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SOME ECOLOGICAL ASPECTS OF THE TIDAL ZONE OF THE NORTH CAROLINA COAST

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The tidal zone of the North Carolina coast presents a wealth of ecological problems. This zone includes the narrow strip along the ocean front, sounds, and rivers, between the high and low tide levels. In this paper, however, the term tidal zone is restricted to the inner belt along the sounds and rivers not affected by the action of the waves of the ocean. The term strand is used for the zone of the beach exposed not only to the rise and fall of the tide but to the direct action of the waves of the sea and the sand blast. Ecologically these two regions are very different. The strand on our coast is practically bare of vegetation and frequented very largely by animals which are scavengers or beach combers. The tidal zone, on the other hand, is often an area of considerable extent and is usually well covered by grasses. At least three species of grasses grow luxuriantly here, a fine short grass growing principally about low tide level, a coarser grass growing principally in the pockets at higher level, and a fine matted grass growing near the high tide level. To these three should be added the common sea oats (*Uniola paniculata*) which starts just below high tide level and continues up into the higher dunes, and the salt marsh sedges which grow in shallow water and are more or less exposed at low tide. In addition to the areas covered by grasses there are many of considerable extent which are devoid of vegetation. The tidal zone supports a number of terrestrial forms which invade it during low tide, as well as several forms which live permanently here. We need look for no special adaptations in the former group as they are for the most part active creatures which make the most of any situation. In the latter class there are, however, many unsolved questions of interest, not the least important one being the factors which make it possible for these normally terrestrial air breathing animals to maintain themselves in a locality which is strictly aquatic for a longer or shorter period each day. Are we to look for morphological or for physiological adaptations? Are the groups that are present represented by a single species of several species? If a group is represented by several species, are the species of independent origin or are they perhaps descendants of an early ancestral type that has wandered into this region? These and many other questions might be asked. Some of them I believe can be an-

swered even with the limited data at hand; others will require much more study.

A brief review of some of the papers bearing on the subject may help to make the problem clearer. Arndt (1) gives a short discussion of the results of this work in the between tide zone at Woods Hole, and lists seven species of terrestrial animals which occur there. Taxonomically these are distributed as follows: three insects of the order Homoptera, one of the order Heteroptera, and three spiders.

In regard to the insects Arndt (1) concludes that the three species of leaf hoppers are distributed in three zones, a lower zone of *Megamelus marginata,* a middle zone inhabited by a delphacid (species not determined), and an upper zone inhabited by a species for which the family is not even indicated. He also observes that the calcar on the *Megamelus* is large, that on the delphacid only intermediate in size, while the third species is without a calcar. He concludes from this that the calcar is an organ developed by the *Megamelus* to enable it to walk or leap about on the water; while the delphacid would have less occasion to walk on the water and hence a smaller calcar, and the leaf hopper, living in the higher regions not much subjected to inundations, is freed from this necessity and has no calcar. The absurdity of this position has been pointed out recently by Metcalf and Osborn (2), so that it is only necessary to note in passing that the calcar is a very specialized structure in a single subfamily of the plant hoppers (Fulgoridæ), and that it is as well developed in species occurring in arid situations as in species living either in the between tide zone or in swamps. Furthermore, Metcalf and Osborn have found *Deltocephalus marinus,* a species of Cicadellidæ without a calcar, living in short grass at the very edge of the water at low tide where it must have been submerged under from 8–10 feet of water at high tide. The paper just mentioned lists ten species of Homoptera belonging to eight genera distributed among six subfamilies of three families which occur in the between tide zone, and gives a discussion of the general ecological situation which surrounds these species. Other papers deal with species of animals living in the between tide zones, but so far as I am aware none deal with the modifications, either morphological, physiological, or ecological, that the species of this zone must undergo to enable them to maintain themselves.

The following incomplete notes are offered at this time in the hope of stimulating others to make observations in this interesting field.

So far as I am aware no vertebrates make their permanent home in the tidal zone region along our coast. Further south, in Florida, the beach mouse (*Peromyscus polionotus neveventris*) lives "on the sand dunes and beaches wherever there is a growth of sea oats (*Uniola*) which appears to be its principal food plant. It is a nocturnal animal and its nightly activities may be read early in the morning from the multitude of tiny tracks

which lead in all directions and often form a network on the sand. A single track sometimes extends for a hundred yards or more from a burrow, and with all its windings may aggregate several hundred yards of travel, showing the activity of this small worker during many hours.

"Tracks are most plentiful immediately about growths of sea oats, patches of saw palmetto or scrubby bushes. The homes of these mice are usually in short burrows sheltered by growing vegetation or under fallen palm fronds. As in the case of many of our mammals we have scanty information concerning the life of these active animals" (3).

This mouse has not been collected in North Carolina, but may live in the abundant sea oats just at the edge of the tidal zone along our coast.

Birds of various species, especially shore birds, visit the tidal zone during migrations; but their connection with this zone is so limited that they cannot be said to be an important factor in its life.

The diamond-backed terrapin is a rare incidental visitor in which our interest is more gastronomical than ecological.

Arndt discusses three species of spiders belonging to the genera *Clubiona, Grammonata,* and *Lycosa.* Spiders of at least two species have been observed on our coast, but none have been identified.

Solitary wasps are also common on the sandy stretches of bare beach, and Kellogg (4) describes the behavior of a species of *Ammophila* on the salt marshes of San Francisco Bay. Another group of solitary wasps common on the strand and in the tidal zone is the velvet ants or cow killers (Mutillidæ). Since practically nothing is known about the life history or habits of these wasps nothing more can be done than to indicate that here is a profitable field of investigation.

The beach tiger beetle (*Cicindela dorsalis media*) is very common along the strand, and wanders up into the higher dunes. Although it is frequently taken in the tidal zone I have no evidence that it breeds there and hence must class it is an incidental visitor only.

The salt marsh cicada (*Tibicen viridifascia* Walk.) is common in the tidal zone along our coast, as has been recently pointed out (5). It must pass most of its life cycle either in close proximity to or within the tidal zone, as it breeds in the sea oats and, while the sea oats grows more abundantly above high tide level, some of it grows just at the border of high tide and would be inundated in case of storm or during times of especially high water. While the adults are active flying insects and could readily escape from the incoming tide the larvæ are subterranean and must be subjected to submergence at times.

Four species of Delphacids have been captured in this region, and, although they are active insects, some of them at least occur in such situations that it would seem impossible to escape the incoming tide. It is interesting to note that one of these species, *Megamelanus spartini* Osb., col-

lected from sea oats, is described from the region of Cold Spring Harbor, Long Island, where it was collected from the common salt meadow grass (*Spartina patens*), which grows in situations similar to these in which we find sea oats along our coast. This species is restricted, therefore, to a habitat rather than to a food plant, and it is interesting to speculate on the forces that have brought about these conditions. It is easier for me to believe that these terrestrial animals have followed their mesophytic hosts into these half hydrophytic situations, and that their evolution has paralleled the evolution of their hosts; so that gradually these air-breathing animals have become adapted to a condition that is aquatic for part of the time. If this assumption is sound we have in this instance a species that has become adapted to a given locality and that has followed that locality regardless of food plants. So far as we have been able to discover these species show no morphological modifications that would fit them for long periods of submergence. What then are the physiological modifications that make it possible for these highly active terrestrial animals to remain inactive for long periods of submergence?

Three other species of plant hoppers (Fulgoridæ) have also been taken in this region, but, since they have been reported on elsewhere (2), no discussion is required here.

Two species of leaf hoppers (Cicadellidæ) occur on grasses growing rather close to low tide level, and, since the nymphs of both species have also been taken in the same situation, it seems safe to conclude that they are naturally confined to this zone. While they both belong to the same genus, *Deltocephalus,* this genus is such an extensive one, and the species are so different in many of their characters, that it hardly seems probable that they are descendants of a common ancestor living within the tidal zone but rather that they have had an independent origin outside of this zone.

The beach grasshopper (*Trimerotiopis maritima*), like the beach tiger beetle, really belongs to the strand and higher sand dunes, and, while it is too active an insect to be caught by the incoming tide, it wanders into the tidal zone so commonly that it must be mentioned here.

Three species of fiddler crabs occur along our coast, and, while all three of them occur in the tidal zone, *Gelasimus pugelator* occurs more commonly on our sandy beaches, especially at tide level where the beach is fringed by sedges and grasses. Countless numbers occur on our beaches, and a belt averaging a foot or more in width and extending for several miles is not uncommon. *Gelasimus pugnax* occurs more commonly along rivers where it haunts the boggy marshes that are exposed at low tide (6). *Gelasimus minax* seems to prefer the higher banks and dunes where it lives a more or less solitary life. It is exceedingly active, and, while rarer along our coast in comparison with the other two species, still it feeds on the tidal zone at low tide, and the females go down to the edge of the water to lay their eggs, so that its life is more or less intimately connected with the tidal zone.

Numerous snails feed on the sedge exposed at low tide, and are so abundant that in favorable localities it is rather the exception to find a sedge that does not support one or more.

In such a general discussion one can hope to merely open the field for consideration, and to direct attention to the possibilities and many unsolved question involved.

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