HABITAT PREFERENCE OF COASTAL *CULICOIDES* SPP. AT YANKEETOWN, FLORIDA

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ABSTRACT. Larval habitats of salt marsh *Culicoides* spp. were delineated. Twenty-six habitat categories were equally sampled. Four broad physiographic zones were identified from aerial photographs and ground surveys. Two salt marsh zones were identified and separated on the basis of differences in plant cover type and distribution, number and conformation of islands, tidal creeks and ponds, and substrate structure. The other 2 zones were an extensive brackish-freshwater marsh and an upland area dominated by mixed pine and live oak. The more frequently flooded salt marsh zone provided the most productive *Culicoides* larval habitats. Data obtained from samples held for adult emergence indicated that *C. mississippiensis* was largely confined to these lower elevation marsh areas, but *C. furens* was found in both salt marsh and freshwater habitats.

INTRODUCTION

Approximately 303,750 ha (750,000 acres) of tidal marsh occur in Florida, of which 14,722 ha (36,378 acres) are in Levy County (Coastal Coördinating Council 1973). These coastal areas are attractive for many kinds of economic development including recreational (marinas, campgrounds and fishing), residential, and industrial. Coastal marshes are also valuable in their undisturbed state as nurseries and feeding grounds for many estuarine and marine organisms (Heald and Odum 1969). In some parts of Florida, commercial and residential development has been delayed due to the presence of numerous biting midges (*Culicoides* spp.), which cause considerable human discomfort. Except for mosquitoes, probably no other insects in Florida cause more human discomfort (Blanton and Wirth 1979). To many people the lesions produced by their bites last longer and are more painful than those of most mosquitoes. Some coastal species of biting midges are extremely abundant at certain times of the year (Beck 1958, Kline 1986) and are difficult to control. They are so small that they can easily pass through ordinary mesh window screen and mosquito netting.

Despite the human misery that they cause and their adverse impact on economic development in coastal areas, no area management strategy exists for salt marsh *Culicoides* spp. One possible strategy is to interrupt the life cycle by controlling the immature stages. This requires knowledge of the population dynamics of the immature stages. Such knowledge does not exist for the type of marshes found along the north Gulf coast of Florida. Relatively little has been reported on the population dynamics of immature stages in North America. Even the range of habitats in which the immature stages of these species will complete their development is unknown.

Therefore, the objectives of the study were: (1) to identify as many potential *Culicoides* larval habitats as possible at our coastal study site; and (2) to determine which habitats are most productive for salt marsh biting midges and, therefore, require more in-depth studies to elucidate seasonal patterns.

MATERIALS AND METHODS

Habitat categorization: This study was conducted near Yankeetown, Levy County, Florida, a Gulf coast community located ca. 129 km north of Tampa. Salt marshes found here are similar to the northern Gulf coast marshes of Apalachee Bay, Florida, described in detail by Kurz and Wagner (1957). The marshes found in Levy County have the same basic vegetation types of other north Florida Gulf coast marshes, but are more extensive (1–4 km wide). *Juncus roemerianus* Scheele is the predominant vegetation of these marshes. *Spartina alterniflora* Loisel commonly occurs at lower elevations and *Distichlis spicata* (L.) Greene at higher elevations. The Yankeetown site was chosen because of its serious biting midge problem, and because the extensive marshes found here have been relatively undisturbed by man's activities. The only disturbances were a few limestone roads and two black-top roads [state routes (SR) 40 and 40A], which traverse marsh areas to provide access to private residences, a fishing club, and public boat ramps (Figure 1).

Physiographic features and plant distribution patterns were progressively determined by aerial reconnaissance and ground truthing during the course of this study. Two photographic missions (January and August 1981) were flown by the U.S. Air Force 363rd Tactical Reconnaissance Wing (62TRS) from Shaw Air Force Base, South Carolina, to obtain panchromatic black and white and color infrared photographs of the

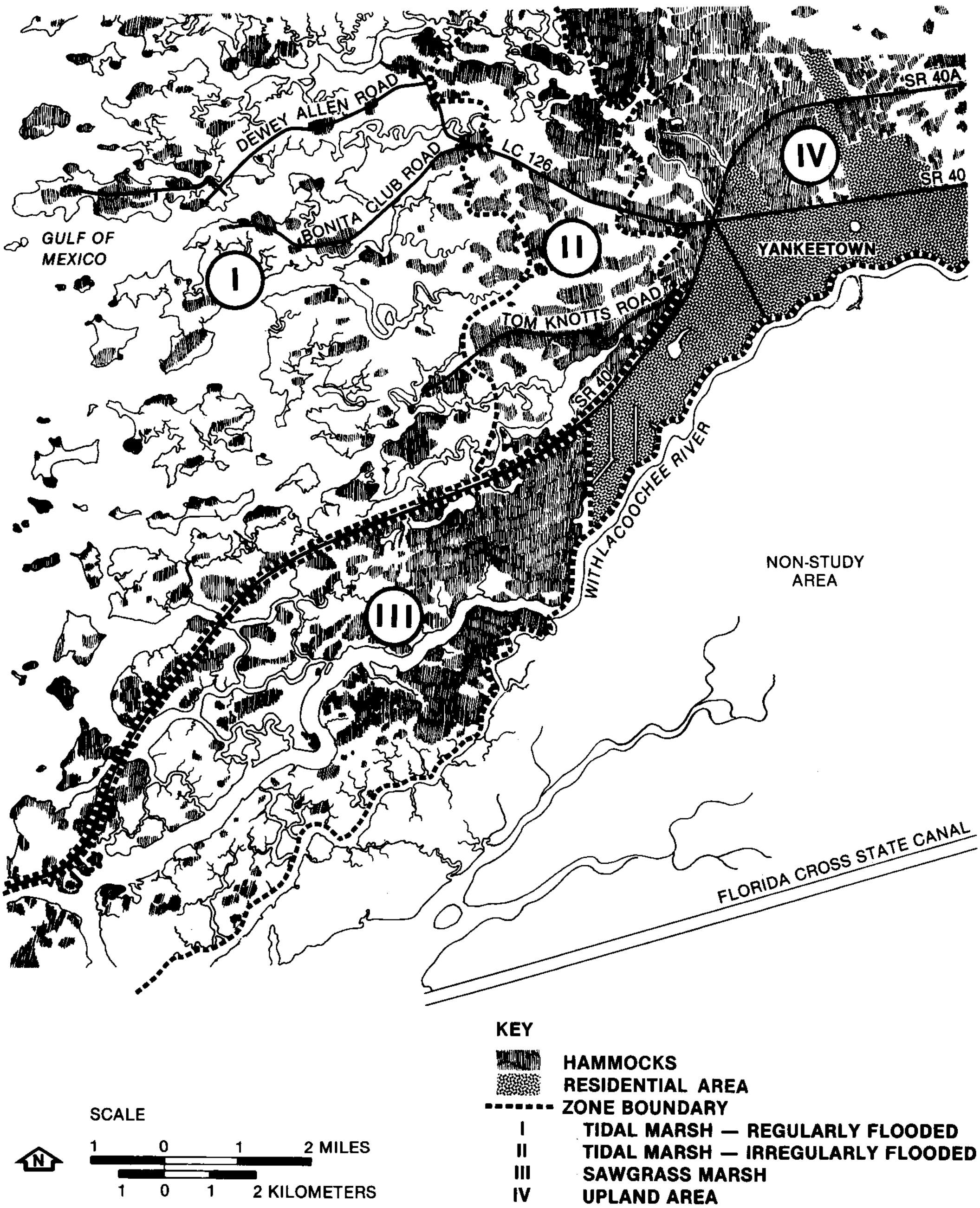

Fig. 1. Map of the Yankeetown, Florida area showing the location of the four physiographic zones.

study area. Two flights to obtain additional color infrared photographs were made (April and September 1983) by the remote sensing team from the USDA Citrus Insects Research Laboratory, Weslaco, Texas. In all flights the color film used was Kodak Aerochrome infrared, type 2443, which is a false color film sensitive in the spectral range from 500 to 900 nanometers. The black and white film was processed at Shaw Air Force Base, and all the color infrared was processed at the Citrus Research Laboratory. The Southwest Florida Water Management District provided additional scaled aerial photographs (contour maps 1:2400) of the Withlacoochee River Basin. After studying the materials obtained above, we made an additional flight over the area in a small aircraft to obtain an overview of the potential larval habitats.

Tidal cycle: Tides are the most obvious physical stress that occurs in these salt marsh areas. Since daily and seasonal tidal patterns undoubtedly play a major role in the distribution of plants and animals in the study area, we made an effort to determine the tidal patterns at Yankeetown. Predicted tide data were obtained from the U.S. Department of Commerce NOAA *Tide Tables* publication. Actual tide data collected every 6 min at Cedar Key were obtained from Control Tide Station No. 7520, located ca. 29 km northwest of Yankeetown; correction factors for time and height differences between the 2 locations were obtained from the *Tide Tables* publication. These data were used to calculate the monthly submergence values for each marsh habitat.

Substrate sampling: This was done in 2 phases. The initial phase was conducted over a 6-yr period (1977–83) to locate and characterize as many potential larval habitats as possible. Emphasis was placed on sampling areas in the salt marsh proper, particularly areas covered with *Distichlis, Juncus* and *Spartina.* As the study progressed, more potential larval habitats were located by our aerial and ground reconnaissance. During this phase no attempt was made to sample all habitats equally, nor was much attention paid to the effect that the time of year might have on larval abundance.

Also, no attempt was made either to rear or identify the larvae for species identification. Adult sampling conducted at this time revealed that the primary pest species was *Culicoides mississippiensis* Hoffman (Kline 1986) and that seasonality is an important sampling consideration.

The 2nd phase was conducted during the first 2 weeks of February 1984 when the *C. mississippiensis* larvae should have been most abundant. During this time, 26 habitat categories, largely defined from phase one, were sampled equally. Five different sampling locations throughout the Yankeetown area were selected for each habitat category. Five substrate samples were taken at each location; larvae were extracted from 4 samples and the 5th sample was held for adult emergence. In both phases all samples were obtained during a 3-hr interval, 1–1.5 hr before and after low tide. Samples were obtained with posthole diggers which yielded a core ca. 12 cm diameter and 10 cm deep (ca. 0.02 m^2 of marsh surface).

Larvae were recovered from each sample using the 2% agar extraction technique (Kline et al. 1981). This technique has been used successfully for all *Culicoides* spp. which are found in intertidal salt marshes and mangrove swamps. Samples kept for adult emergence were held at room temperature. No food was added to these containers since the natural substrate was used, and it contained an abundance of microorganisms. Adults were collected 3 times per week for 7 consecutive weeks with a battery-powered aspirator by placing the sample containers inside a large cage (32 × 32 × 32 cm), removing the lid, and aspirating the specimens resting on the cage walls. A light was placed near one side of the cage to attract the adult *Culicoides* for collection. The aspirator vial was placed in a freezer for ca. 10 min to immobilize the adults, which were subsequently placed in alcohol and identified under a dissecting microscope.

Data obtained during the 2nd phase were subjected to regression analysis and mean comparisons using Statistical Analysis System (SAS) procedures GLM and DUNCAN (SAS 1982). Separate analysis was performed for the larva and adult data.

RESULTS

Habitat categorization: As this study progressed, 4 distinct physiographical zones became obvious from aerial photographs and ground surveys (Figure 1): two distinct salt marsh zones which are stratified with respect to their distance from the Gulf of Mexico (Zones I and II); an extensive brackish-fresh water marsh located between the Withlacoochee River and SR40 (Zone III); and an upland area dominated by mixed pine and live oak (Zone IV).

The salt marsh zones were separated according to: (1) differences in plant cover type and distribution, (2) number and conformation of islands, tidal creeks and ponds, and (3) substrate structure (Table 1). These differences are probably due to a subtle rise in elevation that occurs as one moves inland from the gulf. The extent of each zone at any point along the coast seems to be correlated with the degree of development of the tidal creek network. Generally, the marsh areas of Zone I, which is closest to the Gulf, are lower in mean elevation than marsh areas of Zone II and have a larger number and more intricate network of tidal creeks of all sizes within the same unit area. Also, the tidal creeks of Zone I are generally wide and have steep vertically cut banks and sandy bottoms. Most of the tidal creeks in Zone II are less than 1 m wide, and they generally have silty, sloping banks and muddy bottoms. Approximately 3 times as many islands are found within equal unit areas in Zone I than in Zone II. However, the islands within Zone I are generally smaller and have a lower mean elevation than those within Zone II. Also, the banks of Zone I islands show exposed limestone edges, while Zone II

Table 1. Characteristics of Gulf marsh zones found adjacent to Withlacoochee Bay, Yankeetown, Levy Co., FL.

Zone	Distance (km) zone extends inland from Gulf	Mean no./km^2 of:[1]						Conformation of islands	Conformation of tidal creeks	Elevation (meters)[2]			Vegetative associations	
				Tidal creeks of width										
		Islands	Ponds	<1 m	1–8 m	8–16 m	>16 m			Marsh	Island	Ponds	Marsh	Islands
I	2.4	51.1	0.0	122.2	55.3	28.5	16.8	Generally smaller with exposed limestone banks on sides subject to tidal currents	Generally wider and with vertical cut banks & sand bottoms	0.84 (0.62–1.03)	1.39 (0.30–3.26)		*Distichlis spicata, Juncus roemerianus, Spartina alterniflora*	Pine, oak, cabbage palm, cedar, wiregrass, broomgrass, palmetto, gallberry, holly, Christmas berry, poison ivy, saltgrass (patens), opuntia
II	2.4–3.4	18.1	30.7	58.6	7.0	1.4	0.0	Generally larger and with gentle sloping banks surrounded by marsh on all sides	Small bore creeks with silty sloping banks and mud bottoms	1.03 (0.88–1.23)	1.50 (0.85–3.08)	0.76 (0.64–0.94)	*Salcornia, Distichlis spicata, Juncus roemerianus, Spartina patens,* sea lavender, saltmarsh aster	Same as above

[1] Mean numbers figured from 5 randomly selected aerial photographs of marsh areas representative of zones I and II. Each photograph with approximate area of 0.24 km^2.
[2] Mean elevation figured to the nearest 0.03 m projected from USGS Benchmark TT13T (elevation 2.14 m) above mean low water (MLW); range is in parentheses.

island banks have gentle slopes and are usually surrounded by marsh on all sides.

The depressions of Zone I are usually vegetated and are formed where tidal creeks or drainage areas have reached their full extension within a portion of the low marsh, or on the inside corners of creek banks which are not subject to direct tidal currents. Depression areas of Zone II have a higher mean elevation than those of Zone I and are not usually subject to the periodic emergence and submergence patterns produced by average tides. This discontinuous process of flooding and draining produces the tidal pools, or ponds, characteristic of the higher marsh of Zone II. These ponds are generally found at the point where tidal creeks have made their full extension into the higher marsh. They are usually found adjacent to islands and probably also serve as freshwater collection basins for the runoff from the higher elevations of Zone II.

Differences in the varieties, sizes and lushness of marsh vegetation also distinguish Zone I and Zone II. For example, a typical Zone I vegetation profile from island to creek bank would include *Baccharis halimifolia* L. (groundsel), *Spartina patens* (Ait.) Muhl. (salt-grass), *D. spicata* (marsh spike-grass), *J. roemerianus* (black needle-rush) and *S. alterniflora* (smooth cord-grass). *Spartina alterniflora* prevails along the banks of tidal creeks in pure stands forming a 1-5 m band along the channel. Irregularly shaped *S. alterniflora* patches are found interspersed among *Juncus* and isolated from creeks in low-lying marsh areas. Various mixtures of *Juncus* and *S. alterniflora* occupy large areas and are formed between pure stands of either species. Vast expanses of *Juncus* cover most of the Zone I tidal marsh and can be found in pure tall stands from the flatwoods islands to the edge of steep creek banks. *Distichlis* exists in pure stands or in various mixtures with *Juncus* and/or *S. alterniflora*, but is usually found throughout the marsh in small, thickly matted patches. Large areas can be found at suitable elevations bordering creeks. The substrate is usually silty.

A typical Zone II profile from island to creek or pond bank would include an area dominated by sandy soil supporting various salt-tolerant plants such as *Batis maritima* L. (saltwort), *Borrichia frutescens* (L.) (sea ox-eye), *Iva frutescens* L. (marsh elder), *Salicornia* spp. (dwarf saltwort) and *S. patens* (Ait.) Muhl (salt grass). This sandy soil also supports short forms of *J. roemerianus* and *D. spicata*. Panne areas (not occupied by any vegetation) are common at these higher elevations. *Juncus* is also the dominant vegetation of Zone II marsh and is found as pure tall stands growing from a mud substrate along pond and tidal creek banks. *Aster tenuifolius* L. and *Limonium carolinianum* (Walter) Britton, although present in Zone II, do not form large communities. *Spartina alterniflora* is rarely found in Zone II and is replaced by *Juncus* and *Distichlis* as the dominant vegetation bordering creeks and ponds.

The key factor that causes this zonal distribution in substrate types and vegetational associations is the interaction between tidal dynamics and marsh elevation. In general there is a linear relationship between distance from the Gulf of Mexico and vegetational associations in Zones I and II. There were exceptions, however. We found some Zone II substrate types and vegetational associations (e.g., *Juncus* with almost pure sand substrate) within our Zone I boundary for areas with elevations within the range of those established (Table 1) for the typical Zone II marsh.

The Zone III habitat is dominated by extensive areas of sawgrass, *Cladium jamaicense* Crantz. Occasional clumps of *Typha* spp. (cattail) and widely scattered patches of *Eleocharis quadrangulata* (Michaux) R. & S. (foursquare grass) can be found throughout this marsh. The substrate is generally very dark black mud, rich in decomposing organic matter. Islands of the size and vegetation composition that occur in Zone I are scattered throughout this marsh zone. The overstory is dominated by *Pinus elliotti* Engelm. (slash pine), sabal palm, and *Quercus virginiana* Mill. (live oak). The understory is primarily a mixture of *Myrica cerifera* L. (wax myrtle), *Sabal palmetto* (Walt.) Todd (cabbage palm), *Serenoa repens* (Batr) Small (saw palmetto), *Juniperus silicicola* (Small) Bailey (red cedar), *Yucca gloriosa* L. (Spanish bayonet), *Ilex vomitoria* Ait. (yaupon), *I. frutescens* L. (marsh elder) and *Lycium carolinianum* Walt (Christmas berry).

Zone IV is the upland area. Some of it has been developed for residential purposes, but most of it remains undeveloped. The vegetation composition is basically the same as that of the islands already described.

Tidal cycle: Tide influences the type and distribution of plants. The Gulf coast of Florida shows very pronounced annual sea level patterns (Provost 1974). The monthly sea level usually rises above the mean annual level for the Cedar Key area (near Yankeetown) in May and continues above the mean annual level until November (Figure 2). From December through April monthly sea level is less than the mean annual level. This peculiar annual sea level pattern creates a unique flooding pattern for the marsh. Higher elevation portions of the marsh, such as the *Juncus* and *Distichlis* areas of Zones I and II remain unflooded by high tides during

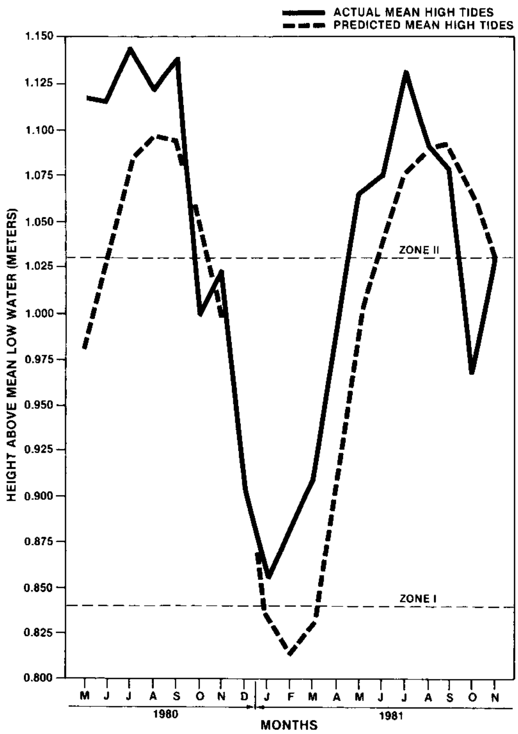

Fig. 2. Annual tidal cycle at Yankeetown, Florida, based on predicted mean high tides (——) for Yankeetown obtained from NOAA *Tide Tables* (1980 and 1981) and actual mean high tide data (- - - - -) collected at Cedar Key (Tidal Station #7520) and adjusted for Yankeetown.

late fall, winter and spring months. Conversely, during summer and early fall months, tidal intervals similar to those of fall, winter and spring will consistently flood the high marsh. This pattern coincides with our field observations made within the study area during 1980–81, when between September and May the higher portions of the marsh (e.g., *Distichlis* areas) were rarely flooded by regular high tides.

Substrate sampling: A total of 2,521 substrate samples were processed during phase one (Table 2); 87% of these samples were productive, i.e., yielded at least 1 larva. The majority (92.5%) of samples were taken from Zone I marsh areas; 90% of these samples were productive. In 138 samples taken from Zone II marshes, only 53% were productive; 30% of the 23 samples from Zone III and 60% of the 28 samples taken from Zone IV were productive. Within Zone I, *S. alterniflora* areas had the highest percentage (95%) of productive substrate samples, followed by areas covered with *Juncus* (83%) and *Distichlis* (79.6%).

Twenty-six habitat categories (650 substrate samples) (Table 3) were sampled in phase two. There were 14, 6, 2, 3 and 1 categories taken from Zones I, II, III, IV and the transition area between II and IV, respectively. Only those substrate samples taken from under *Baccharis* shrubs, found in the transition area between Zones II and IV, failed to produce any larvae. The most productive samples were taken from Zone I marsh areas where *S. alterniflora* was the plant cover. In 9 of the categories from Zone I, 90–100% of the substrate samples contained at least 1 larva. In the remaining 5 Zone I categories, only 30–65% of the samples were productive. These latter 5 categories were in more limited and specialized habitats than the other 9. The substrate in 4 out of 5 of these specialized habitats was almost pure sand, and in the 5th habitat the substrate was silty mud along the bottom part of tidal creek banks. Two of these specialized habitats were located where a relatively abrupt elevation change created a Zone II-type substrate and plant association within the Zone I marsh as previously mentioned. The sandy substrate of these areas supported a shorter and less dense stand of both *Juncus* and *Distichlis* (within roadside ditch banks), and yielded significantly fewer larvae than the more typical habitat categories of Zone I. Two of the remaining 3 specialized habitats (muddy tidal creek banks and sandy beach areas) occupy very limited areas within Zone I and also produced very few larvae. The 5th specialized habitat, *Spartina* found within old house foundations, produced a moderate number of larvae, but this habitat does not occur naturally.

Only 2 of the 6 habitat categories in Zone II had 90% of the samples containing at least 1 larva. These were tall *Juncus* areas in very mucky substrate around the margins of ponds and *Distichlis*-covered areas. Substrate in most Zone II *Juncus* areas sampled was about 50:50 sand:silt, and 75% of these samples were productive. The substrate in the *S. patens* area and panne areas was almost pure sand, and only 35% and 25% of the substrate samples taken from these 2 areas, respectively, contained any larvae.

In both categories of substrate taken from Zone III, 60% of the samples contained at least 1 larva. In Zone IV only 1 of 20 samples, taken from the banks of the Withlacoochee River, contained any larvae. In the other two Zone IV categories, 40% and 70% of the samples taken from the banks of freshwater ditches and ponds, respectively, contained larvae.

Six species of *Culicoides* (*C. bermudensis* Williams, *C. furens* (Poey), *C. haematopotus* Malloch, *C. melleus* (Coquillett), *C. mississippiensis* and *C.* n. sp. 109 Wirth) were recovered from those substrate samples held for adult emergence (Table 3).

Twelve of the 14 substrate categories from

Table 2. *Culicoides* spp. larval abundance in various marsh and upland habitats found at Yankeetown, FL, during phase one studies on larval distribution

				Positive samples						
						% samples in each larvae density group				
Habitat category	No. of samples	Avg. no. larvae/sample	% positive samples	Min. no. larvae/sample	Max no. larvae/sample	1–25	26–50	51–75	76–100	>100
Zone I										
Spartina alterniflora areas										
Marsh proper	293	7.5	83.6	1	57	89.8	9.4	0.8	0.0	0.0
Roadside ditch	730	34.0	98.4	1	281	51.2	27.1	11.9	6.0	3.8
Interface with *Juncus*	373	42.3	98.7	1	320	44.6	27.4	12.5	5.4	10.1
Sandy beach	23	11.3	100.0	2	48	91.3	8.7	0.0	0.0	0.0
Bordering islands	40	7.1	77.5	1	46	93.5	6.5	0.0	0.0	0.0
Within old house foundation	20	28.0	100.0	1	102	65.0	10.0	15.0	5.0	5.0
Distichlis areas										
Marsh proper	286	8.7	82.5	1	141	89.0	8.5	1.3	0.4	0.8
Roadside ditch	40	5.7	67.5	1	33	96.3	3.7	0.0	0.0	0.0
Sand substrate	51	5.1	70.6	1	38	94.4	5.6	0.0	0.0	0.0
Within old house foundation	5	4.0	100.0	2	5	100.0	0.0	0.0	0.0	0.0
Juncus areas										
Marsh proper	303	4.6	80.2	1	54	97.5	2.1	0.4	0.0	0.0
Juncus/S. alterniflora (50:50) Marsh proper	59	12.1	91.5	1	89	81.5	16.7	0.0	1.9	0.0
Roadside ditch	22	19.1	100.0	1	86	81.8	13.6	0.0	4.5	0.0
Juncus/Distichlis Interface	46	4.7	82.6	1	31	97.4	2.6	0.0	0.0	0.0
(Marsh proper)	35	18.1	82.9	1	86	69.0	17.2	10.3	3.4	0.0
Sandy beach										
Unvegetated sandy areas	6	1.8	66.7	2	4	100.0	0.0	0.0	0.0	0.0
Zone II										
Juncus areas										
Marsh patches	94	2.5	59.6	1	25	100.0	0.0	0.0	0.0	0.0
Muddy margins of creek bands	19	6.5	68.4	1	55	92.3	0.0	7.7	0.0	0.0
Spartina patens	7	0.0	0.0	—	—	—	—	—	—	—
Salicornia spp.	3	0.0	0.0	—	—	—	—	—	—	—
Distichlis around ponds	5	1.0	60.0	1	3	100.0	0.0	0.0	0.0	0.0
Panne	10	0.1	10.0	1	1	100.0	0.0	0.0	0.0	0.0
Zone III										
Freshwater ditch	18	1.1	22.2		13	100.0	0.0	0.0	0.0	0.0
Sawgrass marsh	5	0.6	60.0	1	1	100.0	0.0	0.0	0.0	0.0
Zone IV										
Freshwater ditch	5	0.4	40.0	1	1	100.0	0.0	0.0	0.0	0.0
Muddy banks										
Withlacoochee River	18	1.7	66.7	1	5	100.0	0.0	0.0	0.0	0.0
Boat basin	5	2.0	60.0	2	4	100.0	0.0	0.0	0.0	0.0

Table 3. Larvae and adult *Culicoides* spp. (miss = *mississippiensis*; fur = *furens*; mell = *mellus*; haem = *haematopotus*; 109 = n.sp.109) recovered from substrate samples obtained at Yankeetown, FL, during phase two studies on larval distribution.

Habitat category	Larvae recovered[1,3] % Positive samples	Larvae recovered[1,3] Average #/sample	Larvae recovered[1,3] SD	Adults recovered[2,3] Average #/sample	Adults recovered[2,3] SD	*miss*	*fur*	*mell*	*haem*	*109*
Zone I										
Spartina alterniflora areas										
Silty roadside ditch	100	70.2 a	58.1	132.4 a	61.4	88.0 a	44.4 a	0.0 b	0.0 c	0.0 c
Marsh proper	100	44.5 b	20.5	115.2 a	51.4	92.4 a	22.8 b	0.0 b	0.0 c	0.0 c
Sandy beaches	100	36.7 b	17.4	10.6 bc	8.6	4.4 c	6.2 c	0.0 b	0.0 c	0.0 c
Around islands	100	17.3 cd	14.1	14.6 bc	14.1	14.6 bc	0.0 c	0.0 b	0.0 c	0.0 c
Within old house foundation	65	8.0 def	11.7	1.6 c	1.8	0.2 c	1.4 c	0.0 b	0.0 c	0.0 c
J. roemerianus areas										
Marsh proper (mud)	90	10.4 cdef	11.8	1.4 c	1.1	0.6 c	0.8 c	0.0 b	0.0 c	0.0 c
Marsh proper (sand)[5]	60	0.8 f	0.7	0.2 c	0.5	0.0 c	0.2 c	0.0 b	0.0 c	0.0 c
Juncus/Spartina areas										
Roadside ditch	100	16.5 cd	11.1	33.4 b	55.1	31.4 b	2.0 c	0.0 b	0.0 c	0.0 c
Marsh proper	100	13.7 cde	9.1	11.0 bc	19.0	1.6 c	9.4 c	0.0 b	0.0 c	0.0 c
D. spicata areas										
Marsh proper	95	9.7 cdef	7.0	1.4 c	1.7	0.6 c	0.8 c	0.0 b	0.0 c	0.0 c
Roadside ditch[5]	50	2.9 ef	7.0	0.0 c	0.0	0.0 c	0.0 c	0.0 b	0.0 c	0.0 c
Unvegetated areas										
Roadside ditch (sand)	95	11.9 cdef	9.3	4.8 bc	3.6	0.0 c	0.0 c	4.8 a	0.0 c	0.0 c
Sand beaches	30	0.4 f	0.8	0.0 c	0.0	0.0 c	0.0 c	0.0 b	0.0 c	0.0 c
Tidal creek banks (mud)	50	3.0 ef	5.7	7.4 bc	10.7	7.4 c	0.0 c	0.0 b	0.0 c	0.0 c
Zone II										
J. roemerianus areas										
Pond margins	90	20.4 c	28.9	18.6 bc	13.6	6.0 c	12.6 bc	0.0 b	0.0 c	0.0 c
Marsh proper (sand)	75	3.8 ef	7.7	0.0 c	0.0	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c
D. spicata area										
Marsh proper	90	7.4 def	7.6	7.0 bc	12.9	0.4 c	6.6 c	0.0 b	0.0 c	0.0 c
S. patens area	35	2.9 ef	4.9	0.8 c	1.3	0.2 c	0.6 c	0.0 b	0.0 c	0.0 c
Salicornia spp. area	60	2.6 ef	3.2	1.4 c	1.5	0.0 c	1.2 c	0.2 b	0.0 c	0.0 c
Panne areas	25	0.9 f	2.2	0.4[4] c	0.9	0.0 c	0.0 c	0.0 b	0.0 c	0.0 c
Zone III										
Sawgrass marsh	60	4.1 ef	6.3	1.4 c	0.5	0.6 c	0.2 c	0.0 b	0.2 c	0.4 b
Freshwater ditch	60	2.1 ef	3.8	3.2 bc	2.2	0.0 c	0.0 c	0.0 b	1.2 bc	2.0 a
Zone IV										
Freshwater pond banks	70	8.3 def	20.2	3.4 bc	4.1	0.0 c	0.0 c	0.0 b	3.0 ab	0.0 c
Freshwater ditch	40	3.0 ef	7.1	4.0 bc	6.3	0.0 c	0.4 c	0.0 b	3.4 a	0.2 b
Muddy bank of Withlacoochee River	5	0.2 f	0.9	0.8 c	1.8	0.8 c	0.0 c	0.0 b	0.0 c	0.0 c
Zone II–IV interface										
Baccharis shrub	0	0.0 f	0.0	0.0 c	0.0	0.0 c	0.0 c	0.0 b	0.0 c	0.0 c

[1] n = 20.
[2] n = 5.
[3] Columnar values followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.
[4] All *C. bermudensis*.
[5] Habitat category with Zone II soil and vegetational characteristics but located within Zone I boundary.

Zone I marsh areas produced adults. No adults were obtained from the *Distichlis*-covered sandy areas or the unvegetated sandy beaches, and only 0.2 adults/sample were obtained from sandy substrate areas covered with *Juncus*. The single specimen recovered from these sandy *Distichlis* or *Juncus* categories was *C. furens*. Adult emergence in the other 11 categories ranged from 1.4 adults/sample (*Juncus*- and *Distichlis*-covered muddy substrate areas in the marsh proper) to 132.4 adults/sample in *S. alterniflora*-covered areas within silty roadside ditches. *Culicoides mississippiensis* adults emerged from substrate samples from 10 of 11 of these categories; only *C. melleus* emerged from substrate samples taken from the unvegetated sandy areas along roadside ditches. Only *C. mississippiensis* was obtained from the *S. alterniflora*-covered areas on a thin silty mud layer on top of limerock found around many hammocks and from the muddy banks of tidal creeks. *Culicoides mississippiensis* was the most abundant species in *Spartina*-covered areas within the silty roadside ditches, marsh proper and the *S. alterniflora*/*Juncus* interface in marsh areas along roadside ditches. Nearly equal numbers of *C. mississippiensis* and *C. furens* were obtained from substrate samples taken from *Juncus*- and *Distichlis*-covered muddy substrate areas in the marsh proper. *Culicoides furens* was the dominant species recovered from substrate samples taken from *S. alterniflora* covered areas on sandy beaches and the *S. alterniflora*/*Juncus* interface in the marsh proper.

Five of the 6 habitat categories from Zone II produced adults; *C. furens* was the predominant species recovered from this marsh zone. No adults were recovered from sandy substrate samples obtained from *Juncus*-covered areas despite the fact that 3.8 larvae/sample were obtained from these same locations. The only productive area in Zone II where *C. furens* was not recovered was the panne area, which produced only 2 *C. bermudensis* (0.4 adults/sample). The most productive (18.6 adults/sample) Zone II habitat was the tall *Juncus*-covered mucky areas around ponds. In this habitat, 12.6 *C. furens*/sample and 6.0 *C. mississippiensis*/sample were recovered. Lower numbers of *C. mississippiensis* were also recovered from habitats covered with *Distichlis* (0.4/sample) and *S. patens* (0.2/sample). *Culicoides melleus* was recovered in low numbers (0.2/sample) from *Salicornia* spp.-covered sandy areas.

Both habitat categories in Zone III produced adults. *Culicoides furens* (0.2/sample) and *C. mississippiensis* (0.6/sample) were recovered only in the brackish sawgrass marsh, and only in those samples where the marsh was closest to the Gulf of Mexico. Two freshwater species, *C. haematopotus* and *C.* n. sp. 109, were present in both Zone III categories and were the only 2 species recovered from the freshwater ditch area in this Zone.

Some adults were produced by each of the 3 habitat categories sampled in Zone IV. The most productive habitat category was the muddy banks of several rainwater-filled ditches which produced 4.0 adults/sample, consisting of 3.4 *C. haematopotus*/sample, 0.4 *C. furens*/sample and 0.2 *C.* n. sp/sample. This is the only Zone IV category which produced any *C. furens*. Next in productivity were the muddy bank margins of 2 freshwater ponds (3.4 adults/sample) which produced *C. haematopotus* (3.0 adults/sample) and *C.* n. sp. 109 (0.2 adults/sample). Samples taken from the banks of the Withlacoochee River produced only 0.8 adults/sample, all of which were *C. mississippiensis* obtained from the sample closest to the Gulf of Mexico.

DISCUSSION

Studies on the diel and seasonal activities *Culicoides* spp. at Yankeetown (Kline 1986, Lillie et al. 1987), which were conducted concurrently with these larval habitat studies, showed that *C. furens* and *C. mississippiensis* are the dominant species. *Culicoides bermudensis*, *C. haematopotus* and *C. melleus* are not a nuisance problem at Yankeetown and will not be discussed further. Very few complaints were heard about biting activity when *C. furens* was the most abundant species. In contrast when *C. mississippiensis* was the predominant species, complaints were very numerous. This is probably because peak populations of *C. mississippiensis* coincide with the peak in seasonal and diurnal outdoor business and recreational activities of both residents and tourists. Therefore, as this study progressed, we placed increased emphasis on determining the habitat range of this species. In fact the 2nd phase was planned to coincide with the expected peak in overwintering larval populations of *C. mississippiensis*.

The data from both phases indicate that Zone I marsh areas provide the most productive *Culicoides* larval habitats. This is especially true for *C. mississippiensis*. The larvae of this species are largely confined to Zone I marsh habitats. An exception to this was the *Juncus*-covered mucky margins of Zone II ponds. The few adult *C. mississippiensis* which emerged from substrate samples taken from Zones III and IV were from those samples taken along the Withlacoochee River banks and sawgrass marsh in close proximity to the Gulf of Mexico. *Culicoides furens* seems to have a wider habitat range. It was found in both salt marsh and freshwater habitats.

These data are in agreement with information on habitat range of these species that exists in the literature. Most of the published information on *C. furens* comes from studies conducted in the Caribbean Basin with the exception of Florida studies by Rogers (1962) and Linley et al. (1970). Linley and Davies (1971) report that the larval habitat range of *C. furens* is extensive in the Caribbean Basin. Mangrove swamps, salt marshes and the banks of ditches were the most frequently reported habitat for this species, but Williams (1964) also reported it from freshwater habitats in Trinidad. In coastal North Carolina where *C. furens*, *C. hollensis* (Melander and Brues) and *C. bermudensis* occurred together in grassy saltmarshes, Kline and Axtell (1977) found that *C. hollensis* was the most abundant in tall growth of *S. alterniflora* along the margin of a tidal river and man-made drainage ditches. *Culicoides furens* was most abundant in areas of short *S. alterniflora* further from the river. Kline and Axtell (1976) also found *C. furens* larvae in *Spartina*-covered and unvegetated sandy intertidal habitats in North Carolina. There was only one literature reference to the larval habitats of *C. mississippiensis*, and it is based on speculation, not actual sampling data. Blanton and Wirth (1979) stated that no rearings of *C. mississippiensis* have been reported, ". . . but on distributional grounds, it can safely be assumed that the species breeds in tidal saltmarshes with vegetation marked by *J. roemerianus* rushes on the Gulf Coast, similar to the Atlantic Coast *Spartina* marsh habitat of *C. hollensis*."

Based on our data, we feel additional long-term studies on the larval population dynamics of *C. furens* and *C. mississippiensis* are justified if effective larval control is to be implemented. Since Zone III and IV habitats contribute very little to the *Culicoides* problem at Yankeetown, further studies should concentrate on Zone I and II habitats.

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