SOME OBSERVATIONS ON INSECTS OF THE BETWEEN TIDE ZONE OF THE NORTH CAROLINA COAST.

By Z. P. Metcalf and Herbert Osborn.

An opportunity for a brief study of the ecological condition prevailing at Wrightsville Beach near Wilmington, N. C., resulted in the determination of the ecological adaptation of several species of Homoptera which have either been entirely overlooked or so little studied that a record of our observations seems worth while. The particular and very interesting ecological situation common of course to long stretches of the Atlantic coast but admirably exhibited at Wrightsville Beach lies in the between tide zone of the inner beach adjoining the sound. This differs from the outer beach facing the ocean in that it is not subjected to the severe wave action of the exposed coast while it gets the full benefit of the rise and fall of the tides. This results in a most luxuriant growth of tidal grasses which are fully adapted to submergence some of them at levels where the whole plant is submerged for hours at a time other species less completely submerged and merging into the zones of Uniola which for the most part appear to be above the level of the high tides although the roots and at time portions of the stems are no doubt under water.

These grasses support a multitude of insects among them many Homoptera and these were the objects of our special attention. The most abundan tof these were the delphacids (*Liburnia detecta*) but there were other fulgorids, some jassids and one species of cicadid. These insects are fitted in varying degrees to survive the periods of submergence to which they must be subjected but all must have undergone some modification in habit and probably in life history if not in structure to fit them for this mode of life.

It certainly seems rather novel to find these strictly aerial, normally terrestrial insects associated with fiddler crabs and seasnails and maintaining themselves under all the exigencies of tidal forces and alternating aerial and aquatic life. Notes on some of the species observed will illustrate some of the adaptations.

Tibicen viridifascia Walk.

Adults of this species occurred in the grasses of the tidal flats of the Wrightsville Beach on the bay side of the dunes and in many instances the specimens taken were at points evidently below the high tide level. Pupæ were found in considerable numbers attached to the grasses well below the level of high tide and very evidently where they had been attached for the emergence of the adults. Holes were observed at points well below the high tide level which had every appearance of being the openings from burrows which had been occupied by nymphs as they were in the same localities where exuviæ were clinging to the stems of grass. Further there were many pupal cases in the drift and these would appear much more likely to have come from a level below tide than above as otherwise it would have been necessary for the cases to have been dislodged from the grass and blown to the surface of the water. From these observations we feel warranted in the conclusion that the nymphal stages of this species are passed in soil that is for a large part of the time under water in fact only exposed at times of low tide.

A little search for egg punctures was rewarded by the finding of such punctures in the stems of the Uniola which had every appearance of Cicada punctures and later these were proved both by dissection of eggs from females and on hatching to be such. The egg punctures occurred mostly at a height of two to three feet above ground and in the third or fourth internode of the stem and for all observed at such a level that they were above the level of high tide unless possibly for exceptional high tides. The fresh punctures which were the most abundant ones found occurred in the old stems of the grass apparently stems of last year's growth but in one instance an internode of an old stem contained egg punctures apparently of a former year as well as fresh ones just completed.

The adults fly promptly when disturbed.

The *Cicadellidæ* are essentially plant feeding insects adapted to living upon the leaves or stems of their food plants and the species occurring on the tidal flat grasses have undoubtedly adjusted themselves to this condition from ordinary habitats, in all probability simply following the host plant as it has become adapted to this special ecologic condition; an adaptation for both plant and associated insect that must represent the play of ecologic forces through a great lapse of time.

Deltocephalus littoralis Ball.

This species described by Ball in 1905 from specimens collected by VanDuzee at Anglesea, N. J., and since reported from several localities along the Atlantic coast was taken in considerable abundance at Southport, July 28th (1919) and under conditions which showed its adaptation to the between tide habitat very satisfactorily. The grass upon which it occurred was common in certain parts of the tidal flat and where the sugmergence under high tide was very evident although there was not the indication of such complete submergence as where the *Liburnia detecta* was most common. Adults were abundant and also a nymph which is certainly the young of this species as it was the only nymph of a jassid taken in this association and possesses the distinctive characters of the species so evidently that even without rearing we feel assured of its relation to the adult. These nymphs are quite uniformly greenish yellow without marking except that the eyes appear conspicuously black and the frontal arcs are fairly indicated in whitish on a pale smoky brown background. The length is 2½ mm. It seems obvious that the nymphs and probably the adults also, which showed little tendency to flight, are able to survive considerable periods of submergence and that the species is distinctly restricted to the tidal zone or the grasses occurring there. No record of the occurrence of the species at points incompatible with this view have been made so far as we are aware.

Deltocephalus marinus n. sp.

Another species perhaps even more perfectly adapted for the submergence was taken at Wrightsville Beach, July 27th (1919).

This is a minute species found on a very fine-leaved grass that occurs in extensive mats on areas that are completely submerged at high tide and as the grass is very short it would seem certain that the insect must undergo complete submergence for considerable periods. It corresponds very closely in habitat to the *D. minuta* VanDuzee which abounds in the tidal flat matted grasses of the Pacific coast, especially in the vicinity of Long Beach, California. Our species is much darker above bearing some resemblance to a small *compactus* or to a minute and dark colored *nigrifrons* Forbes (balli VanD.).

The grass on which this species was found, the species undetermined, is apparently restricted in its occurrence and from the patches observed would seem to favor the little depressions or pockets protected from the more violent action of the waves but still sufficiently drained to become fairly dry during the period of low tide.

There is every reason to assume that the whole life history is associated with this grass and although we have not had opportunity to determine as to place of egg deposition or the development of the young we are confident that all these stages will be found associated with this plant when the necessary observations can be made.

As the species appears to be undescribed a technical description is appended.

Deltocephalus marinus n. sp.

A small, slender species, soiled yellowish white in color, with the margin of vertex marked by two or three pairs of fuscous spots. Length 2.25 mm.; width across prothorax .6 mm.

Vertex bluntly angulate, slightly convex, scarcely twice as long on middle as between the eyes, front broad, evenly curved to base of clypeus; pronotum narrower than the head, well produced in front between the eyes, lateral edges rounded, without distinct angles, posterior margin slightly sinuate; elytra extending beyond tip of abdomen, venation distinct.

Color: head yellowish white marked with dark fuscous as follows: eyes, two oblique dashes between eyes and median line, sometimes a pair of large triangular fuscous spots bordering anterior margin of vertex with dots below near the eye as in balli, and seven pairs of heavy arcs on front. Pronotum soiled whitish with six faint longitudinal stripes; elytra soiled whitish, veins lighter with more or less fuscous border; legs yellowish the femora crossed by two fuscous bands, one near the middle, broad and another between the middle and the apex; abdomen beneath blackish fuscous with pleurae and genitalia more yellowish.

Genitalia: Female last ventral segment short, about three times as broad as long, posterior margin slightly concave; pygofers rather slender and slightly exceeded by the ovipositor. Male last ventral segment narrow with the apex rather deeply concave, valve broadly triangular, rounded at tip, plates long, two to two and one-half times as long as basal width, gradually tapered to a sharp pointed, upturned and black apex.

Described from 13 males and 14 females collected on small grass below level of high tide Wrightsville Beach, North Car-

olina, July 27, 1919, H. Osborn and Z. P. Metcalf. Type material in collections of authors, North Carolina State College and Ohio State University.

What is quite evidently the larva of this species was collected from the same grass at the same time. Head characters are similar, the general body color is soiled yellowish white, the frons is marked by fuscous arcs and the eyes are blackish fuscous; each segment of the abdomen above from the second to the sixth is bordered by four rectangular black points which are separated from each other by a median white line which runs the length of the abdomen, and also extends forward as a broken stripe over thorax and extends forward on the vertex where it widens anteriorly and fades out near the apex, and by two rows of whitish spots either side of the middle line.

Dictyophara microrhina Walk.

Adults of this species were taken in considerable numbers from beach grasses at about the level of high tide. There was no evidence of their being adapted to complete submergence and as the species occurs on rank lowland grasses away from the coast there is evidently no restriction to the aquatic habitat. The species, however, illustrates the persistence of an insect in following its food plant into conditions of life that must be quite dissimilar from those under which it first formed the association.

Acanalonia pumila VanDuzee.

This species was taken in the same association as the *Dictyophara microrhina* and there is apparently the same or very similar adaptation to the condition prevailing at the high tide line. Among the examples taken were a number which instead of the normal green color were of a dull straw color closely resembling the color of the dead leaves of grass. No evidence as to the place of egg deposition or concerning the early stages was secured but it would seem very probable that the eggs must be laid in such positions that they would be exposed to the submergence at periods of unusual high tide if not in ordinary high tide.

Myndus enotatus VanDuzee.

This species was taken at Southport in a tidal flat much of which was covered with a rather coarse grass and in which *Deltocephalus littoralis* was found in abundance. All specimens of the Myndus secured were in the adult stage and no data was secured as to the larval stages. Inasmuch as *Myndus radicis* Osb. occurs under the surface of the ground and on the roots or crowns of grasses growing in low ground notably, so far as observed, in a river bed subject to periodical overflow, it will be a matter of interest to determine if possible whether the nymphal stages of *enotatus* have a similar habit in the tidal flats.

VanDuzee says of *enotatus:* "This form was swept from the grass on the prairies at Flaw Creek in untold thousands and in lesser numbers at other localities farther south," but nothing is said to indicate their occurrence in areas subject to inundation.

The species is recorded in VanDuzee's Catalogue for "Georgia and Florida," so the North Carolina record gives it a considerably wider range. Specimens in the Ohio State University Collection from Bay Ridge, Maryland, collected by Prof. J. S. Hine, appear to belong here also and these would agree with a maritime distribution. Whether the species is strictly limited to one species of grass and this one confined to the tidal flats of the Atlantic coast will need to be determined by further study but certainly the species has been able to accommodate itself to the tide flat habitat and there is little doubt that it is able to undergo periods of submergence lasting for a number of hours. There does not appear, however, to be any structural modifications differing from species occurring where no such peculiar condition prevails and as in other species it would seem that the insect has simply been able to follow its food plant into an unusual environment.

Megamelanus spartini Osb.

This species was beaten from the heads of the common "sea oats" (Uniola paniculata) which fringe the dunes on and near the tidal flats and while we did not find evidence of this species occurring below tide level the close adaptation of the species to its habitat in the heads of the grass and its relationship to species definitely adapted to submerged conditions seem to warrant mention of it here.

It is apparently identical with the form described from *Spartina patens* and collected at Cold Spring Harbor in 1904.*

While the species is very definitely adapted for the conditions of the head with the parts of bloom and seed and none could be secured by beating or sweeping the leaves or stems there is of course an interesting question as to where the eggs may be laid and whether these are liable to submergence from occurring in parts that may at times be under water. The Uniola is for the most part on the parts of the dunes fairly well above high water mark but some of the plants closer to the tide level may very likely be submerged during periods of unusual high tide or severe storms.

Megamelanus elongatus Ball.

Taken only sparingly but on grass of the higher levels of the tidal flats and where the submergence though shorter in duration must be fairly complete.

Megamelus (Prokelesia) marginatus VanD.

A specimen of this species was taken in connection with the abundant *Liburnia detecta* and very evidently fully adapted to the same conditions of life.

It has much the appearance of the Liburnia and may easily be confused with that species especially for the macropterous form.

No details of life history have been recorded and we were unable to carry on any studies that would give definite results as to adaptations in the life history that might be credited to the particular environment of the tidal flats. However, it seems fairly certain that the eggs must be laid in leaves or stems of plants subject to much submergence as otherwise we could hardly account for the abundance of the insects, especially micropterous forms, on plants subject to complete submergence at every period of high tide.

Arndt (1914)† has discussed a number of insects living in the between tide zone and among others gives an account of *Megamelus* (Prokelesia) *marginatus* VanDuzee which is evidently adapted to much the same conditions as the *Liburnia detecta* found at Wrightsville.

* Ohio Naturalist, Vol. V, p. 375.
† Proc. Indiana Acad. Sci., 1914, pp. 323-336.

In his discussion of the special adaptations for survival under submergence he cites the calcar as a structural modification developed as a reaction to the tidal conditions. To appreciate the absurdity of this inference it is only necessary to note that this structure occurs in all species of Delphacinae and, in many other species having no periods of submergence to contend with in their habits there are fully as large and specialized calcars. Arndt says; "The hoods on its feet, the greatly developed proximal segment and the spur are the peculiar modifications which determined that this leaf-hopper should inhabit this particular region." In all these structures this species is in close accord with the other members of the group. We must look elsewhere for any real modifications of structure.

It should be recognized that these insects and hosts of related forms have been for ages adapted to clinging to the stems and leaves of plants and well fitted for withstanding wind and other forces that might tend to dislodge them. The essential factor that the new environment called for was adjustment to submergence in water and this involves especially the ability to hold sufficient quantities of air in or adjacent to the tracheal system to carry over the periods of submergence.

Liburnia detecta VanD. (= circumcincta VanD. micropterous form).

This species of Delphacid occurred in great abundance on a grass that grew luxuriantly near the level of low tide and where there were enormous swarms of fiddler crabs. At this level the grass must be completely submerged during high tide and for much of the time during the rise and fall of the tide. It is evident, therefore, that the species both as nymphs and adults and doubtless also in the egg stage must be successfully adapted to survive long periods of submergence, several hours at a time at least. The exact method of protection during this submergence could not be determined but from the shape of the insect, both nymph and adult, it would appear that they can crowd themselves into the spaces between leaf-sheath and stem or into the furrows of the leaf blades in such manner as to hold their attachment to the plant, detachment from which would in all probability mean disaster.

It may be added that this species was not found at any point above the between tide zone and therefore its adaptation to this situation is evidently complete and it is probably restricted to the species of grass which is confined to this habitat.

SUMMARY.

Reviewing these facts briefly it may be said that the adaptation to the submergence of tidal flats at some stage of their existence has been acquired by Homopterous insects of several different families, the Cicadidæ, Cicadellidæ and Fulgoridæ and, for the latter, three principal subfamilies that are so widely separated that we may assume entirely independent origin for the habit. In all then, five groups in which the adaptation is present in greater or less degree. Even in the different genera as Megamelus, Megamelanus and Liburnia there is no reason to assume a common origin since many species in each genus are entirely terrestrial.

Each of the species found in this habitat is closely associated with some one species of plant which in turn must be considered as having been derived from a more strictly mesophytic habitat and the conclusion seems warranted that the insect has simply followed its host plant in this adaptation to hydrophytic habitat.

The structural modifications in all the species studied are practically negligible but there is evidently a considerable physiological modification to accommodate the insect to long periods of submergence under water. The structures fitting the insect for close adherence to its plant host were already developed before the aquatic condition was met and if changed at all would only need intensification to provide against the movement of water. No special adaptations for swimming or skimming on the surface of the water are present although these insects, like practically all others when accidentally thrown on water, will float and may to some extent propel themselves over the surface by active movements in jumping or running.

The physiological adaptations which seem probable present a special problem and one which is apparently of considerable interest but we have not had opportunity to follow it up. It may be noted, however, that insects in general, especially when inactive, are able to survive on a minimum supply of air.

EXPLANATION OF PLATES.

PLATE X.

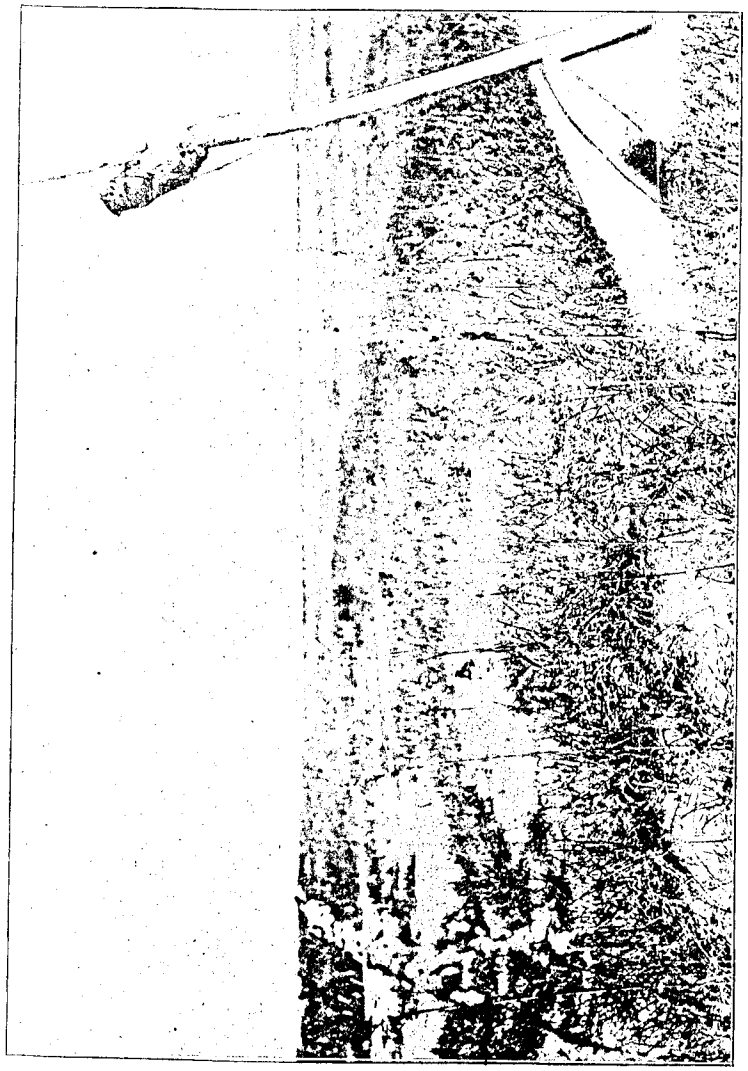
A general view of the tidal flats at Wrightsville Beach, North Carolina, taken from the higher sand dunes. The plants in the immediate foreground are the sea oats. In the right foreground insert is an adult male Tibicen viridifascia Walker resting on a stem of the sea oats.

PLATE XI.

Fig. 1. Deltocephalus marinus sp. n. adult.
Fig. 1a. Deltocephalus marinus sp. n. face.
Fig. 1b. Deltocephalus marinus sp. n. male genitalia.
Fig. 1c. Deltocephalus marinus sp. n. female genitalia.
Fig. 1d. Deltocephalus marinus sp. n. nymph.
Fig. 2. Deltocephalus littoralis Ball.

PLATE XII.

Fig. 1. Acanalonia pumila Van Duzee.
Fig. 2. Myndus enotatus Van Duzee.
Fig. 3. Dictyophora microrhina Walker.
Fig. 4. Liburnia detecta Van Duzee.
Fig. 5. Megamelanus elongatus Ball.
Fig. 6. Megamelanus spartini Osborn.



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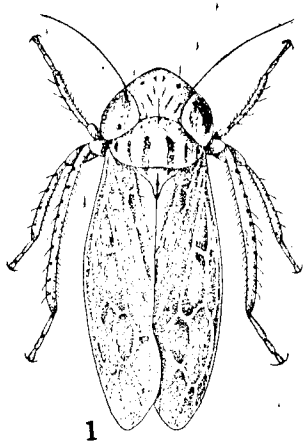

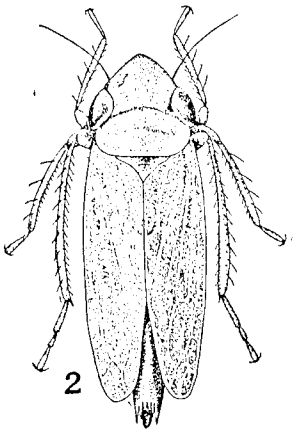

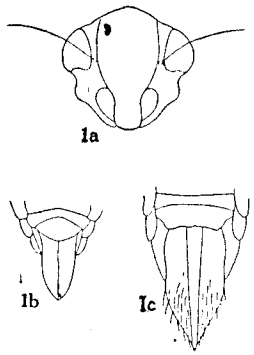

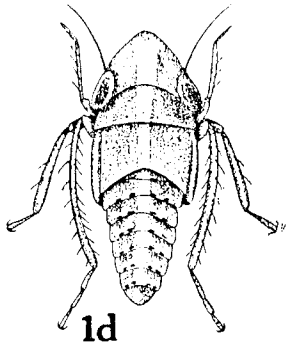

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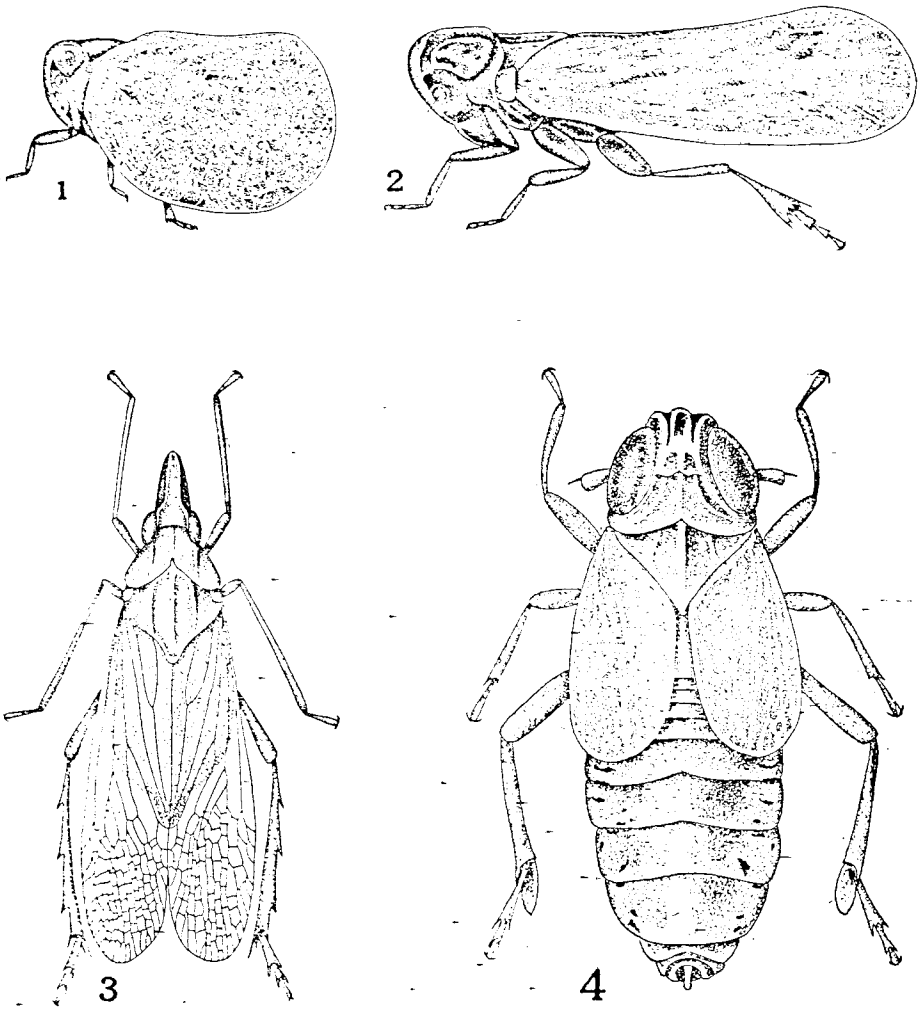

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