

The Cirripedia associated with Loggerhead Sea Turtles, *Caretta caretta*, in the Gulf of Gabès, Tunisia

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Abstract: The barnacles associated with loggerhead sea turtles from the Gulf of Gabès are reported. Eleven species were identified from four families: Chelonibiidae (3 species), Lepadidae (2 species), Platylepadidae (3 species) and Balanidae (3 species). The chelonophilic barnacle *Stephanolepas muricata* is recorded for the first time from the south and central Mediterranean Sea. The preferential distribution of epibiotic Cirripedia is discussed.

Résumé: Les Cirripèdes associés à la tortue caouanne, *Caretta caretta*, dans le golfe de Gabès, Tunisie. Les cirripèdes épibiontes de la tortue caouanne ont été étudiés dans plusieurs localités du golfe de Gabès (Tunisie). Les cirripèdes déterminés appartiennent à quatre familles: les Chelonibiidae (3 espèces), les Lepadidae (2 espèces), les Platylepadidae (3 espèces) et les Balanidae (3 espèces). Le cirripède *Stephanolepas muricata* est signalé pour la première fois comme épibionte de la tortue caouanne en Méditerranée centrale. La distribution préférentielle des cirripèdes sur le corps des tortues est discutée.

Keywords: Cirripedia • *Caretta caretta* • Preferential distribution • Gulf of Gabès

Introduction

In the marine environment, any submerged surface is susceptible to be colonized by a variety of algae spores and larvae circulating in the water column. Organisms growing on the surface of a living creature may compose a complex assemblage known as a fouling community or epibionts.

Sea turtles provide substrate for diverse communities of epibionts (Bjorndal, 2003). Epibionts on sea turtles may benefit from increased survival, foraging, and dispersal compared with those on inanimate flotsam (Dellinger et al., 1997), and they may provide clues into the migratory routes of the host (Baez et al., 2001).

Among all species of sea turtles, the loggerhead, *Caretta caretta*, is colonized by the largest and the most diverse communities of epibionts (Frick et al., 2000). Barnacles (Cirripedia) are the most characteristic epibionts of

loggerhead turtles (Frazier et al., 1992; Bugoni et al., 2001). To date, studies on loggerhead epibionts from the Mediterranean Sea represent primarily the northern region (Kitsos et al., 2003 & 2005; Badillo, 2007), while such information from the southern region is scarce (Gramentz, 1988). The Gulf of Gabès (Tunisia, central Mediterranean Sea) (Fig. 1) is an important foraging and wintering area for loggerheads in the southern Mediterranean Sea (Margaritoulis et al., 2003; Bradai et al., 2009) but data on the Cirripedia from this region are missing.

The present study represents an advancement of the available information on the Cirripedia from loggerheads, by reporting new data on the distribution of barnacles on host turtles in the Gulf of Gabès. Data were compared with those reported in other areas of the Mediterranean Sea.

Material and Methods

The study of the epibiotic assemblage on loggerhead turtles was carried out within the framework of the cetaceans and sea turtles national stranding network established in 2004, and operated within the scope of on-going, fisheries bycatch surveys (Bradai, 2009).

All Cirripedia were carefully scraped with a knife from various parts of the turtle's body and then fixed and preserved in 70% ethanol. They were later counted and identified according to the identifications of Monroe & Limpus (1979) and Relini (1980).

Barnacle's positions on the sea turtle body were noted. The turtle's body was divided into 7 zones: the head (Z1), the neck (Z2), the forelimbs (Z3), the hind limbs (Z4), the carapace (Z5), the tail (Z6) and the plastron (Z7) (Fig. 2). The presence rate of Cirripedia (P%) was calculated for each body zone as follows: $P\% = (\text{number of the Cirripedia on the zone X of the turtle body} / \text{number of Cirripedia counted on the whole-body}) \times 100$.

The frequency of occurrence for each Cirripedia species (F%) was calculated as follows: $F\% = (\text{number of turtles hosting Cirripedia species} / \text{total number of turtles}) \times 100$.

Results and Discussion

A total of 113 loggerhead sea turtles were examined in various localities of the Gulf of Gabès between May 2004 and July 2010: 52 were freshly dead stranded and 61 were incidentally captured alive. A total of 2,204 barnacles were collected. The frequencies of occurrence of the Cirripedia species found and their preferential positions on the turtle's body are given in Table 1 and 2. The recorded Cirripedia belong to four families: Lepadidae, Chelonibiidae, Platylepadidae and Balanidae.

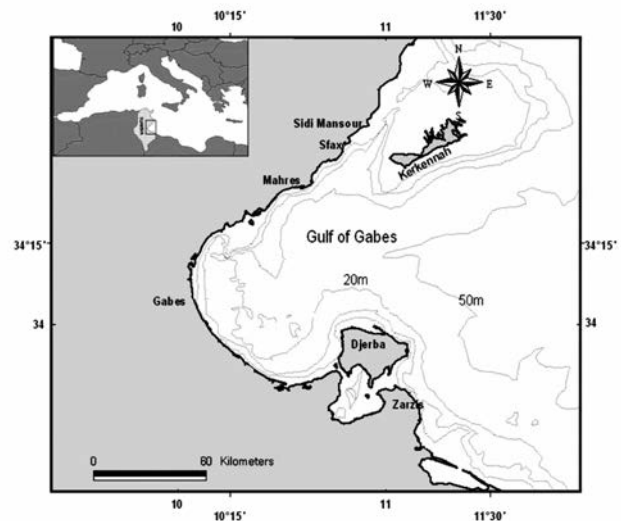


Figure 1. Map of the Gulf of Gabès.

Figure 1. Carte du Golfe de Gabès.

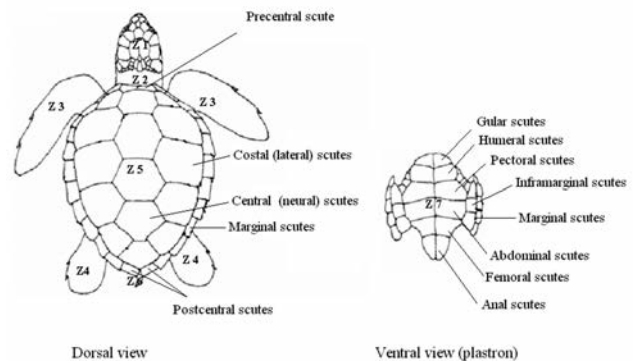


Figure 2. Different parts of the body of loggerhead sea turtle.

Figure 2. Différentes parties du corps de la tortue caouanne.

Family Lepadidae

Lepas anatifera Linnaeus, 1758

Material examined

211 individuals on 5 loggerhead turtles (Min = 6 per turtle, Max = 121, SD = 45.92).

Remarks

Lepas anatifera is circumglobally distributed. It is reported as an epibiont of loggerheads in the Pacific (Monroe & Limpus, 1979), Atlantic (Caine, 1986; Frick et al., 1998) and Mediterranean Sea (Relini, 1980; Gramentz, 1988; Koukouras & Matsa, 1998; Kitsos et al., 2005; Prazzi et al., 2009; Badillo, 2007; Fuller et al., 2010). In the Mediterranean Sea, *L. anatifera* is reported to colonize

Table 1. Cirripedia species occurring on the loggerhead body.**Tableau 1.** Cirripèdes présents sur le corps de la tortue caouanne.

Suborder	Family	Species	Number of specimens			Number of turtles	Occurrence (%)
			Min	Max	Total		
Lepadomorpha	Lepadidae	<i>Lepas anatifera</i> Linnaeus, 1758	6	121	211	5	4.42
		<i>Conchoderma virgatum</i> (Spengler, 1790)	2	3	5	2	1.76
Balanomorpha	Chelonibiidae	<i>Chelonibia testudinaria</i> (Linnaeus, 1758)	2	110	526	35	30.97
		<i>Chelonibia caretta</i> (Spengler, 1790)	1	4	34	13	11.50
		<i>Chelonibia patula</i> (Ranzani, 1818)	2	68	250	11	9.73
	Platylepadidae	<i>Platylepas hexastylus</i> (Fabricius, 1798)	2	132	607	18	15.92
		<i>Stephanolepas muricata</i> Fischer, 1886	17	50	299	12	10.61
		<i>Stomatolepas elegans</i> (Costa, 1838)	1	96	243	7	6.19
	Balanidae	<i>Balanus trigonus</i> Darwin, 1854	1	8	23	5	4.42
		<i>Balanus amphitrite</i> Darwin, 1854	5	5	5	1	0.88
		<i>Balanus perforatus</i> Bruguière, 1789	1	1	1	1	0.88

many types of floating objects (Koukouras & Matsa, 1998). In this study, we found it attached to loggerheads, wood, plastic, glass and metal. As epibiont, it was usually attached in clusters and occurred mainly on the carapace (marginal plates), the plastron (inframarginal scutes) and in small numbers on the head (Table 2).

Conchoderma virgatum (Spengler, 1790)

Material examined

5 individuals on 2 loggerhead turtles (Min = 2 per turtle, Max = 3, SD = 0.7).

Remarks

Conchoderma virgatum is a cosmopolitan species and attaches primarily to floating objects but is also reported from inanimate objects at shallow depths (Koukouras & Matsa, 1998; Chan, 2009). It is also associated with parasites such as pennelid copepods (Merella et al., 2005) and it attaches to sea turtles and cetaceans (Fernandez et al., 1991; Vivaldo et al., 2006). The presence of *C. virgatum* on the loggerhead turtle in the Mediterranean Sea was initially reported by Chevreux & De Guerne (1893), and subsequently by Relini (1980), Kitsos et al. (2003 & 2005) and Badillo (2007). We found *C. virgatum* on the 8th marginal scutes and on the 3rd inframarginal scutes of host turtles.

Family Chelonibiidae

Chelonibia testudinaria (Linnaeus, 1758)

Material examined

526 individuals on 35 loggerhead turtles (Min = 2 per turtle, Max = 110, SD = 23.60).

Remarks

Chelonibia testudinaria is circumblogal and occurs prodigiously on sea turtles (Newman & Ross, 1976) and rarely on inanimate floating objects (Relini, 1980).

In this study it was the most frequently observed turtle barnacle (30.97% occurrence) with an average of 15.03 individuals per host turtle.

The preferential settlement location exhibited by *C. testudinaria* has been reported in several studies. Frick & Slay (2000) and Kitsos et al. (2005) reporting it primarily on the marginal scutes on subadult loggerheads. Caine (1986) and Frick et al. (1998) reported it primarily from the posterior third of the carapace region of nesting loggerheads. In this study *C. testudinaria* was prevalent in all turtle's body, mostly on the entire carapace surface. Similarly, Matsuura & Nakamura (1993) found that the distribution of *C. testudinaria* on loggerheads nesting in south-west Japan was significantly non-uniform. Moriarty et al. (2008) discovered that *C. testudinaria* is capable of substantial post-settlement locomotion, generally from relatively low current flow (marginal region) to higher current flow (anterior and vertebral region of the carapace) in order to situate more desirable locations for feeding. Consequently, the observed colonization pattern observed for *C. testudinaria* may not exactly reproduce preferential settlement locations for barnacle larvae.

Chelonibia caretta (Spengler, 1790)

Material examined

34 individuals on 13 loggerhead turtles (Min = 1 per turtle, Max = 4, SD = 0.96).

Table 2. Distribution of Cirripedia species on the turtle's body.**Tableau 2.** Répartition des espèces de cirripèdes sur le corps de la tortue.

Species	Number	Presence rate of Cirripedia species (%) by body zone						
		Carapace	Plastron	Forelimbs	Hind limbs	Neck	Head	Tail
<i>Lepas anatifera</i> Linnaeus, 1758	211	82.0	10.4	0	0	0	7.6	0
<i>Conchoderma virgatum</i> (Spengler, 1790)	5	40	60	0	0	0	0	0
<i>Chelonibia testudinaria</i> (Linnaeus, 1758)	526	79.5	10.6	3.9	2.0	1.2	0.5	2.3
<i>Chelonibia caretta</i> (Spengler, 1790)	34	97.1	2.9	0	0	0	0	0
<i>Chelonibia patula</i> (Ranzani, 1818)	250	100	0	0	0	0	0	0
<i>Platylepas hexastylus</i> (Fabricius, 1798)	607	4.8	14.3	32.1	26.7	12.2	3.3	6.6
<i>Stephanolepas muricata</i> Fischer, 1886	299	0	0	74.6	25.1	0	0.3	0
<i>Stomatolepas elegans</i> (Costa, 1838)	243	0	0	63.0	5.8	27.6	0	3.7
<i>Balanus trigonus</i> Darwin, 1854	23	87.0	4.3	0	0	0	8.7	0
<i>Balanus amphitrite</i> Darwin, 1854	5	60	0	0	0	0	40	0
<i>Balanus perforatus</i> Bruguière, 1789	1	0	100	0	0	0	0	0

Remarks

This species commonly occurs on loggerheads in the Mediterranean Sea (Gramentz, 1988; Badillo, 2007; Fuller et al., 2010), in the Atlantic (Caine, 1986; Frick et al., 1998; Williams et al., 2006), Caribbean (Torres-Pratts et al., 2009) and in the Pacific Oceans (Monroe & Limpus, 1979). Almost all *C. caretta* associated to the turtles sampled were situated beneath the cuticle of the carapace and mainly on the vertebral scutes.

Chelonibia patula (Ranzani, 1818)

Material examined

250 individuals on 11 loggerhead turtles (Min = 2 per turtle, Max = 68, SD = 21.14).

Remarks

This species has a cosmopolitan distribution (Newman & Ross, 1976). Darwin (1854) reports that this species was found attached to crustacean and gastropod shells. Additionally, Ross & Newman (1967) include xiphosurans and marine snakes as hosts of *C. patula*.

In the Mediterranean Sea, Relini (1980) mentioned *C. patula* on a floating jar. Frazier & Margaritoulis (1990) found 35 individuals of this species fixed on a piece of yellow plastic, the first report of this species on an inanimate surface. More recently, *C. patula* has been documented as an epibiont of the loggerhead turtle in the Mediterranean Sea (Kitsos et al., 2003 & 2005). Badillo (2007) provides the first report of this species on loggerheads in the Western Mediterranean Sea, Spanish waters.

Ours is the first report of this species from sea turtles in the southern Mediterranean Sea. In these turtles, *C. patula* were located only on the carapace and mainly on the vertebral scutes.

Family Platylepadidae

Platylepas hexastylus (Fabricius, 1798)

Material examined

607 individuals on 18 loggerhead turtles (Min = 2 per turtle, Max = 132, SD = 32.33).

Remarks

Platylepas hexastylus was the second most abundant Cirripedia inventoried in this study. This cosmopolitan species (Koukouras & Matsa, 1998) has been reported from the Mediterranean Sea (Gramentz, 1988; Scaravelli et al., 2004; Kitsos et al., 2005; Prazzi et al., 2009; Badillo, 2007), and the Atlantic (Eckert & Eckert, 1988; Bugoni et al., 2001; Williams et al., 2006) and Pacific Oceans (Monroe & Limpus, 1979; Hernández & Valadez, 1998). *Platylepas hexastylus* was found shallowly embedded in the turtle tissue. It is largely superficial when attached to the skin on the flippers, around the neck, and on the plastron (Table 2). This species produces fine and serrated ornamentations along the basal margin that entrain or pinch the host tissue that is being depressed, so anchoring or holding the shell in place. Similar results were reported by Monroe & Limpus (1979). In some cases, when barnacles were present in large number, they covered the entire marginal scutes and they grew in a distorted way on the head. The similar preferential distributions of this species on loggerheads from the Adriatic Sea were also reported (Scaravelli et al., 2004).

Stomatolepas elegans (Costa, 1838)

Material examined

243 individuals on 7 loggerhead turtles (Min = 1 per turtle, Max = 96, SD = 34.23).

Remarks

This cosmopolitan species (Newman & Ross, 1976; Young, 1991; Frick et al., 2010) has been found as an epibiont of leatherback sea turtles in the Atlantic Ocean (Frick et al., 2010) and in the Mediterranean Sea (Duron-Dufrenne, 1986). Stubbings (1967) recorded this species as an epibiont of the loggerhead turtle from the west coast of Africa (Senegal). The first record of *S. elegans* as an epibiont of the loggerhead turtle in the Mediterranean Sea was reported by Kitsos et al. (2003) in the Aegean Sea. Subsequent studies reported this species on Mediterranean loggerhead (Scaravelli et al., 2004; Kitsos et al., 2005; Prazzi et al., 2009). In this study we found it attached to the soft skin of loggerheads, between the neck and the limbs. In other areas, *S. elegans* was cited attached to carapace, flippers and skin of sea turtles: *Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea* and *Lepidochelys olivacea* (Frick et al., 2010).

Stephanolepas muricata Fischer, 1886

Material examined

299 individuals on 12 loggerhead turtles (Min = 17 per turtle, Max = 50, SD = 11.49).

Remarks

This species occurs on loggerhead turtles in the Pacific (Newman & Ross 1976) and Indian Oceans (Hughes, 1974). In the Mediterranean Sea *S. muricata* has been mentioned only in Spanish waters (Badillo, 2007). This species was observed to penetrate nearly 1 cm into the turtle's integument colonizing in important numbers the anterior edge of their flippers. Only one *S. muricata* was located on the head of one turtle (Table 2). According to Monroe (1981) and Monroe & Limpus (1979), some platylepadids (i.e. *Stephanolepas* and *Stomatolepas*), go further and penetrate the skin and even bone of turtles, but rather than causing an infection or abscesses as one might expect, the turtle generally reacts by encysting them in fibrous connective tissue where by the barnacle is not only held in place by the host but can continue to grow.

Family Balanidae

Balanus trigonus Darwin, 1854

Material examined

23 individuals on 5 loggerhead turtles (Min = 1 per turtle, Max = 8, SD = 3.5).

Remarks

Balanus trigonus is a cosmopolitan species with an affinity

for tropical and warm temperate seas (Koukouras & Matsa, 1998). Moreover, it is a common infra littoral species in the Mediterranean Sea (Relini, 1980; Koukouras & Matsa, 1998). It is reported from loggerhead turtles in the Atlantic Ocean (Caine, 1986; Frick et al., 2000), Pacific Ocean (Monroe & Limpus, 1979) and the Mediterranean Sea (Kitsos et al., 2003 & 2005; Badillo, 2007). The large geographic distribution of this species can be explained by its capacity to colonize boats (Zullo & Bleakney, 1992). It is an opportunistic colonizer and will occur on most hard substrates including the rhizomes of *Posidonia oceanica* and on mollusc shells (Relini, 1980). This species was located primarily on the carapace and the head as well as to a lesser degree on the plastron. Some specimens were found attached to *C. testudinaria*.

Balanus amphitrite Darwin, 1854

Material examined

5 individuals on 1 loggerhead turtle.

Remarks

Five individuals of *B. amphitrite* (three on the second right costal scutes and two on the head) were found on one loggerhead. It is a cosmopolitan, infralittoral species that is found attached to most hard substrata including artificial substrates, like rocks, harbour pilings, pipes from desalination plants, boats, floating objects, the rhizomes of *P. oceanica*, and molluscs shells (Mangum et al., 1972; Relini, 1980; Koukouras & Matsa, 1998). This species is reported as an epibiont of sea turtles in the Atlantic Ocean (Caine, 1986; Frick & Slay, 2000; Frick et al., 1998). It's known from loggerheads, in the south (Aegean Sea; Kitsos et al., 2003 & 2005) and in the western Mediterranean Sea (Badillo, 2007). In Tunisia, *B. amphitrite* is a common and widespread epifaunal species (Zouari et al., 2008).

Balanus perforatus Bruguière, 1789

Material examined

1 individual on 1 loggerhead turtle.

Remarks

This species is reported from the Atlantic coasts of Europe and Africa, from the Black and the Mediterranean Sea (Relini, 1980; Koukouras & Matsa, 1998). It is a characteristic species of the hard substratum infra littoral zone (Relini, 1980).

In the Mediterranean Sea, this species is considered as an epibiont of loggerhead sea turtles in the Aegean Sea (Kitsos et al., 2003 & 2005) and in the Spanish coasts where Badillo

Table 3. Cirripedia epibiont of the loggerhead turtle in the Mediterranean Sea.**Tableau 3.** Cirripèdes épibiontes de la tortue caouanne en Mer Méditerranée.

Locality	Present study Gulf of Gabès (Tunisia)	Badillo (2007) Valancia (Spain)	Gramentz (1988) Pelagian Islands (Italy)	Scaravelli et al. (2004) Adriatic Sea (Italy)	Kitsos et al. (2005) Aegean Sea (Greece)	Fuller et al. (2010) Cyprus
Number of sampled turtles	113	177	107	30	37	100
<i>Lepas anatifera</i>	+	+	+		+	
<i>Lepas hilli</i>		+	+	+		
<i>Lepas anserifera</i>		+				+
<i>Lepas pectinata</i>		+				
<i>Chonchoderma virgatum</i>	+	+	+		+	
<i>Chelonibia testudinaria</i>	+	+	+	+	+	+
<i>Chelonibia caretta</i>	+	+	+			+
<i>Chelonibia patula</i>	+	+			+	
<i>Platylepas coriacea</i>			+			
<i>Platylepas hexastylus</i>	+	+	+	+	+	
<i>Stephanolepas muricata</i>	+	+				
<i>Stomatoleps elegans</i>	+	+		+	+	
<i>Balanus trigonus</i>	+	+		+	+	
<i>Balanus perforatus</i>	+	+			+	
<i>Balanus Amphitrite</i>	+	+			+	
<i>Balanus eburneus</i>					+	
<i>Pachylasma giganteum</i>					+	
Total species	11	14	7	5	11	3

(2007) mentioned it as a generalist species colonizing rocks, floating molluscs shells and many other objects.

To date seventeen barnacle species, belonging to five families and eight genera, occur on loggerhead turtles in the Mediterranean Sea (Gramentz, 1988; Scaravelli et al., 2004; Kitsos et al., 2005; Badillo, 2007; Fuller et al., 2010). Of these, 5 species were most common on loggerhead sea turtles in the Gulf of Gabès: *Chelonibia testudinaria*, *Chelonibia caretta*, *Platylepas hexastylus*, *Stephanolepas muricata* and *Stomatolepas elegans*. Table 3 demonstrates the similarity of our qualitative results with similar studies conducted in the northern Mediterranean Sea. The diversity of the cirriped taxa present on Tunisian loggerheads approaches similar amounts to those observed from loggerhead turtles in Spanish waters, where it is the highest documented for the Mediterranean (Badillo, 2007).

The most common barnacle species from loggerheads sampled in the Gulf of Gabès was *Chelonibia testudinaria* (30.97% of occurrence). Actually, the occurrence percent of this species varies from region to region in the Mediterranean Sea: 97% in the Aegean Sea (Kitsos et al., 2005), and only 7% in Valencia (Badillo, 2007), however the factors associated with these differences are currently unknown.

Platylepas hexastylus is the second most common and second most abundant barnacle species from loggerheads in Tunisian waters (Table 1). Kitsos et al. (2005) found this

species on 10% of the loggerhead sampled in the Aegean Sea, and Scaravelli et al. (2004) reported an occurrence of more than 75% on loggerheads in the Adriatic Sea. As for *C. testudinaria*, the conditions driving the density and distribution of *P. hexastylus* in the Mediterranean Sea are poorly understood, but likely reflect differences in survey methodologies and the respective ontological stage of the turtles being examined. Nonetheless, the cosmopolitan *P. hexastylus* is capable of settling upon nearly any surface, hard or soft, of loggerhead turtles.

Attachment sites on the turtles varied with Cirripedia species. The chelonibiid, lepadid and balanid species, as no burrowing harmless barnacles, attached to turtles superficially whereas the platylepadid species produce a body chamber that extends above and below the surface of the host's skin and allow them to firmly colonizing the soft parts of the turtle's body in different location; these barnacle were partially embedded (such as *P. hexastylus* and *Stomatolepas elegans*) or fully embedded (in instance *Stephanolepas muricata*).

According to Frick et al. (2011), *S. muricata* produces a relatively fragile shell with a complex series of sutural elaborations. Those series radiate outwards so as to cross-anchor the animal deep within the epidermis of the host turtle in order to draw barnacle tissue into contact with the tissue of the host; in this contact, there would be a chemical

mediation that may prevent the host turtle from rejecting these deeply embedded symbionts (Frick et al., 2011).

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