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Effects of Habitat Change From Ecological Succession and Human Impact on Tiger Beetles

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ABSTRACT

This paper reports on 3 case histories of how changes in habitat have affected distribution and abundance of several species of tiger beetles in Virginia. Between 1980 and 1990, at a borrow pit site, the numbers of *Cicindela tranquebarica* decreased dramatically, *C. sexguttata* increased then decreased slightly, and *C. repanda* disappeared. These changes were associated with plant succession, specifically a rapid increase in density and size of loblolly pines throughout the site. The apparent extirpation of *Cicindela abdominalis* at a southeastern Virginia pine barrens habitat where it occurred in 1936 is believed to be the result of increased vegetation encroachment which eliminated open areas needed by this species. The distribution and abundance of *Cicindela dorsalis media* on barrier island beaches was correlated negatively with the amount of human impact. This species was abundant and widespread on Fisherman, Hog and Cobb Islands, but on Assateague was restricted to areas where vehicle and pedestrian use are low. The results of our study confirm the habitat-specific nature of tiger beetles and their need for open habitats with little human disturbance. Some species may quickly decline or disappear when their habitats change either naturally or from human activity.

Key Words: *Cicindela*, habitat, human impact, tiger beetles, succession

INTRODUCTION

Tiger beetles are an interesting group of ground surface predators that attack small arthropods with short runs, using their large mandibles to capture and process prey. Ants are probably the most common prey but a variety of other organisms may be taken (Willis, 1967; Hori, 1982). Larvae are sedentary predators that live in burrows in the ground. They capture prey which passes within a few cm of their burrow opening. Typically, larval development through the 3 instars takes 1-3 years and occurs in the same burrow.

Preferred habitats of tiger beetles include water edges, sandy flats, dunes, woodland paths, open patches in grasslands and recently cleared areas. Most species are very habitat specific and the diversity of species in an area may be largely determined by the variety of suitable habitats (Willis, 1967; Knisley, 1984). A key habitat feature is bare ground, open to sunlight, which allows for behavioral thermoregulation (Dreisig, 1980) and the maintenance of the high body temperature necessary for prey capture (Dreisig, 1981).

Both natural processes and human activities may be responsible for creating and maintaining open areas and insuring the suitability of the habitat for tiger beetles. In his classic studies of ecological succession in the Lake Michigan dunes, Shelford (1908, 1911) demonstrated how the distribution of tiger beetle species changed with the progression of plant successional stages across increasingly older dunes. He also showed that the selection of an oviposition site by the adult female was the factor determining larval (and often subsequently adult) habitat. Elimination and disturbance of habitat were primary causes of the decline and possible extirpation of several tiger beetle species on the southern California coast (Nagano, 1980). Human impact on habitat, particulary off road vehicle (ORV) activity, was reported to be the factor responsible for the decline of *Cicindela oregona* along an Arizona stream edge (Schultz, 1988) and *C. dorsalis* on coastal beaches in the Northeast (Knisley et al., 1987).

Among Virginia's tiger beetles (2 species of *Megacephala* and ca 18 species of *Cicindela*) are 6 rare or seldom collected species (Knisley, 1991). Of these, *Cicindela abdominalis, C. formosa*, and *C. limbalis* have not been collected recently and may have been extirpated because of loss of habitat. Other very common species like *Cicindela repanda, C. punctulata*, and *C. sexguttata* probably occur in every county and may benefit from activities of man which create edges and cleared, open areas. The objective of this paper is to present 3 case histories of the effects of habitat changes on some of these species. The case histories include: the change in abundance of 3 common species during natural succession of a borrow pit, the probable extirpation of a rare, localized species, *C. abdominalis* at a known site beause of fire suppression and subsequent vegetation encroachment, and a study of the effects of human impact on *C. dorsalis media* on several barrier islands.

METHODS

The borrow pit studied was the Mechumps borrow pit located 2 km east of Ashland, Hanover County, Virginia. It was roughly oval-shaped, 260 m x 110 m. In the mid-1970's a 5-8 m layer of soil was removed from the surface, creating a very moist to waterlogged soil over most of the site. A small drainage ditch, which held water for several weeks after rains, and a shallow pond were also present (Fig. 1a). On the first visit to the site in spring 1980, tiger beetle abundance and vegetation were sampled. Vegetation samples included measurement of heights and nearest neighbor distances of woody plants along 5 50 m transects crossing the site. Vegetation was resampled in spring 1990.

Adult tiger beetles were sampled 1 to 2 times during peak abundance (April to early May) each year from 1980 to 1990 by walking through the open areas of the site and counting all beetles observed. The highest number counted in a year was used as that year's population size estimate. This census technique is a commonly used and effective method for determining tiger beetle abundance (Knisley, 1984, Hori, 1982). Larvae of *C. repanda* and *C. sexguttata* were sampled in May and June of 1980 and 1981 by walking the site and searching for burrow openings on the ground surface. All burrows found in 1980 were marked with numbered tags and checked at several week intervals through October and again the following spring to determine survival and progress of development (Knisley, 1987).

The Blackwater Ecologic Preserve (formerly known as Zuni Pine Barrens) in Isle of Wight County, Virginia, was surveyed for adult tiger beetles in July, 1988 and 1989. Trails, open patches and other areas of potential tiger beetle habitat were checked for adult beetles and the existence of suitable *C. abdominalis* habitat. Our description of the present vegetation at the site was based on our observations and information in Frost and Musselman (1987). Descriptions of the vegetation as it was in the 1930's is given in Fernald (1937, 1939) and Frost and Musselman (1987).

The study of human impact on *C. dorsalis media* involved a comparison of abundance of this species on several relatively undisturbed Virginia barrier islands and on Assateague Island where there are varying levels of beach use and human impact. Assateague Island includes a 42 km long shoreline portion of National Seashore and State Park in Maryland and a 16 km portion of Chincoteague National Wildlife Refuge in Virginia. The amount of human impact on the islands was determined by our observations of vehicle and pedestrian use during visits in 1985 and 1990 and from information provided by park personnel.

Censuses of adult *C. d. media* were done at times of highest beetle abundance (late June through early August) at least once between 1986 and 1990 by counting all beetles present along the water edge. Counts were made along the whole Assateague shoreline and along most of the shoreline (3-6 km lengths) at Hog, Cobb, and Fisherman Islands where beetles were present. These censuses thus give a rough estimate of total abundance on the islands. Larvae were sampled on Assateague in late August and October of 1990 and on Hog in September 1990, by counting all open larval burrows in 2 m wide transects across the beach from mid tide to back beach. At both islands we sampled 2 or more transects in areas where adult beetles had been most abundant.

Information of past and current distribution of *Cicindela dorsalis dorsalis* and *C. d. media* was obtained from our own collection records, from specimen label records of collections in major museums and private collections, from field notes provided by collectors, and from published records.

RESULTS AND DISCUSSION

Borrow Pit Succession. The vegetation and tiger beetle communities at Mechumps borrow pit changed dramatically between 1980 and 1990 (Fig. 1). Woody vegetation, mostly scattered loblolly pines, was very sparse in 1980. Mean nearest neighbor distance of pines was 26.0 m and mean height was 0.6 m throughout the site, except for a dense patch of trees which was apparently left intact when the soil was removed from this site (Fig. 1a). In 1990 loblolly pine mean nearest neighbor distance decreased to 2.2 m and mean height increased to 6.2 m, and all open areas were eliminated. The pond became more shallow and choked with vegetation but still held water and supported breeding frogs in 1990. The drainage ditch filled in and held little or no water, even after rains (Fig. 1b). Soil moisture seemed to decrease significantly, but we made no measurements to document this.

The dominant tiger beetle in 1980 was the water edge species *C. repanda* with over 200 adults counted, mostly near the stream edge. Larvae were concentrated along the ditch edge and at the base of the cliffs in early summer of 1980. Adults and larvae of *C. tranquebarica* were common but widely scattered throughout the

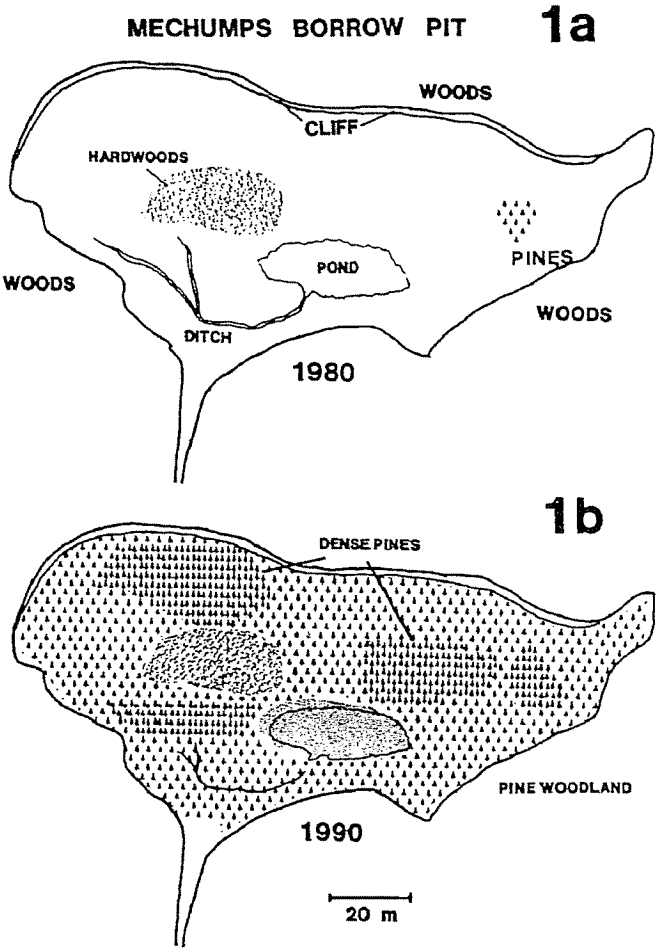

FIGURE 1. Map of Mechumps borrow pit in Hanover County, Virginia, showing the major features and vegetation at the site in 1980 (a) and in 1990 (b).

open flats. *Cicindela sexguttata*, a woodland species, was rare with only a few scattered individuals found. Numbers of these 3 species changed greatly after 1980 (Fig. 2). *Cicindela repanda* numbers declined very rapidly by 1982-1983 and then gradually until the species disappeared completely by 1986. The decline of *C. tranquebarica* was more gradual, with numbers dropping to <15 by 1986 and continuing at that number until 1990. Numbers of *C. sexguttata* increased gradually to 40-50 by 1985 then declined slightly between 1986 to 1990.

We believe the changes in the composition of the tiger beetle community at this borrow pit are the result of changes in the habitat due to natural plant succession. Both adults and larvae of *C. repanda* and *C. tranquebarica* were probably affected by the decrease in open areas which adults apparently need for foraging and oviposition. Larvae of *C. tranquebarica* preferred the open flats which were largely eliminated by rapid encroachment of vegetation. *Cicindela repanda* larvae were

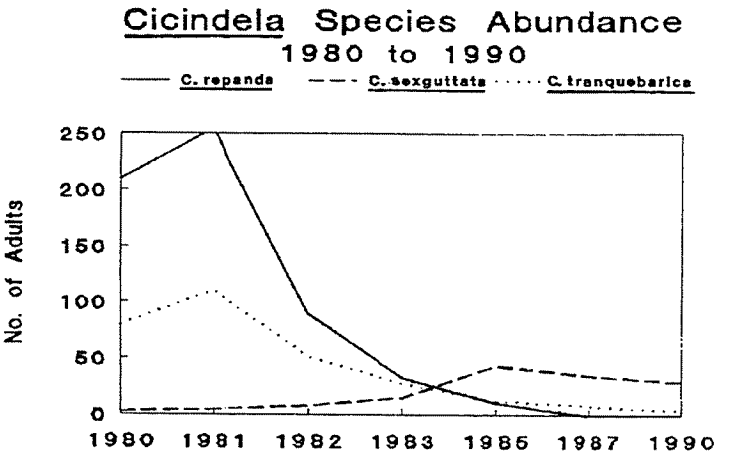

FIGURE 2. Yearly numbers of adults of 3 species of *Cicindela* at Mechumps borrow pit between 1980 and 1990. Numbers are the highest values of 1-2 yearly counts at the site during peak abundance and represent an estimate of the total population for each species.

present along the open areas near the steam bed, but these areas gradually dried out and became vegetated, making the habitat less favorable. *Cicindela sexguttata* may have benefited from the increased edge habitat created by growth of pines by 1984-86, then declined later as pines became more dense and eliminated some of the edge areas.

Studies of larvae at this site indicated some additional factors involved in the decline of these 2 species. About 85% of 150 first and second instars of *C. repanda* which were marked for observation in May 1981 did not survive beyond the second or early third instar. The cause of this high mortality may have been soil desiccation during a very dry 5-6 week period in June and early July. Soil desiccation can contribute to high rates of mortality in tiger beetle larvae (Knisley, 1987). A sample of *C. tranquebarica* larvae examined in summer 1981 indicated that nearly 75% of 120 were parasitized by the bee fly, *Anthrax analis*. Most or all of these larvae would have been killed by this parasite, thus reducing the number of new adults in 1982.

Cicindela abdominalis. This species is an inhabitant of deep sandy soils of open pine habitats (Boyd, 1978). It is known from pine barrens areas of New Jersey, North Carolina, South Carolina and Florida. There are no published Virginia records, but there are several specimens in the University of Richmond insect collection taken 5 km South of Zuni in 1936. This area is the Zuni pine barrens site, now known as the Blackwater Ecological Preserve. The beetles were taken by entomologist C. Williams on the same collecting trip that Fernald collected many rare pine barrens plants (Frost and Musselman, 1987).

We found no specimens of *C. abdominalis* during thorough surveys of this area in 1988 and 1989, suggesting it no longer exists at this site. If extirpated, the cause is probably the result of changes in its natural habitat brought about by the suppression of natural fires. Vegetation density has apparently increased since the 1930's, eliminating open areas preferred by this species. We found no large open

areas ($>1000m^2$) when we surveyed this site, and vegetation cover was much greater than at sites in other states where we have collected this species.

In his initial visits to the site in 1936 Fernald (1937, 1939) indicated the presence of open areas, which were apparently maintained by periodic natural fires. The extirpation of some of the rare endemic herbs that Fernald found at the site was probably the result of the absence of fires which increased understory ericaceous shrubs and the loblolly-oak communities (Frost and Musselman, 1987). A plan of prescribed regular burning was recommended to prevent the loss of additional rare, disjunct savannah herbs which occur at the site. Burning has been implemented with the first burn in January 1986 (Frost and Musselman, 1987). The burning plan may make conditions again favorable for the reintroduction and establishment of *C. abdominalis*. This species may still occur in southeastern Virginia if other more open pine barrens sites exist.

The loss of this species is comparable to the rapid decrease and local extirpation of *Cicindela debilis* Bates in an Arizona grassland (Knisley, unpublished). Within 3 years the population went from 85 to 0 adults as grasses and herbs encroached and then completely covered several open patches where both adults and larvae had been found. Increased vegetation cover may reduce habitat quality for tiger beetles by eliminating oviposition sites and by decreasing adult foraging efficiency through interference with vision and thermoregulatory behavior.

Cicindela dorsalis. This case history includes a review of the effects of human impact on distribution and decline of *C. dorsalis* Say. Two of the 4 subspecies of *C. dorsalis* recognized by Boyd and Rust (1982) occur in Virginia. *Cicindela d. dorsalis* has a disjunct historic range from Cape Cod to central New Jersey and on beaches along both eastern and western shores of the Chesapeake Bay. This subspecies is Federally listed as Threatened (Jacobs, 1990) but is well established along the Chesapeake Bay, occurring at ca 40 sites. In the Northeast, however, it now occurs at only one site, on Martha's Vineyard Island. Its extirpation from Long Island, New Jersey and other northeastern sites is believed to be the result of disturbance and destruction of its coastal beach habitats through a variety of impacts, especially the increase in pedestrian foot traffic at many public and resort beaches, real estate and commercial development, and vehicular use on beaches (Knisley et al., 1987). Its survival at the Martha's Vineyard site is apparently because this site is so inaccessible and has been well protected for a long time (T. Simmons, pers. comm.).

But why does *C. d. dorsalis* survive at many sites within the Chesapeake Bay? The primary reason may be that none of these sites has received the level of human impact or disturbance typical of the northeastern sites. Most are privately owned with limited public access or for other reasons have little or no pedestrian or vehicle traffic. None of the sites is a heavy-use bathing or resort beach. There also exists within the Bay a large number of scattered suitable beach habitats of varying size which can support populations of this beetle over a wide area and allow for recolonization if some populations decline or are extirpated due to natural factors (Knisley et al., 1987).

Cicindela d. media is widespread and abundant on several of the Virginia barrier islands which we have surveyed, but like *C. d. dorsalis*, has declined in the northern part of its range. In Maryland it is listed as Endangered and occurs only on

Assateague Island. North of this, its only known occurrence is a recently discovered population on Little Egg Island, near Atlantic City (H. Boyd, pers. comm.). Unlike the other Atlantic and Cape May County, New Jersey sites where this species was present as late as the 1940's and 1950's, this site has received little human impact. Access is limited and the only apparent use is from a small number of fisherman and boaters, mostly on weekends. Some sites where *C. d. media* was once abundant, like Sea Isle City, Avalon, Ocean City, and Cape May, have become heavily used as public recreational or resort beaches. Other less accessible sites like Long Beach Island have received heavy vehicle use.

Our censuses of the 3 Virginia barrier islands (Cobb, Hog, Fisherman) indicated numbers of 1000 or more adults at each site (Fig. 3). These islands are a part of the Nature Conservancy's Virginia Coast Reserve and virtually undisturbed. On the 42 km section of Assateague in Maryland we counted 275 adults in 1986 and 375 in 1990. Nearly all of these were on the northernmost 5 km where human foot traffic is light and vehicle traffic is limited to a maximum of several trips per day by park personnel (Fig. 4). In 1985 and in 1990 we found no adults on the State Park and Sinepuxent development zone beaches. The only beetles present in the ORV zone were 13 individuals in 1990 within a 0.5 km section which had been roped off to protect a piping plover nesting area from vehicles. The State Park, Sinepuxent, and ORV areas all had clear evidence of beach disruption by vehicle activity. Glaser (1977) reported *C. d. media* from the Sinepuxent area in 1973 but found them absent in 1976 when he noted a great increase in ORV use which he suggested was the cause of their disappearance.

In the Virginia portion of Assateague we counted 40 beetles along the northernmost 2 km of beach in June 1986 and 15 beetles on the northern 6 km of wild beach in early July, 1990 (Fig. 4). An estimated 150 adult *C. d. media* were found on the bay side of the Toms Cove hook portion of the island in late June 1985. In none of the surveys were adults or larvae found on the public beach or ORV portions of Assateague in Virginia.

Censuses of larvae at Assateague indicated a similar pattern to that for adults except that larval numbers were generally low. In our 1990 surveys we found only 6 larvae in 20 transects from the Maryland portion of Assateague, and all were in the northern section of the island where adults were found. Twenty two were found in 5 transects in this northern section in 1986, but none in any transects to the south. On Hog Island in October 1990, we counted 71 larvae (48 second and 23 third instars) on one 2 m wide by 110 m long transect on the ocean side of the island and 4 larvae along a 26 m long transect on the bay side. These high numbers were due largely to the presence of larvae throughout the extremely wide, low beach.

The distribution of *C. d. media* on Assateague is clearly related to levels of beach habitat disturbance. Both ORV activity and heavy pedestrian foot traffic have apparently eliminated this species, probably by interfering with adult mating and oviposition and larval feeding, and by disrupting and compacting larval burrows. Also, ORV activity mixes up the soil and may interfere with the natural moisture gradient of larval burrows (Schultz 1988). The lesser beach slope and corresponding greater beach width on Hog and other barrier islands provides a greater amount of suitable habitat than at Assateague (Fig. 5). This is another factor contributing to the lower number of *C. d. media* on Assateague compared to the other barrier

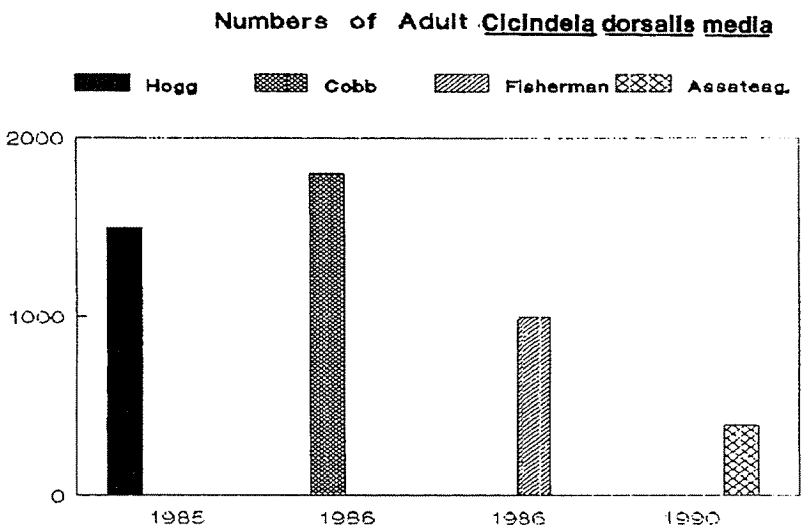

FIGURE 3. Numbers of *Cicindela dorsalis media* along the sandy beach at 4 barrier islands. Numbers are for the whole shoreline of Assateague and 3-6 km of beach where most adults were found at the other 3 islands.

islands. On the steeper, even narrower beaches within the Bay where *C. d. dorsalis* occurs (Fig. 5a), larvae occupy a much narrower band. The more gently sloping barrier beaches also have long tidal and washover zones which provide a much wider band of suitable larval habitat.

In summary, the results of this study demonstrate that tiger beetles are highly sensitive and can quickly respond to changes in their habitat, and may thus be useful as indicators of habitat type and quality. Natural successional changes and human activities are shown in this study to be two important factors affecting tiger beetle communities. While many species may quickly colonize new areas of habitat, as was apparently the case with *C. tranquebarica* and *C. repanda* at Mechumps borrow pit, they may also disappear quickly when conditions change. We have also shown how rare species like *C. dorsalis* may be limited by human disturbance to their habitat.

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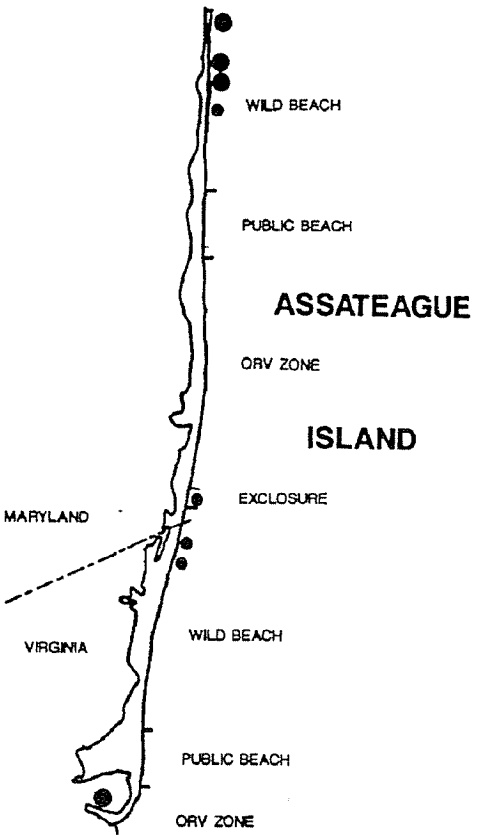

FIGURE 4. Map of Assateague Island showing features relevant to this study and location of *Cicindela dorsalis media*. Filled dots show specific locations of *C. d. media* (large dots indicate over 100 individuals each, smaller dots indicate fewer than 25 individuals each).

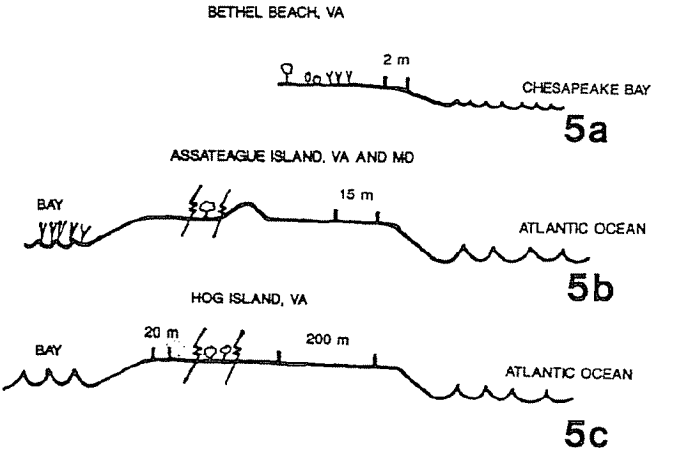

FIGURE 5. Diagramatic profiles of 3 beaches showing the width of the larval habitat zone of *Cicindela dorsalis dorsalis* (a. Bethel Beach) and *C. d. media* (b. Assateague and c. Hog Island).

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