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ISSN 0173-9565/InterCode: MAECDR

Accepted: 28. 5. 1984

Epizoan Communities on Marine Turtles

I. Bivalve and Gastropod Mollusks

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With 4 figures and 1 table

Key words: Marine turtles, mollusks, epizoa, symbiosis.

Abstract. Marine turtles harbour a variety of epizoa, some of which are specific to these hosts, but shelled gastropod and bivalve mollusks were previously unrecorded on marine turtles. Thousands of turtles of five species from all major oceans were examined. Loggerheads, *Caretta caretta,* from Greece and the states of Georgia and Florida, USA, were the most remarkable hosts to mollusks. At least 15 species of bivalves and 5 species of gastropods were found on turtles. Many turtles hosting mollusks carried only one species and few individuals. Edible oysters, the most common molluscan epizoan on Grecian Loggerheads, may grow to more than 10 cm in diameter, so in some cases the mollusks may survive for several years on the turtle. Large epizoan bivalves may in turn serve themselves as substrates for epizoa, molluscan or otherwise. There are no known obligate relationships between turtles and mollusks, although there may be a parasitic relationship between the Loggerhead turtle, a spirorchid blood fluke, and a gastropod intermediate host. It is unknown if turtles carrying mollusks are at a disadvantage.

Problem

Marine turtles *(Cheloniidae* and *Dermochelyidae)* are known to carry diverse kinds of epizoic organisms. ERNST & BARBOUR (1972) provided the most thorough review of sea turtle symbionts, listing: algae of four phyla and dozens of species; bryozoans; tube worms; leeches of two species; barnacles of seven species; an isopod; and a fish. Crabs, both oceanic (CHACE, 1951) and nearshore (CLARK, 1965), and an amphipod (BARNARD, 1967) have also been recorded on sea turtles. During the Challenger Expedition a variety of epizoa was recorded on sea turtles, including: hydroids, barnacles, amphipods, crabs, and a nudibranch (MURRAY, 1895: 123, 262).

The number of epizoa on a single host can be large; CRIBB (1969) reported 38 species of algae on a single turtle. The occurrence of epizoa is, however, poorly quantified and many individual turtles have no external symbionts.

In some cases the epizoa are known only from turtles; three algae (HOLLENBERG & NORRIS, 1977) and several epizoic barnacles (ROSS & NEWMAN, 1967) are found on sea turtles but not on other substrates. A new genus of amphipod was described from the buccal cavity of a sea turtle (BARNARD, 1967).

This note reports, apparently for the first time, the occurrence of motile shelled gastropods as well as sessile bivalve mollusks on marine turtles. It provides a summary of the host-epizoa relationships, in addition to details about epizoan habitats on turtles.

Material and Methods

The external surfaces of sea turtles were examined for epizoa as part of more extensive field studies. Most turtles inspected were nesting females because they are easily accessible while nesting, but immatures and reproductive males were also investigated when they were found stranded on beaches or caught in turtle nets. Turtles of all five of the pantropical species were studied. JF (FRAZIER) has looked specifically for epizoa on live or recently killed turtles involving several hundred *Chelonia mydas* (L.) and about 50 *Eretmochelys imbricata* (L.) mainly from the western Indian Ocean; and over 100 *Lepidochelys olivacea* (ESCHSCHOLTZ) and about 50 *Dermochelys coriacea* (L.) from Pacific Mexico. About 50 *L. olivacea* were also examined in the Bay of Bengal. Observations of JF, DM (MARGARITOULIS), KM (MULDOON), CR (RUCKDESCHEL) and SS (SALAS) include nearly 1,000 *Caretta caretta* (L.) in Greece and the states of Georgia and Florida, USA. Each turtle found with molluscan epizoa is identified by the collector's field number for the turtle (*e. g.*, "JF Ei 129"). The mollusks are identified, together with either their National Museum of Natural History *(Mollusca)* number (*e. g.*, "USNM 749840") or their Applied Biology, Inc. (Jensen Beach, Florida) number (*e. g.*, "ABI CC 10 GV"). The community of epizoa, with details on the mollusks, is described. Subsequent studies will deal with other groups of epizoa. Curved medial carapace length ("CCL") is given for each turtle where available; length of a bivalve, or patellid gastropod, ("GL") is the greatest "diameter" across the valve(s), taken at the umbo if possible (*e. g.*, from umbo to venter for a mussel); each gastropod was measured across the greatest length, or height, of the spire ("SH").

Results

Mollusks have been collected on only three species of marine turtles: *Eretmochelys imbricata, Caretta caretta,* and *Lepidochelys olivacea;* the numbers of each species involved are: one, twenty and three, respectively. Of the *C. caretta,* ten were from Greece, five from Georgia, U. S. A., and five from Florida, U. S. A. No mollusks have been found on *Dermochelys coriacea,* but there are two sight records from *Chelonia mydas.*

1. *Eretmochelys imbricata* (L.), the Hawksbill turtle

a. Host I – Maziwi Island, Tanzania (5°30'S 39°4'E)

I: On 8 February 1974, a female (JF Ei 129; CCL = 91.0 cm) was examined while nesting. It was infested with several types of epizoa, including: barnacles (*e. g., Chelonibia* sp.); leech (*Ozobranchus* sp.); and both encrusting and filamentous algae (*Cladophora* sp., *Enteromorpha* sp., *Polysiphonia* sp., and *Sphacelaria furcigera* KÜTZING). A juvenile *Septifer bilocularis* (L.) (USNM 749840; GL = 6 mm) was removed from the anterior of the fifth vertebral scute from under the ventral posterior surface of the imbricate fourth vertebral scute.

2. *Caretta caretta* (L.), the Loggerhead turtle

a. Hosts II to VII – Sekania Beach, Zakynthos Island, Greece (37°43'N 20°56'E)

II: On 16 July 1982, epizoa were collected from the carapace of a nesting female (JF & SS Z-285; CCL = 78.5 cm). These included: a polychaete; barnacles (*e. g., Chelonibia* sp. and *Lepas* sp.); non cirriped crustacea (*e. g., Caprella* sp.); and four oysters, *Ostrea edulis* L. (USNM 804411; GL = 15 to 40 mm). All of these epizoa were attached to the central part of the carapace.

III: A female (DM E 882) nesting in early August 1982 had four bivalves (GL = 1 to 3 mm) attached to the carapace. They were clustered together near a patch of filamentous algae (tentatively identified as *Cladophora* sp.). As spat, the mollusks are not possible to identify, but they appear to be mytilids.

IV: On 5 July 1983, a nesting female (DM Z-940; CCL = 85.0 cm) carried a large oyster, *Ostrea edulis* (USNM 836259; GL approx. 91 mm). This was collected from the turtle's carapace, and the dorsal valve in turn had sparse cover of filamentous algae.

V: A female (DM Z-971; CCL = 89.5 cm) nesting on 24 July 1983 had an oyster, *Ostrea edulis* (USNM 836256; GL = 117 mm), weighing 286 g, on the carapace between the 4th and 5th vertebral scutes. On the oyster was a *Petricola lithophaga* (RETZIUS) (USNM 836262; GL = 7 mm), together with annelid and sipunculid worms, and algae (Fig. 1).

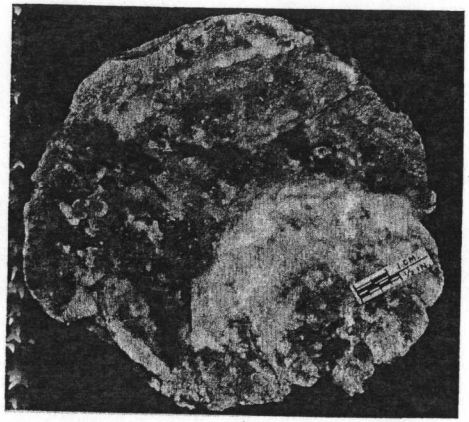

Fig. 1. Ventral valve of *Ostrea edulis* L. (USNM 836256) from the carapace of a nesting female *Caretta caretta* (L.) on Zakynthos Island, Greece; note: parts of three scales, divided by three radiating lines, left by the removal of parts of the keratinous scales of the turtle's carapace.

VI: On 28 July 1983, a nesting female (DM Z-801; CCL = 83.5 cm) had two oysters, *Ostrea edulis* (USNM 836257; GL = 80 and 100 mm), cemented together and attached to the carapace between the 4th and 5th vertebral scutes and the 5th left pleural scute. The dorsal valves had sparse cover of filamentous algae.

VII: The 3rd August, 1983, a nesting female (DM S 030883) had several species of epizoa. An oyster, *Ostrea edulis* (USNM 836258; GL = 119 mm), weighing 256 g, was taken from the carapace. On the oyster were algae, annelid and sipunculid worms and amphipods (Fig. 2). A cluster of 8 *Mytilus edulis* L. (USMN 836260; GL = 10 to 17 mm) were also affixed to the turtle, as was a barnacle, *Chelonibia* sp. (USNM 211342; "GL" = 43 mm), which in turn had on it a worm tube and a *Mytilus edulis* (GL = 12 mm) (Fig. 3).

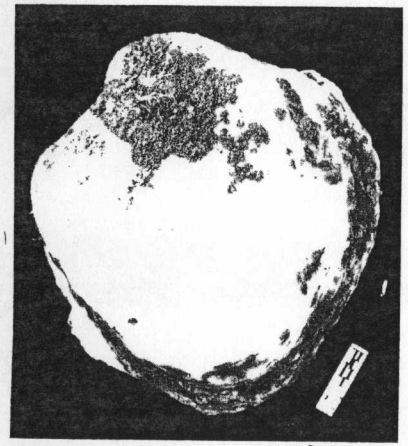

Fig. 2. Dorsal valve of *Ostrea edulis* L. (USNM 836258) from the carapace of a nesting female *Caretta caretta* (L.) on Zakynthos Island, Greece; note: thick cover of filamentous algae and deep scratches in shell.

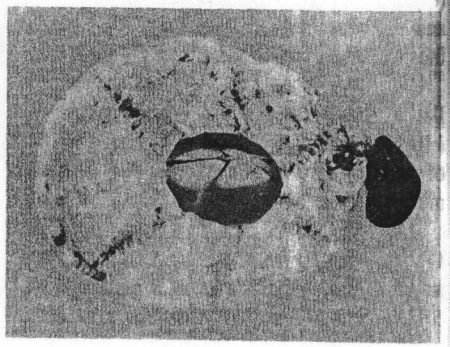

Fig. 3. *Chelonibia* sp. (USMN 211342) with a *Mytilus edulis* L. attached to it; the barnacle, 43 mm in diameter, was attached to the same nesting female *Caretta caretta* (L.) from Zakynthos Island, Greece which carried the *Ostrea edulis* L. illustrated in Fig. 2.

b. Hosts VIII to XI – Western coast of Peloponnesus, Greece (37°30′N 21°35′E)

VIII: In 1982 a female (DM 8182; CCL = 90.5 cm) was caught by fishermen. Epizoa from the carapace and plastron included barnacles, *Chelonibia* sp. and *Platylepas* sp.; an amphipod, *Caprella* sp.; and a polychaete, *Serpula* sp. A pit about 3 mm deep in the posterior of the carapace (supracaudals) contained a 3 mm bivalve of the family *Veneridae* (probably *Venus* sp. or *Venerupis* sp.). The mollusk was destroyed in the process of examination.

IX: On 25 July 1982, a nesting female (DM Z-231; CCL = 89.0 cm) had a large oyster, *Ostrea edulis* (USNM 804417; GL = 88 mm), attached near the centre of

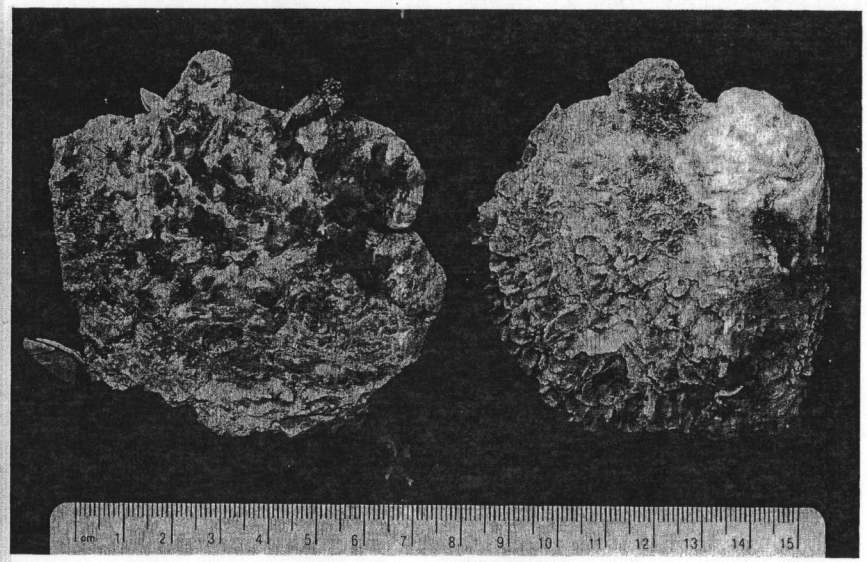

Fig. 4. Ventral (left) and dorsal (right) valves of *Ostrea edulis* L. (USMN 804417) from a nesting female *Caretta caretta* (L.) on Peloponnesus, Greece; note: *Lepas hillii* LEACH and *Mytilus edulis* L. attached to ventral valve and algae and worm tubes on dorsal valve.

the carapace. The oyster in turn served as a substrate for other epizoa (Fig. 4), including three filamentous algae: *Sphacelaria tribuloides* MENEGHINI, *Chaetomorpha linum* (MÜLLER) KÜTZING, and *Polysiphonia* sp. The former was abundant and covered dense patches, especially near the hinge. Attached near the hinge at the edge of the ventral valve was a mussel, *Mytilus edulis* (USNM 819631; GL = 15 mm), broken during collection. Two barnacles, *Lepas hillii* LEACH (USNM 189078), were attached to the edges on the other side of the ventral valve. Two worm tubes, each about 5 mm long, were cemented to the dorsal valve, near patches of algae; they are consistent with *Pomatoceros* sp.

X: A female (DM 141 G; CCL = 84.5 cm) nesting on 29 July 1983, had a large *Chelonibia* sp. on the carapace. A *Mytilus* sp. 4 mm long was attached to the rostrum of the barnacle (specimens in the collection of D. MARGARITOULIS).

XI: On 31 July 1983, a nesting female (DM 28 G; CCL = 89.5 cm) was examined. In an old crack in the carapace were two *Mytilus edulis* (USNM 836261; GL = 21 and 23 mm). Barnacles, *Chelonibia* sp. and *Platylepas* sp., also attached to the carapace were collected as well.

c. Hosts XII to XVI – Cumberland Island, Georgia, U.S.A. (30°56′N 81°23′W)

XII: On 7 June 1974, a female (tag 1120; CCL = 114.0 cm) was examined while nesting. Four species of mollusks were on the carapace; 16 *Musculus lateralis*

(SAY) (USNM 819615; GL = 4 mm); 12 *Sphenia antillensis* DALL & SIMPSON (USNM 819616; GL = 3 to 5 mm); and nestled among them were two *Hiatella arctica* (L.) (USNM 819617; GL = 4 mm) and one slipper limpet, *Crepidula plana* SAY (USNM 819614; GL = 18 mm).

XIII: An immature (CR 79.09.29.01; CCL = 58.0 cm) was dead on the beach at "Dungeness" on 29 September 1979. In addition to a *Crepidula fornicata* (L.) (USNM 804413; GL = 46 mm), four mytilids, *Brachidontes modiolus* (L.) (USNM 804412; GL = 18 to 21 mm), were removed from the turtle's carapace.

XIV: On 5 June 1982, a non-gravid female (CR 82.06.05.04; CCL = 86.0 cm) was found dead on the beach. The carapace had five species of mollusks: two *Sphenia antillensis* (USNM 819628; GL = 6 and 8 mm); one *Anadara* sp. (USNM 819629; GL = 5 mm); one cf. *Rupellaria typica* (JONAS) (USNM 819630; GL = 7 mm); five *Crepidula plana* (USNM 819626; GL = 5 to 10 mm); and one *C. fornicata* (USNM 819627; GL = 14 mm).

XV: An immature male (CR 82.06.13.02; CCL = 63.0 cm) was found dead on the beach on 13 June 1982. Three species of mollusks were on the carapace: five *Sphenia antillensis* (USNM 819623; GL = 5 to 9 mm); two *Anadara* sp. (USNM 819625; GL = 4 to 7 mm); and one *Crepidula fornicata* (USNM 819624; GL = 14 mm).

XVI: On 14 July 1982, a gravid female (CR 82.07.14.02; CCL = 96.5 cm) was dead on the beach. On the carapace were 10 *Sphenia antillensis* (USNM 819618; GL = 5 to 8 mm); two *Ostrea equestris* SAY (USNM 819619; GL = 17 to 20 mm); two *Chama macerophylla* GMELIN (USNM 819620; GL = 6 to 18 mm); three *Brachidontes exustus* (L.) (USNM 819622; GL = 2 to 15 mm); and two *Crepidula fornicata* (USNM 819621; GL = 11 to 18 mm).

d. Hosts XVII to XXI – Hutchinson Island, Florida, U. S. A. (27°21'N 80°13'W)

XVII: On 30 March 1982, a female (tags AAH 166 & 167; CCL = 88.0 cm) was caught in good condition in a turtle net. Between the carapace and the base of the tail were six *Costoanachis floridana* (REHDER) (ABI CC 11 GV; SH = 6 to 8 mm). Associated with these was a single *Costoanachis avara* (SAY) (ABI CC 10 GV; SH = 6 mm).

XVIII: An immature (tags AAH 271 & 272; CCL = 70.0 cm) was caught in fair condition in a turtle net on 28 September 1982. Between the carapace and the base of the tail was a single *Costoanachis floridana* (ABI CC 15 CV; SH = 8 mm).

XIX: On 26 October 1982, an immature (tags AAH 279 & 280; CCL = 74.5 cm) was caught in fair condition in a turtle net. Between the carapace and the base of the tail were five *Costoanachis floridana* (ABI CC 17 GV; SH = 7 to 9 mm). They were together with one *Thais haemastoma floridana* (CONRAD) (ABI CC 18 GV; SH = 8 mm). On the plastron of this turtle were three *Costoanachis avara* (ABI CC 20 GV; SH = 7 to 9 mm); one *C. floridana* (ABI CC 19 GV; SH = 8 mm); and one *Anadara transversa* (SAY) (ABI CC 21 GV; GL = 3 mm).

XX: An immature (tags AAH 281 & 282; CCL = 77.5 cm) was caught in poor condition in a turtle net on 15 November 1982. At the base of the tail near the plastron was one *Thais haemastoma floridana* (ABI CC 23 GV; SH = 21 mm).

XXI: On 10 January 1983, an immature (tags AAH 321 & 325; CCL = 76.0 cm) was caught in good condition in a turtle net. Between the carapace and the base of the tail were seven *Costoanachis floridana* (ABI CC 25 GV; SH = 5 to 8 mm). Also present was a *Costoanachis* cf. *avara* (ABI CC 26 GV; SH = 6 mm).

3. *Lepidochelys olivacea* (ESCHSCHOLTZ), the Olive Ridley turtle

a. Hosts XXII to XXIV – Gahirmatha Beach, Bhitarkanika Wildlife Sanctuary, Cuttack District, Orissa, India (20°40'N 87°00'E)

XXII: On 2 February 1984, a female (JGF 4229; CCL approx 65 cm) was examined while ascending the beach to nest. The posterior of the carapace carried filamentous green and brown algae, dozens of anemones and two bivalves, *Crassostrea* cf. *gigas* (THUNBERG) (USNM 836263; GL = 11 to 27 mm).

XXIII: A female (JGF 4230; CCL = 65.5 cm) was found dead on the beach, on the 3rd of February 1984, evidently drowned in an offshore trawl about a week before. On the posterior of the carapace were filamentous algae, bryozoan mats, about ten barnacles and about 25 calcified circles, evidently sites of attachment of *Crassostrea* cf. *gigas,* three of which were present with both valves (USNM 820298; GL = 9 to 29 mm).

XXIV: A second dead female (JGF 4231; CCL = 71.5 cm) was examined under the same conditions as the previous one. At least two *Crassostrea* cf. *gigas* (USNM 820299; GL = 17 to 31 mm) were present on the posterior of the carapace, *i. e.,* supracaudals.

4. *Chelonia mydas* (L.), the Green turtle

a. Isla Gardner, Galapagos Archipelago, Ecuador (1°20'S 90°17'W)

A Green turtle was photographed while swimming with a large gastropod attached to its carapace. The turtle's shell was estimated to be 80 cm long and the gastropod, at least 25 cm long (J. N. NORRIS, pers. comm.). The shape of the mollusk is similar to *Pleuroploca princeps* which is known from the Galapagos.

b. Barra do Rio Grande do Sul, Brasil (32°11'S 52°10'W?)

An immature turtle photographed in 1983 had its carapace covered with bivalves *(Mytilus edulis),* hydrozoans (*Tubularia* sp.), and bryozoans. As it died soon after being caught (G. M. F. G. MARCOVALDI, *in litt.* 21 September 1983), it was evidently in poor condition.

Discussion

Epizoan mollusks have previously been recorded from only two turtle species. The "Challenger" record of a nudibranch on a *Chelone imbricata* (MOSELEY in MURRAY, 1895: 262) has two problems.

Eretmochelys (= Chelone) imbricata is extremely rare in the North Atlantic (BRONGERSMA, 1972), and it is likely that the turtle involved was a misidentified

Table 1. Epizoan mollusks collected on marine turtles (a)

Mollusks	Host Number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Species (b)	Ei	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca
	Locality (c)	Maz	Zak	Zak	Zak	Zak	Zak	Zak	Pel	Pel	Pel	Pel
BIVALVES												
Anadara transversa (SAY)		.	.	.	.	.	.	.	.	.	.	.
Anadara sp.		.	.	.	.	.	.	.	.	.	.	.
Brachidontes exustus (L.)		.	.	.	.	.	.	.	.	.	.	.
Brachidontes modiolus (L.)		.	.	.	.	.	.	.	.	.	.	.
Chama macerophylla GMELIN		.	.	.	.	.	.	.	.	.	.	.
Crassostrea cf. *gigas* (THUNBERG)		.	.	.	.	.	.	.	.	.	.	.
Hiatella arctica (L.)		.	.	.	.	.	.	.	.	.	.	.
Musculus lateralis (SAY)		.	.	.	.	.	.	.	.	.	.	.
Mytilus edulis L.		.	.	.	.	.	.	9	.	1	.	2
Mytilus sp.		.	.	.	.	.	.	.	.	.	1	.
mytilid spat		.	.	x	.	.	.	.	.	.	.	.
Ostrea edulis L.		.	4	.	1	1	2	1	.	1	.	.
Ostrea equestris SAY		.	.	.	.	.	.	.	.	.	.	.
Petricola lithophaga (RETZIUS)		.	.	.	.	1	.	.	.	.	.	.
cf. *Rupellaria typica* (JONAS)		.	.	.	.	.	.	.	.	.	.	.
Septifer bilocularis (L.)		1	.	.	.	.	.	.	.	.	.	.
Sphenia antillensis DALL & SIMPSON		.	.	.	.	.	.	.	.	.	.	.
venerid		.	.	.	.	.	.	.	1	.	.	.
GASTROPODS												
Costoanachis avara (SAY)		.	.	.	.	.	.	.	.	.	.	.
Costoanachis cf. *avara*		.	.	.	.	.	.	.	.	.	.	.
Costoanachis floridana (REHDER)		.	.	.	.	.	.	.	.	.	.	.
Crepidula fornicata (L.)		.	.	.	.	.	.	.	.	.	.	.
Crepidula plana SAY		.	.	.	.	.	.	.	.	.	.	.
Thais haemastoma floridana (CONRAD)		.	.	.	.	.	.	.	.	.	.	.
Total: species (individuals)		1(1)	1(4)	x(x)	1(1)	2(2)	1(2)	2(10)	1(1)	2(2)	1(1)	1(2)

(a) "x" = mollusk species unknown.
(b) "Ei" = *Eretmochelys imbricata;* "Ca" = *Caretta caretta;* "Lo" = *Lepidochelys olivacea.*
(c) "Maz" = Maziwi Island, Tanzania; "Zak" = Zakynthos Island, Greece; "Pel" = Peloponnesus, Greece;

Caretta caretta. In addition, the mollusk reported, *Aeolis,* was not described in the treatise of nudibranchs collected during the Expedition (BERGH, 1884).

The only other records of mollusks involve *Malaclemys terrapin* (SCHOEPFF), the North American diamondback terrapin, predominantely an inhabitant of brackish water that also enters fresh water. Three examples have been documented and illustrated: ALLEN & NEILL (1952: 42) reported an individual that could not swim normally for the mass of encrusting "oysters". JACKSON & Ross (1971) detailed seven oysters, *Crassostrea virginica* (GMELIN) and a slipper shell, *Crepidula plana,* on a large female terrapin. JACKSON *et al.* (1973) described six mytilids, *Brachidontes exustus,* within the vacant "shell" of a barnacle, *Balanus eburneus* GOULD, which was attached to the posterior of an adult female terrapin. Two of these three mollusks have now been documented from marine turtles (Table 1).

A total of 20 different epizoan mollusks are now documented from marine turtles, including 15 bivalves and five gastropods as well as several unidentified

XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	Total (d)	
Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Lo	Lo	Lo	H	(I)
Cu	Cu	Cu	Cu	Cu	Ht	Ht	Ht	Ht	Ht	Ga	Ga	Ga		
.	.	.	.	.	.	.	1	.	.	.	.	.	1	(1)
.	.	1	2	.	.	.	.	.	.	.	.	.	2	(3)
.	.	.	.	3	.	.	.	.	.	.	.	.	1	(3)
.	4	.	.	.	.	.	.	.	.	.	.	.	1	(4)
.	.	.	.	2	.	.	.	.	.	.	.	.	1	(2)
.	.	.	.	.	.	.	.	.	.	2	25	2	3	(29)
2	.	.	.	.	.	.	.	.	.	.	.	.	1	(2)
16	.	.	.	.	.	.	.	.	.	.	.	.	1	(16)
.	.	.	.	.	.	.	.	.	.	.	.	.	3	(12)
.	.	.	.	.	.	.	.	.	.	.	.	.	1	(1)
.	.	.	.	.	.	.	.	.	.	.	.	.	1	(x)
.	.	.	.	.	.	.	.	.	.	.	.	.	6	(10)
.	.	.	.	2	.	.	.	.	.	.	.	.	1	(2)
.	.	.	.	.	.	.	.	.	.	.	.	.	1	(1)
.	.	1	.	.	.	.	.	.	.	.	.	.	1	(1)
.	.	.	.	.	.	.	.	.	.	.	.	.	1	(1)
12	.	2	5	10	.	.	.	.	.	.	.	.	4	(29)
.	.	.	.	.	.	.	.	.	.	.	.	.	1	(1)
.	.	.	.	.	1	.	3	.	.	.	.	.	2	(4)
.	.	.	.	.	.	.	.	.	1	.	.	.	1	(1)
.	.	.	.	.	6	1	6	.	7	.	.	.	4	(20)
.	1	1	1	2	.	.	.	.	.	.	.	.	4	(5)
1	.	5	.	.	.	.	.	.	.	.	.	.	2	(6)
.	.	.	.	.	.	.	1	1	.	.	.	.	2	(2)
4(31)	2(5)	5(10)	3(8)	5(19)	2(7)	1(1)	4(11)	1(1)	2(8)	1(2)	1(25)	1(2)		(156)

"Cu" = Cumberland Island, Georgia, U. S. A.; "Ht" = Hutchinson Island, Florida, U. S. A.; "Ga" = Gahirmatha, Orissa, India.
(d) "H" = Host; "I" = Individuals.

species (Table 1). The majority of records involve *Caretta caretta,* both males and females, as well as adults and immatures. Within the molluscan epizoa, *Ostrea edulis* is the largest, and it is the most common species from the Mediterranean. *Sphenia antillensis* is the most frequent species from Georgia; and *Costoanachis floridana,* from Florida, U. S. A.

The mytilid from Tanzania, *Septifer bilocularis,* is found normally on littoral and sublittoral substrates of the Indo-Pacific; and it can grow to 50 mm in length. *Ostrea edulis* and *Mytilus edulis* are common and widespread in low littoral zones of the Mediterranean. In one case, epizoic oysters from Greece were immature (Host II), but in several cases (Hosts IV, V, VI, VII, and IX) they were of adult size and had evidently been attached to the turtle for several years. Each of these bivalves was well cemented to its hosts' shell, and remained affixed to parts of the turtle's scutes, even after having been pryed off (Fig. 1). In several cases, the dorsal valves are heavily abraded and even deeply scratched (Fig. 2), indicating that considerable pressure had been applied to the oyster (perhaps by a copulating male turtle), but they remained affixed to the turtles' shells until pryed off when collected.

The epizoan mollusks from Georgia and Florida are common sublittoral species in the western Atlantic, and although many individuals were immatures, their respective sizes indicated that they had settled onto their respective hosts at least several weeks before being collected.

Most *Costoanachis* spp., found on Hosts XVII to XXI, were of adult size. Probably the gastropods attached themselves to the turtles while they were resting on the sea floor.

In 12 of the cases presented, only one species of mollusk was present, and six of these involved only one individual mollusk. The greatest number of species present on a turtle was five, and a maximum of 31 individual mollusks were recorded on one turtle (Table 1).

An interesting comparison can be made between the marine turtle epizoa and the molluscan fauna found on a buoy that was moored for three and one half years off the southern end of Cumberland Island, Georgia (MERRILL, 1963). When the buoy was brought to land nearly 5,000 individual mollusks were collected and examined, comprising nine species of bivalves and three species of gastropods. None of the gastropods have been recorded on turtles, but three of the bivalves have: *Brachidontes exustus* constituted about 70 % of the mollusks identified from the buoy; *Ostrea equestris* made up the majority of the biomass of the buoy collection; and *Chama macerophylla* was represented by six individuals.

With the possible exception of some populations of *Caretta caretta,* the occurrence of molluscan epizoa on turtles is rare, and this needs explaining. Most sedentary mollusks may be poorly adapted to survive on living substrates which move and can easily crush or scrape off attached objects. Yet, even the remains of valves attached to turtle shells are not documented. Mytilids, such as *Lithophaga* sp., that bore into live scleractinian corals and other stationary substrates have avoided the problems of both exposure and unstable substrates. Although there are a variety of burrowing bivalves *(Lithophaga, Petricola, Martesia,* and *Teredo),* some of which are common or abundant on free-floating objects (*e. g.* teredinids in wood), burrowing bivalves are rare on free-living

organisms (see CLAPP & KENK, 1963). Only two boring species of bivalves were found in this study. An immature *Petricola lithophaga* was attached to an epizoic oyster, and not directly to the turtle (Host V), and a single *Rupellaria typica* (which bores into coral) was found on Host XIV.

Of the turtles that are encountered at Cumberland Island, Georgia, it is the emaciated ones that have larger numbers of barnacles on the carapace and a larger variety of epizoic taxa. The heavily infested *Chelonia mydas* from Brazil was evidently in poor health when captured. However, "healthy, normal" female *Caretta caretta* that nest in Greece have unusually heavy epizoan loads, and the same applies to the *Lepidochelys olivacea* that nest in Orissa. In addition to differences between turtles in a population, there are geographic differences not only in taxa but also in general levels of epizoan infestation.

JACKSON & ROSS (1971) and JACKSON *et al.* (1973) discussed the requirements of settling veligers and concluded that the diamondback terrapin shell is "marginally acceptable as a substrate". They mentioned problems of the wide thermal and salinity regimes in which the terrapins occur and especially the vulnerability of spat to desiccation when their hosts leave the water for basking, nesting and other activities.

The same problems are, however, of minor importance with sea turtles. Basking on land is known in only *Chelonia mydas,* and nesting occurs in only a part of the population – the adult females. *Dermochelys coriacea* has no keratin on its shell, but instead a thick, grease-backed integument, whereas all other sea turtles *(Cheloniidae)* have hard, horny scutes. Hence, an apparently suitable substrate is available on female cheloniids at least until they reach sexual maturity and on all males of this family. Turtles frequently present available substrates, being in the "right" places at the "right" times for veligers to settle, for turtles are frequent inhabitants of reefs and other coastal waters rich in mollusks: *Caretta* feeds avidly on mollusks (HUGHES, 1974: 17). *Eretmochelys imbricata* and *Caretta caretta* are commonly immobile for many minutes on the bottom, a behaviour that would enhance the chances of veligers settling, and some populations of *Chelonia mydas* and *Caretta caretta* even hibernate on the sea floor for periods of months (FELGER *et al.,* 1976; CARR *et al.,* 1980). The turtle shell would seem to be an ideal substrate onto which to attach or into which to burrow, and it is unclear why it is not colonized more often by mollusks.

On the other hand, the turtle apparently has nothing to gain by carrying epizoa. ALLEN & NEILL (1952) and JACKSON & ROSS (1971) mentioned the complications caused by encrusting mollusks. Terrapins could not swim normally and were probably more liable to predation, and a female might be unable to copulate because the space occupied by mollusks attached to her carapace could prevent a male turtle from mounting and holding onto her. These problems are less likely for sea turtles which attain much greater sizes, but a mass of encrusting organisms probably increases drag, thereby impeding locomotion, and burrowing organisms cause internal damage and possibly structural weakening of bones (J. FRAZIER, pers. obs.). It is not known how important these considerations are; but, the smaller the turtle, the greater the relative impact is likely to be.

The frequency of mollusks was similar on three sea turtle species, but field observations suggest that mollusks occur on *Caretta* more frequently than on any other species of sea turtle. This could be related to the morphology, or behaviour, or habitat of the turtle. *Caretta* is more typical of inshore, subtropical and temperate waters than are the other marine turtles. It feeds especially on mollusks, which it crushes with its tremendous beak and jaws. Scutes of this turtle are often rough and appear to be flaking. These characteristics increase the chances of *Caretta* being near veligers, stationary, and presenting a textured substrate.

Colonization is simpler for mobile gastropods as they can simply crawl onto a stationary turtle. The occurrence of certain gastropods on marine turtles may have implications for the health of the turtles. In the few spirorchid fluke life cycles that are known, gastropods are the first intermediate hosts. These flukes are known to infest marine turtles, but the link in the turtle-fluke relationship has not been identified (WOLKE *et al.*, 1982). It is possible that *Costoanachis* spp. serve as intermediate hosts in the life cycles of spirorchid flukes, and this topic needs further study.

The absence of previous records of sessile mollusks on sea turtles is probably due to two factors: few observers have made careful collections and observations; and the mollusk-turtle relationship is relatively uncommon. Nevertheless, these records are valuable, for they help define the habitat utilization and requirements of both host and epizoa. They may also help explain biogeographic distributions of certain mollusks. The rareness of the relationship suggests an antifouling mechanism by the turtle. Marine turtle scutes are not shed, but they may flake away, especially in *Caretta* and *Lepidochelys*. In the case of *Dermochelys coriacea,* the grease-impregnated integument may inhibit successful colonization by veligers. There also may be an avoidance of turtles and other living substrates by veligers. Neither antifouling nor substrate avoidance are well understood, and, consequently, they warrant further study.

Summary

Surveys of epizoa on five species of marine turtles revealed the first records of bivalve and shelled gastropod mollusks; 15 different bivalves and five species of gastropods were identified. Three species of turtle carried mollusks with approximately similar frequencies. Twenty records of *Caretta caretta* are discussed, and field observations suggest that this turtle is most commonly associated with epizoan mollusks. One case of *Eretmochelys imbricata* and three cases of *Lepidochelys olivacea* are also presented, and there are two sight records for *Chelonia mydas*. The most common epizoan mollusk in Greece was *Ostrea edulis;* in Georgia, *Sphenia antillensis;* and in Florida, *Costoanachis floridana.* There are no known obligate mollusk-turtle relationships, although there may be a casual one including a spirorchid blood fluke. In many cases only one species or one individual of a mollusk was found on a turtle, but as many as five species and 31 individuals were recorded on single hosts. Shells of cheloniid turtles appear to be suitable substrates for mollusks, so the rareness of turtle epizoa needs explaining. The impact on the turtle may be minimal, but mollusks could increase drag. Burrowing mollusks, unknown in turtles, could cause damage to the host, and the turtles appear to have some anti-mollusk defenses.

Note added in proof

The difference in epizoan mollusks reported from *Caretta caretta* in Georgia and in Florida may not be as great as indicated above. During 1982 and 1983, Applied Biology, Inc., was collecting only those mollusks readily observable on Hutchinson Island turtles, although barnacle infestations were frequently noted. Since the present paper was drafted, further studies have included detailed examinations of barnacle encrustations. These show that, as in Georgia, *Sphenia antillensis* is a frequent bivalve epizoan on *Caretta caretta*.

Acknowledgements

We are grateful SUSAN FREDERICQ for identifying the algae; Dr. K. FAUCHALD, the worms; Mrs. E. JOAKIMIDOU, the venerid bivalve, Dr. H. W. HARRY, the *Crassostrea* sp. from India, and Dr. B. KENSLEY, the *Lepas*. Drs. C. BERG, T. BOWMAN, C. H. ERNST, G. M. F. G. MARCOVALDI, J. N. NORRIS, P. C. H. PRITCHARD, E. PROFFITT, E. REESE, C. R. SHOOP and G. ZUG made valuable comments. Studies on Hutchinson Island by Applied Biology, Inc. were funded by Florida Power & Light Company, Miami, Florida. We are grateful to many organizations and individuals in many countries who assisted with the field work.

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P.S.Z.N. I: Marine Ecology, 6 (2): 141–165 (1985)
Accepted: 10. 10. 1984

ISSN 0173-9565/InterCode: MAECDR

Growth Dynamics in *Posidonia oceanica* (L.) DELILE

I. Seasonal changes of soluble carbohydrates, starch, free amino acids, nitrogen and organic anions in different parts of the plant

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With 9 figures and 11 tables

Key words: Seagrasses, *Posidonia,* growth dynamics, carbohydrates, nitrogen, free amino acids.

Table of contents

Abstract. Amounts of photosynthate in the rhizomes, in photosynthetically inactive basal parts of the leaves and different old leaf blades were examined. Winter leaf growth was supported by mobilisation of starch in the rhizome. This winter growth enables *Posidonia oceanica* to utilize the increased energy influx in early spring via the substantial leaf area already developed and to approach highest productivity in spring. During summer and autumn considerable concentrations of soluble carbohydrates were found in the leaves and rhizomes. Starch was stored in the rhizomes in concentrations of up to 6.8 % of dry weight. Levels of nitrogen and free amino acids were correlated with growth rates. The percentage of total nitrogen present as free amino acid-nitrogen decreased