Occurrence and Effects of Barnacle Infestations on Diamondback Terrapins (Malaclemys terrapin)

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ABSTRACT: The occurrence and effects of barnacle infestations on two populations of diamondback terrapins were studied from 1977 to 1979 at the Merritt Island National Wildlife Refuge, Brevard Co., Florida. Three species of barnacles were found on *Malaclemys: Balanus eburneus, Chelonibia manati* and *C. testudinaria.* Of 125 turtles examined, 76% were infested by barnacles. Barnacles settled on the carapace of turtles significantly more frequently than on the plastron. Infestation rates differed sharply between the two populations. No differences in fouling rates were found between the sexes. The major effects of barnacles on *Malaclemys* were interference with nesting activity and shell erosion. In a few cases, such erosion was severe enough to cause fatal injuries to turtles. It is suggested that barnacles infesting turtles be considered as parasites, rather than commensals.

INTRODUCTION

Barnacles (Order Cirripedia) are well-known and conspicuous fouling organisms of marine animals, including such diverse forms as cetaceans (Ross and Newman, 1967), sea snakes (Jeffries and Voris, 1979) and marine turtles (Ernst and Barbour, 1972). However, barnacles have also been reported to infest a number of so-called freshwater turtles (Chelydridae, Emydidae) as well, including *Macroclemys temminckii* (Jackson and Ross, 1971a), *Pseudemys alabamensis* (Jackson and Ross, 1972), *P. rubiventris* (Arndt, 1975) and especially *Malaclemys terrapin* (Jackson and Ross, 1971b; Ross and Jackson, 1972; Jackson *et al.*, 1973). Reports of barnacle infestations of turtles are primarily descriptive, and are insufficient to indicate either what proportion of a given population is infested by barnacles, how infestation rates differ between populations, or what effects such infestations have on individual turtles. In this paper I examine quantitatively the occurrence and effects of barnacle infestations on two populations of diamondback terrapins *(Malaclemys terrapin tequesta)* in E-central Florida.

MATERIALS AND METHODS

Malaclemys populations were studied from 1977 to 1979 at the Merritt Island National Wildlife Refuge, Brevard Co., Fla., a large (22,700 ha) coastal area composed primarily of brackish water lagoons and impoundments. A more detailed description of the study area is given elsewhere (Seigel, 1979). Turtles were collected mainly from two lagoons, known locally as the Indian and Banana rivers (hereafter abbreviated as IR and BR, respectively). The study sites were separated by approximately 20 km of land and water so the two populations were effectively isolated from one another. *Malaclemys* (IR) were collected with small-mesh gill nets, whereas BR turtles were captured by hand (Seigel, in press). The following data were recorded for all individuals: straight-line carapace and plastron length, wet body weight and sex. The presence of external scars or injuries was also noted. All turtles were given an individual mark (Ernst *et al.*, 1974), and released at point of capture. Data taken on barnacles included species, number, location and rostro-cranial diameter. Salinity was measured with a refractometer.

Because barnacles on many turtles were too numerous to count accurately, infestations were ranked according to the following scale: absent = no barnacles present; light = 1-5 barnacles; moderate = 6-15 barnacles; heavy = 16-25 barnacles, and ex-

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tremely heavy = 26 or more barnacles. Separate counts were maintained for the carapace and plastron, as well as by sexes of turtle.

Statistical tests follow Sokal and Rohlf (1969) and Ott (1977). All tests are significant to the 0.05 level, unless otherwise indicated.

RESULTS AND DISCUSSION

Fouling organisms.—Three species of barnacles were taken from Merritt Island *Malaclemys: Chelonibia manati lobatibasis* and *Balanus eburneus* were the most abundant species, representing 47.9% and 42.4% of identified samples (n = 73); *C. testudinaria* was found in only 9.5% of the samples. *Balanus eburneus* ranges from South America to New England (Bousfield, 1954) and has been reported previously from *Malaclemys* in western Florida (Jackson *et al.*, 1973). *Chelonibia testudinaria* is also widespread (Ross and Newman, 1967) and is commonly associated with marine turtles (Ernst and Barbour, 1972). *Chelonibia m. lobatibasis* is a tropical species, known primarily from manatees (Ross and Newman, 1967). This report apparently is the first record of *C. m. lobatibasis* on turtles; however, V. Zullo (pers. comm.) suggests that the *C. m. lobatibasis* found on *M. t. tequesta* may represent a form of *C. testudinaria* limited to lower salinities, but this has not been confirmed.

Settling sites.—Of 125 *Malaclemys* examined, 96, or 76.8%, were infested by barnacles. Common settling sites included all parts of the shell (carapace, plastron, bridge and marginals) and (rarely) on the head and limbs. At both study sites the carapace had a significantly heavier infestation rate than the plastron (Table 1; paired sign test, $p < .05$). Other reports of barnacle infestations on turtles also indicate that the carapace is the most likely site to be infested (Jackson and Ross, 1971, 1972; Arndt, 1975). Settling on the carapace may be advantageous for barnacles due to increased water (and food) flow, and in freedom from abrasion when the host moves on land. In addition, if barnacle larvae settle on *Malaclemys* while the turtles are quiescent, the carapace would be the most likely site to be exposed. However, barnacles inhabiting the carapace might face an increased chance of desiccation if the host basks frequently, as does *Malaclemys*.

Infestation rates.—Infestation rates in the BR were significantly higher ($X^2 = 82.2$, $df = 4$, $p < .01$) than in the IR (Table 2). The reasons for these differences are not immediately clear. Bousfield (1954) listed salinity and temperature as the major factors limiting barnacle distributions. The close proximity of the two populations in this study (< 20 km apart) suggests that temperature differences are minor. Although there are significant differences in salinity levels between the sites (IR $\bar{X} = 31.6 \pm 2.34\%^{\circ}$; BR $\bar{X} = 27.6 \pm 2.52\%^{\circ}$, $t = 4.03$, $p < .05$), the levels in both areas fall well within the range of salinities necessary for normal development of *Balanus eburneus* (Crisp and Costlow, 1963). Comparable data for *Chelonibia testudinaria* and *C. manati* are lacking, but the congener *C. patula* survived well in the salinities found at both study sites (Crisp and Costlow, 1963).

Another possible cause for these differences may be the behavior of the hosts. Ross and Jackson (1972) suggested that desiccation might be an important source of mortality for barnacles inhabiting basking turtles. Owing to a lack of suitable basking sites, BR *Malaclemys* basked less frequently than IR turtles (Seigel, pers. observ.). Increased

TABLE 1.—Comparison of infestation rates of the carapace vs. the plastron for Indian River *Malaclemys*. Similar results were found for the Banana River, but are not shown. N = 93

# Barnacles (infestation class)		Carapace (%)	Plastron (%)
0	(Absent)	32.0	70.5
1-5	(Light)	44.9	23.0
6-15	(Moderate)	14.1	1.3
16-25	(Heavy)	7.7	5.1
26 +	(Ext. Heavy)	1.3	0.0

basking by IR turtles may serve to limit barnacles through higher desiccation rates than are encountered in the BR. A third possibility is that barnacles are being shed at different rates in the two populations. Despite the contention of Jackson and Ross (1971b) that ecdysis is absent in *Malaclemys,* terrapins at Merritt Island shed their scutes (and often the associated barnacles) at least once/year. If ecdysis was more frequent in the IR population, this might account for the different infestation rates noted above. However, data to confirm this possibility are lacking.

Given the marked degree of sexual size diorphism in *Malaclemys* (Fitch, 1981; Seigel, in press), it was anticipated that the much larger female terrapins would experience a higher infestation rate than males. However, there was no significant difference between the sexes ($X^2 = 2.50$, df = 4, $p < .10$). The only ready explanation for this result concerns the amount of time individuals are exposed to fouling organisms. Owing to differences in growth rates (Seigel, in press), a male terrapin with a plastron length of 9 cm may be older than a female with a plastron length of 12 cm, and thus may have been exposed to barnacles for a longer period of time. Possibly, this difference in duration of exposure may be sufficient to counter the increased surface area available for barnacles infesting female *Malaclemys,* resulting in equal infestation rates between the sexes.

Effects of barnacle infestations. — The effects of barnacles on *Malaclemys* may be divided into two general categories: interference with normal activities and physical damage.

Interference with normal activities may be subdivided as follows: (1) interference with movement, (2) interference with mating, and (3) interference with nesting. Barnacles appeared to have little or no effect on the swimming and/or feeding ability of terrapins. Even those individuals with heavy or extremely heavy infestations appeared to be hydrodynamically stable in the water and seemed to have no difficulty in swimming normally. Jackson and Ross (1971b) also found that even those turtles with heavy fouling loads could move normally in the water. A more important effect of barnacle fouling is interference with mating. Like most turtles, *Malaclemys* mate with the plastron of the male pressed against the carapace of the female (Seigel, 1980b). Any factor which could cause the two individuals to be kept apart (such as barnacles on the female carapace or male plastron) might prevent mating by making it impossible for the cloaca of the male to reach that of the female. Although such interference was never witnessed in the field, it seems probable that any female with an extremely heavy barnacle infestation on the carapace, or any male with similar fouling on the plastron, might experience reduced mating success. Limited data on males suggest that they are rarely, if at all affected. However, 3.1% of the BR females and 1.3% of the IR females had carapace infestations heavy enough to potentially prevent mating (Fig. 1).

As Jackson and Ross (1971b) suggested, the most important effect of barnacles on turtles is interference with nesting. Many females in this study with heavy to extremely heavy infestations on the plastron had considerable difficulty in moving on land. In one case, a BR female had an infestation 3 cm thick on the plastron, which completely prevented her limbs from touching the ground. Females affected in such a manner are probably incapable of constructing a normal nest chamber, and will probably experience reduced reproductive success as a result of decreased egg survivorship. In ad-

TABLE 2. — Comparison of infestation rates of Banana River (N = 32) and Indian River (N = 93) *Malaclemys*

# Barnacles	(infestation class)	Banana River (%)	Indian River (%)
0	(Absent)	6.0	29.0
1-5	(Light)	12.1	41.9
5-15	(Moderate)	15.2	16.3
16-25	(Heavy)	60.6	11.6
26 +	(Ext. Heavy)	6.0	1.2

dition, such females may be less mobile than nonaffected turtles, and might be more susceptible to predation while nesting (Jackson and Ross, 1971b; Seigel, 1980a). Barnacles may cause interference with nesting in 28% of the BR turtles examined, and in 5.1% of the IR turtles.

Most damage caused by barnacles took the form of shell erosion, especially of the carapace (Fig. 1). Although most barnacle-related shell erosion was minor, in two cases barnacles appeared to be at least partly responsible for fatal injuries. In the first case, a

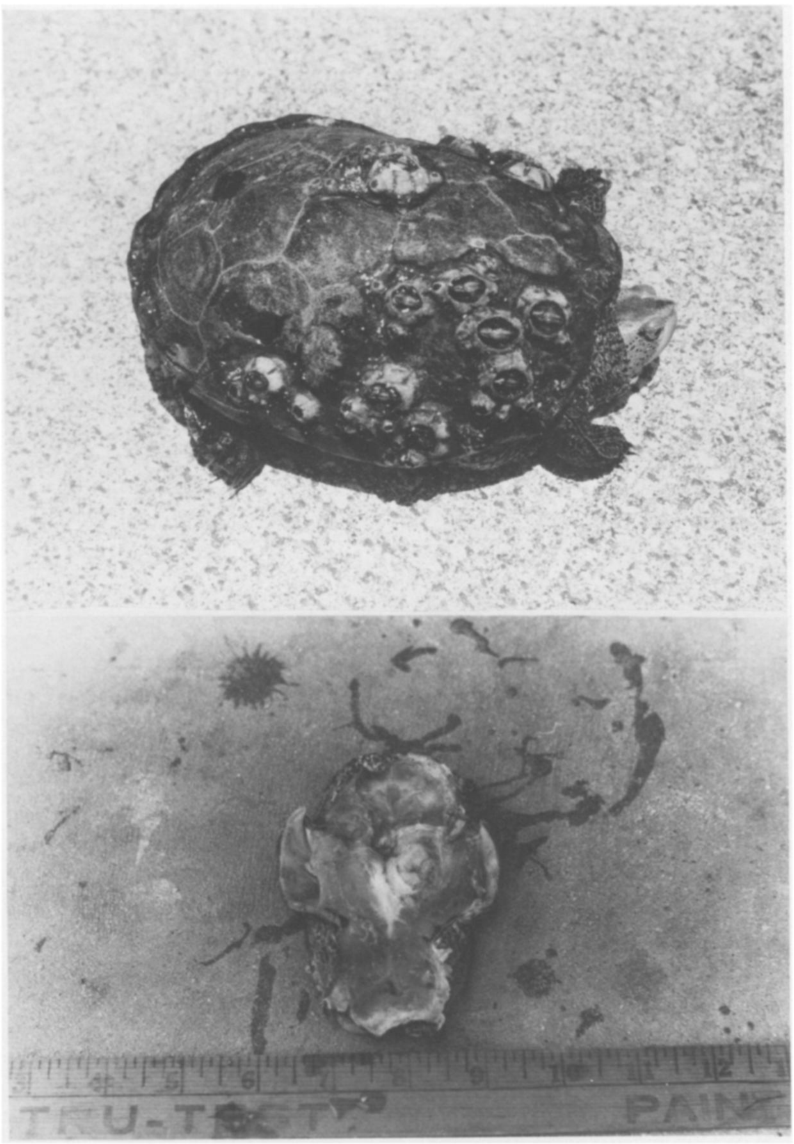

Fig. 1.—Upper. Banana River female with an extremely heavy barnacle infestation on the carapace. Note shell erosion along the anterior edge of carapace. Lower. Plastron of Banana River male showing scar tissue mass resulting from barnacle growth

BR female (plastron length = 15.7 cm) was initially captured on 21 September 1977 with a large clump of barnacles located over the pectoral and abdominal scutes. This individual was subsequently recaptured on 16 June and 8 July 1978. By 8 July, the turtle had grown 0.1 cm in plastron length, but had lost 25 g in body weight. On 3 August 1978 the turtle was found dead in the water, about 50m from the original capture site. When the barnacles were removed, a deep pit (ca. 2 cm wide x 1.0 cm deep) was found in the plastron, clearly caused by the growth of the barnacles. Upon dissection, a large mass of scar tissue (ca. 2 cm wide x 1.5 cm thick) was found on the inside of the plastron, directly opposite where the barnacles had been growing (Fig. 1). This mass was pressing directly against the heart, and it is suggested that this was at least partly responsible for the death of the turtle. In the second case, a BR male (plastron length = 10.2 cm) was initially captured on 24 July 1978, in apparently good condition. On 10 August 1978, this individual was found dead with a small hole (0.5 cm diam) in the plastron, apparently caused by barnacle erosion. Because the deaths of these individuals was not actually witnessed, it cannot be claimed with certainty that barnacles were the direct cause of death, but there is strong circumstantial evidence that barnacles were involved.

Ernst and Barbour (1972) noted that it is often difficult to determine whether barnacles represent commensals or true parasites of turtles. Pianka (1978) considered interactions between organisms to be parasitic, if "population A, the parasite, exploits members of population B, the host, which is affected adversely." This definition suggests that barnacles should be considered as parasites of turtles, rather than commensals, because they may significantly interfere with the activities of the turtles (especially nesting activity) and may, in rare cases, cause the death of some individuals.

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