Journal of the Arkansas Academy of Science

Volume 50 Article 32

1996

Microorganisms Associated with the Carapace and Plastron of Aquatic Turtles (Pseudemys concinna and Trachemys scripta) in Southwestern Arkansas

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The "mossback condition" (the presence of epizoophytic algae) on the carapace of aquatic turtles is well documented (Edgren et al., 1953; Neill and Allen, 1954; Proctor, 1958; Gibbons, 1968; Belusz and Reed, 1969). The degree of colonization varies among species of turtles, presumably due to differential use of habitat and basking activities (Edgren et al., 1953; Ernst and Barbour, 1972) and the fact that some turtle species periodically shed scutes thereby removing the growth of algae (Gibbons, 1968; Ernst and Norris, 1978).

The most common and best studied forms of algae causing this condition are *Basicladia chelonum* and *B. crassa* (Proctor, 1958), although *Cladophora glomerata, Rhizoclonium hieroglyphicum, Dermatophyton radicans,* and *Gongrosira debaryana* also have been reported (Edgren et al., 1953; Dixon, 1960; Belusz and Reed, 1969; Ernst and Barbour, 1972; Hulse, 1976). In addition to these green algae, Belusz and Reed (1969) reported the cyanobacterium *Plectonema tenue* on the carapace of a common snapping turtle (*Chelydra serpentina*), and another cyanobacterium (*Entophysalis rivularis*) was found growing epiphytically on *Basicladia* spp. on the stinkpot turtle (*Sternotherus odoratus*) and on the common snapping turtle (Edgren et al., 1953). *Oscillatoria* sp., *Trichodesmium* sp., and *Lyngbya* sp. also have been reported (Ernst and Barbour, 1972).

Basicladia spp. were thought to occur exclusively on the carapace of aquatic turtles, but Proctor (1958) reported it attached to stones and concrete walls of turtle pens, and Curry et al. (1981) reported it on the shells of freshwater clams in Louisiana. Additional algae not reported on turtles were associated with *Basicladia* spp. in these situations, and it is likely that other algae occur on turtles.

Algae that colonize a substrate set up conditions which allow a community of microorganisms to develop. However, literature lacks any documentation of the diversity of other microorganisms present on turtles. Proctor (1958) noted only that "several other filamentous algae that are common to streams occasionally attach to turtle shells." Further, Neill and Allen (1954) stated simply that the algal growth on turtles supports a fauna of crustaceans, including cladocerans, copepods, ostracods, and amphipods. A few commensal organisms have been documented on certain turtles. Evermann and Clark (1916) reported the protozoan *Opercularia* sp. on the plastron of stinkpots; Dixon (1960) found the bryozoan *Plumatella* sp. on several turtle species, and Goodrich and Jahn (1943) listed epizoic suctorian protozoans from the western painted turtle (*Chrysemys picta*).

Turtles move between bodies of water, and because they often carry a community of micro-organisms on the carapace and plastron, they likely aid in the dispersal of at least some forms of life associated with the shell. The objective of this study was to evaluate the diversity of organisms that could be found associated with the shell of aquatic turtles in Arkansas.

The study was focused on a pond near Highway 70 in the southeastern corner of Montgomery County, Arkansas, in which turtles were abundant. Collections of Missouri cooter (*Pseudemys concinna metteri*) and red-eared slider (*Trachemys scipta elegans*) were made during September, October, and December, 1995, and March, 1996. A long-handled dipnet was used to capture turtles, which were placed separately in buckets for transportation to the laboratory. The condition of the shell was noted as being clean, muddy, or "mossy." Within one day of capture, the carapace and plastron were scraped in several locations and the samples placed on slides for identification of organisms. Identification of motile organisms was aided by use of Protoslo® medium (Carolina Biological Supply Company). The entire slide was searched using transects across the viewing field. Occurrence of species was tabulated and relative abundance of some organisms was noted, but counts were not taken. After sampling of organisms, turtles were released in a similar habitat in Montgomery County (not the same pond to avoid resampling).

Classification of organisms was based generally on Whitford and Schumacher (1984) for algae and Pennak (1978) for invertebrates. Pennak (1978) arbitrarily was followed for classification of flagellates.

At least 92 different taxa of microorganisms were identified, including 4 Cyanobacteria, 21 green algae (of which 9 were desmids), 13 diatoms, 12 flagellated protozoans, 4 sarcodinians, and 19 ciliates (Table 1). Also encountered were flatworms, gastrotrichs, rotifers, nema-

todes, oligochaetes, cladocerans, copepods, ostracods, and bloodworms.

Most of the turtles examined (n=38) were cooters, which partly may account for the larger number of taxa of microorganisms found on cooters in comparison with the number found on red-eared sliders (n=12). Due to sample size, statistical analysis was limited to the sample of cooters. Two-way analysis of variance (ANOVA) was used to compare the number of taxa found on the carapace and plastron of cooters over three months of collection. Mean numbers of taxa on the carapace for September, October, and December were 19.6, 21.1, and 8.8, respectively. For the plastron means were 12.3, 11.8, and 7.3. The carapace supported significantly more taxa than the plastron ($P<0.0001$), and the number of taxa of microorganisms present varied with month of collection ($P<0.0001$). A Tukey's test (Sokal and Rohlf, 1981) indicated no difference between the number of taxa present in September and October, but both months differed from December samples. Conditions during the first two months apparently promoted photosynthesis, whereas by December colder weather, reduced photoperiod, reduced surface activity of turtles, and the shedding of scutes likely affected the decline in diversity of microorganisms found on the shell.

Diversity of microorganisms on the carapace and plastron also was examined in relation to the appearance of the shell. Organisms recovered from clean shells were extracted from the spaces between scutes and often were dominated by *Oscillatoria* spp. and *Anacystis* (=*Polycystis*) sp. These cyanobacteria imparted a blue-green streak to the border between scutes on the plastron. A "mossy" appearance on the carapace was typical of filamentous epizoophytic algae, but a brownish mossy effect on the plastron (and not uncommonly on the chin) was due to attrached protozoans such as *Epistylis* sp.

ANOVA was used to evaluate whether appearance of the shell was related to the diversity of associated organisms on the carapace or plastron. Photosynthetic (autotrophic) and heterotrophic organisms were examined separately because they may respond differently to conditions. Diversity of photosynthetic taxa (Table 2) was greater on the carapace than on the plastron ($P<0.0001$), but diversity of heterotrophs did not differ significantly between carapace and plastron ($P=0.2560$). However, the plastron was observed to support greater densities of attached protozoans (suctorians and peritrichs). Motile protozoans, desmids, and other unattached organisms typically occurred in close association to the filamentous algae.

Table 1. Frequency of occurrence of microorganisms on the carapace and plastron of Missouri Cooter (*Pseudemys concinna metteri*) and Red-eared Slider (*Trachemys scripta elegans*) turtles from a pond in Montgomery County, Arkansas.

	Pseudemys (n=38)		*Trachemys* (n=12)	
	Carapace	Plastron	Carapace	Plastron
Cyanobacteria (Blue Green Algae)				
Anabaena sp.	0.08	0.08	—	—
Oscillatoria spp.	0.97	0.89	1.00	0.83
Anacystis sp.	0.89	0.45	0.83	0.17
Spirulina sp.	0.50	0.34	0.42	0.33
Chlorophyceae (Green Algae)				
Basicladia sp.	0.37	0.16	0.42	—
Spirogyra spp.	0.03	0.03	—	0.08
Oedogonium sp.	0.03	—	—	—
Bulbochaete sp.	0.05	—	—	—
Mougeotia sp.	0.03	—	—	—
Ankistrodesmus sp.	0.18	0.03	0.17	—
Coelastrum sp.	0.05	—	0.08	0.08
Pediastrum sp.	0.03	0.08	—	0.08
Scenedesmus spp.	0.68	0.34	0.75	0.25
Selenastrum sp.	0.05	—	0.17	0.08
Tetraedron sp.	—	—	0.08	—
Treubaria sp.	0.08	—	0.08	—
Desmids				
Arthrodesmus sp.	0.37	0.05	0.50	0.17

Cosmarium spp.	0.21	—	0.17	—
Closterium spp.	0.13	0.05	0.17	—
Desmidium sp.	0.05	—	—	—
Euastrum sp.	0.05	—	—	—
Micrasterias spp.	0.03	—	—	—
Netrium sp.	0.03	—	—	—
Pleurotaenium spp.	0.11	0.08	—	—
Staurastrum spp.	0.71	0.53	0.75	0.42
Xanthophyceae				
Tribonema sp.	0.03	0.03	—	—
Bascillariophyceae (Diatoms)				
Cocconeis sp.	0.11	0.05	—	—
Cymbella spp.	0.34	0.05	0.33	—
Eunotia sp.	0.13	0.03	0.17	0.08
Fragillaria spp.	0.21	0.16	—	0.08
Stauroneis sp.	0.26	0.08	0.33	—
Gomphonema spp.	0.13	0.05	—	—
Gyrosigma sp.	—	0.03	—	—
Melosira sp.	0.03	0.03	—	—
Navicula spp.	0.89	0.39	0.92	0.17
Pinnularia spp.	0.47	0.08	0.58	0.08
Synedra spp.	0.47	0.24	0.25	—
Surirella sp.	0.16	0.03	0.08	—
Tabellaria sp.	0.05	0.03	0.08	—
Protozoa				
Mastigophora				
Dinoflagellida				
Peridinium sp.	0.55	0.13	0.75	—
Unidentified	—	—	0.08	—
Chrysomonadida				
Dinobryon sp.	0.08	—	0.08	—
Volvocida				
Chlamydomonas sp.	0.45	0.13	0.33	0.08
Gonium sp.	0.05	—	—	—
Haematococcus sp.	—	—	0.08	—
Pandorina sp.	0.24	0.03	0.25	—
Pleodorina sp.	0.03	—	0.08	—
Euglenida				
Euglena spp.	0.61	0.29	0.58	0.25
Peranema sp.	0.11	0.11	—	—
Phacus spp.	0.24	0.05	0.25	—
Trachelomonas spp.	0.42	0.18	0.42	0.33
Sarcodina				
Amoebida				
Amoeba sp.	0.08	0.03	0.08	0.08
Testacida				
Difflugia spp.	0.29	0.05	0.17	—
Euglypha sp.	—	0.03	—	—
Sarcodina				
Proteomyxida				
Nuclearia sp.	0.05	0.05	0.08	0.17
Ciliophora				
Holotrichia				
Amphileptus sp.	0.03	—	—	—
Chilodonella sp.	0.03	0.03	0.08	0.08
Dileptis sp.	0.05	—	—	—
Litonotus sp.	0.29	0.18	0.25	0.17

Spirotrichia				
Bursaridium sp.	0.03	—	—	—
Euplotes sp.	0.03	—	—	—
Stentor sp.	0.08	0.05	—	—
Stylonychia sp.	0.08	—	—	—
Unidentified	0.53	0.45	0.58	0.50
Suctoria				
Achineta sp.	0.03	0.08	—	0.17
Metacineta sp.	0.11	0.18	0.17	0.17
Paracineta sp.	—	—	0.08	—
Podophrya sp.	0.11	0.42	—	0.42
Solenophrya sp.	0.11	—	—	0.08
Tokophrya sp.	0.26	0.47	0.17	0.17
Unidentified	0.66	0.87	0.67	0.83
Peritrichia				
Epistylis sp.	0.76	1.00	0.92	1.00
Opercularia sp.	0.05	0.29	0.08	0.08
Vorticella sp.	0.42	0.24	0.17	—
Platyhelminthes				
Turbellaria				
Stenostomum sp.	0.05	0.03	0.08	—
Gastrotricha				
Chaetonotus sp.	0.03	0.03	—	—
Rotatoria				
Bdelloidea				
Philodinidae	0.61	0.61	0.75	0.67
Floscullariacea				
Flosculariidae				
Floscularia sp.	0.03	—	—	—
Ploima				
Notommatidae				
Scaridium sp.	0.03	—	—	—
Unidentified	—	0.03	—	—
Synchaetidae				
Polyarthra sp.	0.03	—	—	—
Brachionidae				
Keratella sp.	0.13	—	0.25	—
Lepadella sp.	—	0.03	—	—
Notholca sp.	0.03	—	—	—
Unidentified	—	0.03	—	—
Nematoda	0.63	0.53	0.58	0.25
Annelida				
Oligochaeta				
Aeolosoma sp.	0.03	0.03	—	—
Crustacea				
Cladocera				
Bosminidae				
Bosmina sp.	0.03	0.03	—	—
Daphnidae				
Daphnia sp.	0.03	—	—	—
Copepoda (nauplius)	0.05	0.03	—	—
Ostracoda	0.18	0.03	—	—
Insecta				
Diptera				
Chironomidae	0.03	—	—	—

Table 2. Mean number of photosynthetic (autotrophic) and heterotrophic organisms on the carapace and plastron of 38 cooters (*Pseudemys concinna*), based on condition of the shell.

	Shell Description	Mean # of taxa on carapace	Mean # of taxa on plastron
Photosynthetic	Mossy (n=5)	12.4	4.0
	Muddy (n=16)	13.6	6.1
	Clean (n=17)	8.7	4.3
Heterotrophic	Mossy (n=5)	7.8	7.4
	Muddy (n=16)	8.8	6.0
	Clean (n=17)	4.7	5.8

Significant variation also was detected based on the condition of the carapace ($P<0.0014$ for photosynthetic taxa and $P<0.0062$ for heterotrophs). Tukey's tests indicated that a clean carapace has significantly fewer taxa ($P<0.05$) of photosynthetic and heterotrophic organisms than do muddy shells. Comparisons of muddy versus mossy and mossy versus clean carapaces did not differ in diversity of organisms.

Only two specimens of cooters were examined during March, but the number of taxa increased from December values ($\bar{x}$=22.5 on carapace, $\bar{x}$=13 on plastron). It appears that lengthened photoperiod and increased turtle activity resulted in increased colonization of the shell. A muddy carapace usually produced the greatest diversity of microorganisms. As turtles move among pools, ponds, lakes, and streams, they aid dispersal and colonization of their associated microcommunity. The diversity or organisms on turtles appears to be much greater than present literature indicates.

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