting phase where over 90% of the population had immature ovaries.

This could be explained as a sexual behavior where females aggregate for mating in preparation for the next spawning season. Such aggregating behavior is called podding. Stevens *et al.* (1992) reported podding in the Pacific species *Hyas lyratus* Dana, 1851, which involved aggregations of 2000 specimens forming mating groups. Paz Sampedro and González-Gurriarán (2004) concluded that podding in *Maja squinado* in Galicia, Spain served as a form of protection during molting.

Mating can occur at any time for species with an extended or year-round breeding, although it may be restricted to a certain season for those species with a defined breeding season (Sastry 1983). Male *H. hilgendorfi* dominated during the months when females were brooding. This could be due to their increased breeding access since females tend to be less active during those months. Hiding during egg incubation has been reported for several brachyuran crabs (Henmi, 1989; Stone and O'Clair, 2002).

The present study showed clearly that *H. hilgendorfi* is a seasonal breeder and multiple spawner. The pattern of gonadal maturation is supported by the incidence of ovigerous females and egg development displayed the clear existence of an annual reproductive cycle in which females performed multiple ovipositions within the reproductive season. This trend is common in crustaceans inhabiting the Suez Canal (Sallam, 2000; Morsy, 2007) as well as other areas (Morgan *et al.,* 1983, Rotlant, *et al*., 2007). Emmerson (1994) stated that breeding periodicity can be controlled by a combination of factors including latitude, temperature, food availability (both adult and larval) and intertidal zonation. The tendency of crabs to release their larvae in a series of successive spawns during the breeding season has been explained as a method of ensuring the widespread of offspring (Cobb and Caddy, 1989). Breeding in tropical crustaceans extends for several months of the year, with pronounced activity during certain months (Pillay and Nair, 1973). An extended breeding season may mean that individuals of a species breed asynchronously, i.e., some are in the earlier stages of maturation while others are already spent (Giese, 1959).

Fecundity of *H. hilgendorfi* ranged between 1,059- 7,625 eggs. Similar results have been reported for the South American spider crab *Libidoclaea granaria* (Schejter and Spivak, 2005). The fecundity of spider crabs ranges from 180 (Hines, 1982) to 4,000,000 eggs per female (Haynes *et al*., 1976), and the carapace width (CW) of mature females ranges from 5 (Hines, 1982) to 400 mm (Haynes *et al*., 1976). The number of eggs carried by a female *H. hilgendorfi* agreed with the expected fecundity of a relatively small spider crab (20 to 40 mm CW).

The total number of sample increased by 21.8%, i.e. 1054 individuals compared to 865 reported in a previous study (Sallam & Wicksten, 2011). This progressive rise in the number of individuals reflects the remarkable ability of this Red Sea species to inhabit and adapt to the Canal environment, particularly by achieving successful reproduction.

The encrustation pattern of *H. hilgendorfi* in the Suez Canal did not vary in terms of covering material and seasonality of epibionts than that previously recorded by Sallam and Wicksten (2011). Mating took place during winter when males and non-ovigerous females were completely covered (Sallam and Wicksten 2011). Berke *et al.* (2006) concluded that the addition of material on the exoskeleton during decorating behavior does not influence fecundity in masking invertebrates but it reduces their mortality risk. The absence of relationship between fecundity of *H. hilgendorfi* and the degree of encrustation implies that camouflage is not the reason behind the increased numbers of this species in the Canal. Drickamer & Vessey (1982) stated that if a species occupies an area and reproduce there, this means that all its needs are met and the environment is suitable for the development and growth of the offspring, and hence the probabilities for its survival increase, which ensures species continuity. It seems, therefore, that the Canal environment has provided *H. hilgendorfi* with all the requirements needed for its survival, thus facilitating its establishment to a great extent.

In *H. hilgendorfi*, the function of the mask has been reported to serve in avoidance of diurnal predators (Sallam & Wicksten, 2011). Members of the families Tetradontidae and Balistidae were known as predators of crabs (Stokes, 1980; Bemert & Ormond, 1981). These coral dwelling fishes are represented in the Suez Canal waters by the pufferfish *Lagocephalus spadiceus* (Richardson, 1844) and the triggerfish *Ballistes carolinesis* Gemlin, 1789 (Elmor, 2002). Both species are Red Sea migrants and have been reported in the Canal as non-established with rare occurrences (Ben Abdallah *et al.,* 2005). Octopuses or sea turtles, known crab predators, were not found in the area. Although Berke *et al.* (2006) concluded that camouflaging behavior of majoid crabs reduces their mortality risk; it was not possible to establish whether the heavy encrustation on *H. hilgendorfi* provides an advantage in surviving to reproduction.

All crabs were in the intermolt condition. As many smaller crabs seemed to be covered as larger, older ones. It could be postulated that the oldest females and males might be the most heavily encrusted or decorated because of the terminal anecdysis. There is no evidence that heavily covered males are more or less successful in mating than smaller, less encrusted ones. Encrusting material particularly ascidians, barnacles, and tube worms have been found on concrete blocks, rocks, piers, buoys in the Canal as well as other crabs. They showed apparent seasonality with high rate of larval settlement during summer (Elkhawass, 2006; Morsy, 2007 ; Sharaf, 2009).

Spider crabs tend to have short larval life spans, ranging from nine to 15 days (Gonzalez- Gordillo & Rodríguez, 2001; Santana *et al*., 2004; Kornienko & Korn, 2006) as well as a short interval between the hatching of one batch of eggs and the laying of the next (Jones & Hartnoll, 1997). De Kergariou, (1971) stated that the rate of larval development of *Maia squinado* in Bretagne varied with seawater temperature, being faster at higher seawater temperatures. It could therefore be proposed that *H. hilgendorfi* larvae develop rapidly in the Suez Canal waters. Their short residency in the plankton helps increase their survival rate. The short larval life span, in addition to the scarcity of predators could be reasons for the apparent flourishing of this species in the Suez Canal.

The entanglement of these crabs has caused severe problems in the traditional fishery of the Canal. Large by-catches cause extra work for the fishermen, damage their gear and ruin the catch. A similar problem has been reported for the red king crab *Paralithoides camtschaticus* in northern Norway (Godøy *et al*., 2003). The authors suggested the use of the "norsel-mounted" nets that float above the seabed which enable crabs to pass beneath them without becoming entangled. They indicated that the gear configuration has been capable of reducing the bycatch to an acceptable level. Raising awareness of the fishermen working in the Suez Canal for not returning alive ovigerous *H. hilgendorfi* females to the water could eventually lead to the reduction of the bycatch. The study also proposes invitation of businessmen in the farmed fish industry to consider investing in these crabs. They could be exploited by using their meals as a protein additive to the fish feed. This would raise the palatability of the feed and increases the food conversion rate.

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Table 1. *Hyastenus hilgendorfi* (De Man), numbers and percentages of the different categories of covered individuals

Months	Number of individuals: Males	Non-ovigerous females	Ovigerous females	Total	Masked individuals: Males N	Males %	Non-ovigerous females N	Non-ovigerous females %	Ovigerous females N	Ovigerous females %	Total N	Total %
Jul. 09	69	4	9	82	38	55.1	0	0.0	1	11.1	39	47.6
Aug.	55	13	22	90	42	76.4	12	92.3	7	31.8	61	67.8
Sep.	70	6	17	93	52	74.3	4	66.6	10	23.5	66	71
Oct.	41	5	11	57	37	82.2	4	80.0	8	72.7	49	86.0
Nov.	97	66	11	174	96	98	64	96.9	11	100	171	98.3
Dec.	10	12	0	22	7	70.0	11	91.7	0		19	86.4
Jan. 10	16	46	0	62	11	68.8	40	87.0	0		51	82.2
Feb.	57	78	0	135	20	35.1	77	97.5	0		97	71.8
Mar.	39	84	0	123	37	94.9	82	97.6	0		119	96.7
Apr.	62	37	32	131	47	75.8	31	83.8	27	84.4	105	80.1
May	26	5	10	41	6	23.1	1	20.0	6	60.0	13	31.7
Jun.	27	7	10	44	5	18.5	3	42.8	6	60.0	14	31.8
Total	569	363	122	1054	398		330		76		804	

N = number of individuals.

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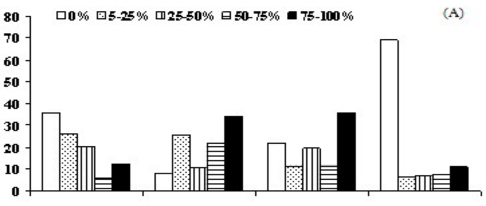

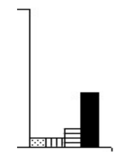

Table 2. Mean number of eggs in the different degrees of coverage for ovigerous females *Hyastenus hilgendorfi*.

Degree of coverage	Mean number of eggs	N
0-5%	3447.9	28
5-25%	4336.8	21
25-50%	3271.3	20
50-75%	3944.5	20
75-100%	3734.5	33

N= number of individuals in each category.

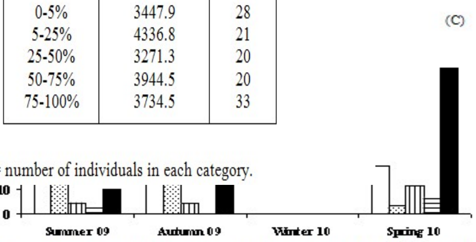

Fig. 2. Seasonal variations in the percentage cover of epibionts on the integuments of *H. hilgendorfi*. A, males; B, non-ovigerous females; C, ovigerous females.

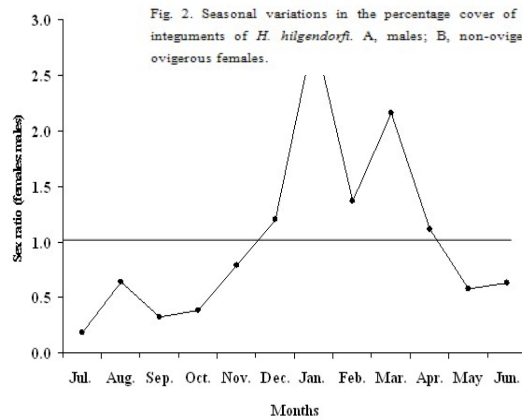

Fig.1. Monthly changes in the sex ratio (females: males) of *H. hilgendorfi*.

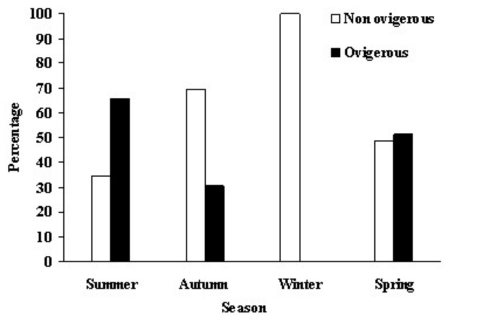

Fig. 4. Seasonal variations in the occurrence of ovigerous and non-ovigeous females *H. hilgendorfi*.

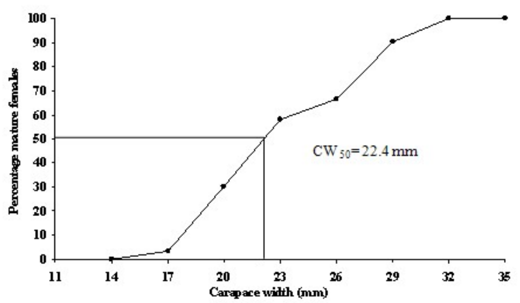

Fig. 5. Percentage maturity of female *H. hilgendorfi* in relation to carapace width.

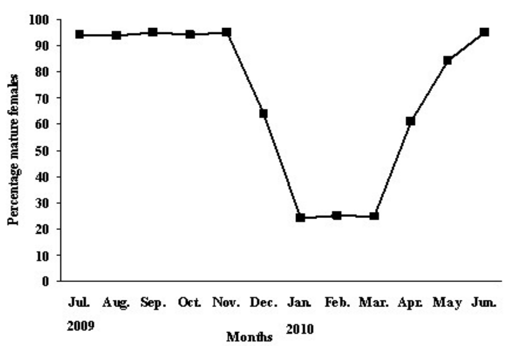

Fig. 6. Seasonality of spawning of females *H. hilgendorfi*.

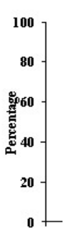

Fig.7.

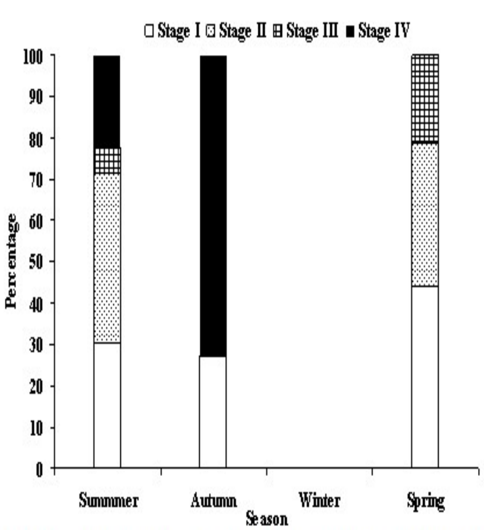

Fig. 8. Seasonal changes in the stages of egg development in *females H. hilgendorfi*.

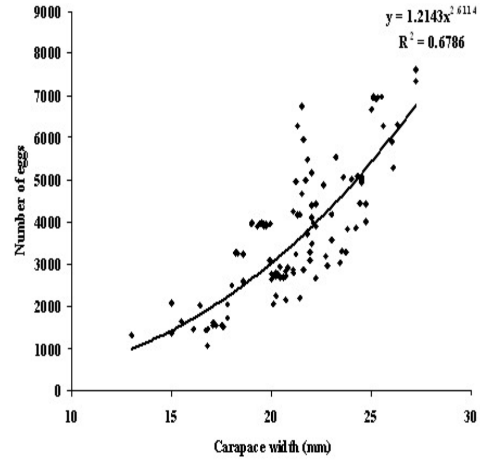

Fig. 9. Relationship between carapace width and number of eggs in female *H. hilgendorfi*.