Diez, C. E. and R. van Dam. 1998. Caribbean hawksbill turtle morphometrics. Bulletin of Marine Science 62(1):145-155.

Frazier, J., I. Goodbody and C. Ruckdeschel. 1991. Epizoan communities on marine turtles:II Tunicates. Bulletin of Marine Science 48(3):763-765.

Frick, M. G., K. L. Williams and M. Robinson. 1998. Epibionts associated with nesting loggerhead sea turtles (*Caretta caretta*) in Georgia, USA. Herpetological Review 29(4):211-214.

Senties, A., J. Espinoza-Avalos and J. C. Zurita. 1999. Epizoic algae of nesting sea turtles *Caretta caretta* (L.) and *Chelonia mydas* (L.) from the Mexican Caribbean. Bulletin of Marine Science 64(1):185-188.

Table 1. Range of straight carapace length (SCL) cm in 13 size classes.

Class	Range
1	20.00-24.99
2	25.00-29.99
3	30.00-34.99
4	35.00-39.99
5	40.00-44.99
6	45.00-49.99
7	50.00-54.99
8	55.00-59.99
9	60.00-64.99
10	65.00-69.99
11	70.00-74.99
12	75.00-79.99
13	> 79.99

Epibiont Community Succession on Nesting Loggerhead Sea Turtles, *Caretta caretta*, from Georgia, USA

Michael G. Frick[1], Kristina L. Williams[1], David X. Veljacic[1], J. Andrew Jackson[2], and Stacie E. Knight[2]

[1]*Caretta Research Project, Post Office Box 9841, Savannah, Georgia 31412, USA (Caretta05@aol.com)*

[2]*Coastwise Consulting, 173 Virginia Avenue, Athens, Georgia 30601, USA*

Docks, buoys, and limestone outcroppings in Georgia support an extensive community of motile and non-motile organisms commonly referred to as 'fouling' organisms. Prior to colonization by fouling forms, a submerged substrate develops a 'slime' coat that consists mainly of algae, bacterium, and nematodes. The accumulated 'slime' coat provides nutrients that ultimately attract larval invertebrates to settle upon the substrate. The first macroscopic fouling forms to colonize the substrate are referred to as the 'pioneer species'. The pioneer species observed in most fouling communities are barnacles (Dean, 1981). Initial colonization by barnacles provides refuge and substrate for the immigration of certain fouling forms into the community based upon how the barnacles have three-dimensionally shaped and nutritionally enriched the existing community. Thus, the presence of a particular fouling organism ultimately influences the colonizing ability of later arriving species.

Generally, fouling communities can be categorized as either successional or non-successional based upon the patterns of immigration and emigration of sessile organisms to and from the observed community (Sutherland and Karlson, 1977). A fouling community is considered to be non-successional when: 1) a pioneer species impedes the subsequent development and colonizing ability of other fouling forms, 2) species recruitment into the fouling community is highly variable from year to year during comparable time periods, or 3) community development does not result in a stable climax.

A fouling community is considered to be successional when: 1) an orderly and directional process of community member recruitment is observed from year to year during comparable time periods, 2) certain fouling organisms prepare the way for other fouling forms, or 3) community development results in a stable climax or common endpoint that perpetuates itself.

By monitoring tagged, nesting loggerhead sea turtles (*Caretta caretta*) we tried to determine whether or not a turtle's epibiota colonized the carapace in a successional pattern. If a successional colonization pattern was observed, we wanted to determine how long it took the observed community to climax. If the observed community climaxed, we wanted to document the species composition of the climax community. Once species composition was determined we would be able to identify any predators which may aid in community turnover or removal or the possible mechanisms a turtle might use to rid itself of the climaxed community.

Methods

Epibiont data was collected from nesting loggerheads on two Georgia barrier islands during the 1998 and 1999 nesting seasons (May-August): Wassaw Island (31°53.4'N, 80°58.4'W) and Jekyll Island (31°03.9'N, 81°24.9'W). Data were collected either by identifying and mapping epibiota onto data sheets or by photographing turtles. Digital photographs were catalogued and sorted into a computer database archive program. To assure that the natural integrity of the observed epibiont communities remained intact no epibionts were removed from turtles for this study.

Frequently observed turtles were picked out of the compiled data. We were able to determine if epibiont colonization was occurring in a successional pattern by using data from only relatively 'clean' remigrators that nested approximately every two weeks and that were observed or photographed from the onset of the nesting season to the end of the nesting season. Data from turtles that were initially seen and not observed for the remainder of the nesting season were not used for epibiont succession analysis. However, notes about their epibiont community were compared to the data obtained from frequently observed turtles and are discussed below.

Results

Out of 52 individual loggerheads surveyed, 12 turtles were seen approximately every two weeks from the onset of the nesting season to the end of the season. Twenty-three percent of the loggerheads observed for this study (23% = 12 turtles) hosted epibiont communities that exhibited a successional pattern of colonization. The average intranesting interval observed from 12 nesting loggerheads from Jekyll Island (n = 7) and Wassaw Island (n = 5) was 12.2 days (range: 10 days-16 days). The average number of nests deposited was 4.6 (range: 4 nests-7 nests).

All 12 turtles had relatively no epibiota when first observed nesting in May, with the exception of a few barnacles (*Chelonibia testudinaria*). *Chelonibia* colonization increased over the next two nesting observations and provided habitat to an assortment of small motile fouling forms (amphipods, crabs, polychaetes, etc.). By their fourth nesting observation (or approximately 42 days after the initial observation) all turtles had well developed epibiont communities of barnacles (*C. testudinaria*), bryozoans (*Bugula neritina*), and hydrozoans (*Tubularia crocea*) that covered approximately 75% of the carapace. Large aggregations of the aforementioned epibionts were also occasionally inhabited by several individual tunicates (*Molgula manhattensis*).

Three of the aforementioned turtles nested more than four times. All three turtles had retained their excessive epibiont loads up through their fifth nesting (or approximately 56 days from the initial observation). Additionally, tunicates (*Molgula manhattensis*) had almost completely overgrown the existing epibiont communities on all turtles. Two of the three aforementioned turtles had lost all their epibiota by their sixth nesting observation (or approximately 70 days after the initial observation). One turtle retained her epibiotic load through the sixth nesting observation. By this time her epibiont community consisted almost entirely of tunicates (*M. manhattensis*) and very few hydrozoans and bryozoans. The aforementioned turtle had lost all of her epibiota by the seventh nesting observation (or approximately 84 days after the initial sighting).

Discussion

Some nesting loggerheads in Georgia appear to host epibiont communities that exhibit a successional pattern of colonization similar to fouling community colonization patterns described by Dean (1981). Barnacles settled only in abundance on bare surfaces. Barnacle colonization was followed by hydrozoan and bryozoan colonization. The presence of hydrozoans and bryozoans enhanced settlement of tunicates. Tunicates subsequently dominated the community until unknown activities or methodologies ultimately rid turtles of their epibiotic community. These observed patterns of colonization suggest that tunicates (*Molgula manhattensis*) are the climax species within the carapace epibiont community on loggerheads in Georgia, and that the epibiotic community may climax in approximately 56–70 days after initial colonization by the pioneer species (*C. testudinaria*). Future studies, which investigate the growth rates of turtle barnacles in Georgia, would help to clarify the life span of a turtle's epibiotic community.

Other fouling community studies (on fixed substrata) report that tunicate colonization following hydroid colonization frequently results in the colonization and subsequent dominance (climax) of mussels within the community (Dean, 1981). On the turtles observed in this study, scorched mussels (*Brachidontes exustus*) did begin to appear following tunicate colonization but they did not dominate the community before turnover occurred. Sutherland and Karlson (1977) reported similar periods of catastrophic mortality (referred to as 'slough-offs') in fouling communities dominated by tunicates. Slough-offs are believed to be a result of spatial competition within the observed fouling community. Yet, it is possible that the observed epibiont communities were removed prematurely by the host turtles or by predators inadvertently 'grooming' the turtles. Based upon the extent of epibiotic colonization of the carapace prior to turnover, it is our belief that the slough-offs observed from loggerheads in Georgia occurred as a result of spatial competition within the epibiotic community. In further support, the largest turtles surveyed for this study hosted the oldest communities. This suggests that the more space available for community development, the longer the community can persist. Spatial competition amongst members of the epibiotic community obviously helps to rid sea turtles of excessive epibiont loads, which could adversely effect the hydrodynamics of the turtle's carapace (Logan and Morreale, 1994). Yet, the possibility exists that since the overall community was eventually replaced by soft bodied tunicates the turtle host would have had a much easier time removing the epibiont community via scratching on hard surfaces underwater or with the front flippers. Live barnacles would be much more difficult to remove, especially types specialized solely as sea turtle commensals (*C. testudinaria*; Caine, 1986).

Obviously there are many more epibiont species present within the epibiotic community than identified within the successional pattern described above. However, we only focused on the most common and most visible sessile organisms frequently observed as epibionts on loggerheads. It is possible that smaller, motile forms do influence patterns of epibiotic succession. Although, increased settlement is generally attributed to the presence of sessile organisms and motile organisms are not considered to be 'long term' residents of the fouling community (Dean, 1981).

A number of turtles initially surveyed for our study were either not seen again for the remainder of the nesting season, seen irregularly throughout the season, or found nesting on beaches well away from the study area (two individuals as far north as northern North Carolina). These turtles and their epibiota were not used to investigate patterns of epibiont community succession since it would be hard or impossible to map successional patterns from these individuals. However, the data collected from the aforementioned turtles was compared to the data obtained from the site fidelity nesters in this study.

Ten percent of all the turtles initially surveyed (10% = 5 turtles) nested in early May (first week) with excessive epibiotic loads similar to those described for turtles observed ~56 days after the initial nesting observation. Dense aggregations of *M. manhattensis* on the carapaces of nesting loggerheads in early May, suggests that these turtles may have entered the nearshore coastal waters off their respective nesting beaches or nesting area at least 56 days prior (early March) to their first nest of the season. Based upon the seasonality and distribution of *M. manhattensis*, the nesting area in question would be the coastal waters between Cape Canaveral, Florida and Cape Romaine, South Carolina (the Georgia Bight; Ruppert and Fox, 1993).

The arrival of adult female nesters, into the Georgia Bight, in March would coincide with courtship and mating observations for this area during the same time period (Caldwell, 1959; Frick *et al.*, 2000). A mated turtle within the Georgia Bight in March could be heavily encrusted by *Molgula* by the time she deposited her first nest. Turtles that began their nesting cycle relatively free of epibiota may have either just arrived to the area or experienced a slough-off of the epibiotic community. An epibiont community slough-off prior to first nesting would indicate coastal residency in the Georgia Bight at least 70-80 days prior to first nesting. Individual loggerheads that migrate throughout the southeast, depositing their nests in various locations within a season, would probably not host quite an extensive epibiont community and appear epibiont free every time they were observed. Since the study of sea turtle epibiota is still very much in its infancy, more comprehensive studies regarding the colonizing ability of animals that occur as sea turtle epibionts will undoubtedly help in our overall understanding of sea turtle populations in the southeastern U.S.

Acknowledgments

We would like to thank the following individuals and organizations for their support: Randy Isbister, Robert A. Moulis, John Robinette, Deb Keineth, Sam Drake, Charles Warnock, Brad Winn, Mark Dodd, Barb Zoodsma, Adam MacKinnon, Lynn Wright, Lianne Pierrard, Anne Frick, Chris Carroll, the Jekyll Island Authority, the Wassaw Island Trust, the Turner Foundation, and the Courtney Gaines Knight Foundation.

Literature Cited

Caine, E.A. 1986. Carapace epibionts of nesting loggerhead sea turtles: Atlantic coast of U.S.A. Journal of Experimental Marine Biology and Ecology 95:15-26.

Caldwell, D.K. 1959. The loggerhead turtles of Cape Romaine, South Carolina. Bulletin of the Florida State Museum of Biological Science 4:319-348.

Dean, T.A. 1981. Structural aspects of sessile invertebrates as organizing forces in an estuarine fouling community. Journal of Experimental Marine Biology and Ecology 53:163-180.

Dean, T.A., and V.J. Bellis. 1975. Seasonal and spatial distribution of epifauna in the Pamlico River estuary, North Carolina. Journal of the Elisha Mitchell Scientific Society 91:1-12.

Frick, M.G., C.K. Slay, C.A. Quinn, A.W. Reid, C.E. Ryder, P.A. Duley, and L.J. Morse. 2000. Aerial observations of courtship behavior in loggerhead sea turtles from southeastern Georgia and northeastern Florida, USA. Journal of Herpetology 34(1):153-158.

Logan, P., and S.J. Morreale. 1994. Hydrodynamic drag characteristics of juvenile *L. kempi*, *C. mydas*, and *C. caretta*. Pages 148-152 in B.A. Schroeder, and B.E. Witherington (compilers). Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341.

Ruppert, E.E., and R.S. Fox. 1993. Seashore animals of the southeast. University of South Carolina Press. Clemson, South Carolina.

Sutherland, J.P., and R.H. Karlson. 1977. Development and Stability of the Fouling Community at Beaufort, North Carolina. Ecological Monographs 47:425-446.