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Assessing the Effects of Development Pressure on Barnegat Bay: Impacts of Marinas on Juvenile Fishes and Crabs

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ABSTRACT

Shallow-water habitats (eelgrass and unvegetated substrate) in two Barnegat Bay marinas and adjacent control areas were quantitively sampled from September 1988 through October 1989. During this period 554 samples were collected and over 2200 fish and 8100 decapod crustaceans representing 28 and 13 species respectively were identified. The fauna at all sampling sites were dominated by juvenile fishes that use the estuary as a nursery and juveniles of resident decapod crustaceans. The most obvious sources of variation were seasonal patterns of abundance and habitat specific patterns in species composition, especially for eelgrass (*Zostera marina*) sites irrespective of location or marina effects. Winter flounder (*Pseudopleuronectes americanus*) and the blue crab (*Callinectes sapidus*) were chosen for particular attention because of their ecological and economic importance in Barnegat Bay. Both species occurred in Viking Village marina and control sites, but winter flounder never occurred at the Long Quay marina on the western shore of Barnegat Bay. Location had a pronounced effect on the fauna of Viking Village Marina, presumably reflecting its proximity to Barnegat Inlet. In this preliminary attempt we determined that the secondary impacts of marinas (i.e. resulting from marina operation and use) were not obvious.

INTRODUCTION

The extremely rapid population growth along the shores of Barnegat Bay has occurred with little planning or concern for the Barnegat Bay ecosystem. As a result, the effects of development pressure on Barnegat Bay are poorly understood. Continued use of Barnegat Bay as a prime area for recreational and residential use, and the location of some of the most important inshore recreational and commercial fisheries in New Jersey, may be compromised with increased development.

One of the potentially most significant pressures on Barnegat Bay is marina development (Chmura and Ross, 1978; Sugihara, 1979; Hershner, 1986). Based on recent information there are approximately 200 commercial marinas in Barnegat Bay with about 12,000 slips (Anon., 1986). Marinas may have two types of ecological impacts. Direct impacts refer to those which are a consequence of the construction of the facility. Secondary impacts are those resulting from the operation and use of the marina (Hershner, 1986) and could include alteration of water and habitat quality and changes in distribution of recreationally and economically important species of fishes and crabs.

Of particular concern are the impacts that result from the introduction of hydrocarbons and heavy metals. These substances have been found to be toxic to a wide variety of marina animals (Stekoll et al., 1980; MacDonald and Thomas, 1982; Bryan, 1971; LaParke and Talbott, 1977) and can inhibit the growth of submerged vegetation (Lyngby and Brix, 1984).

In Barnegat Bay, blue crabs (*Callinectes sapidus*) and winter flounder (*Pseudopleuronectes americanus*) are economically important species (Kennish and Lutz, 1984; Hillman and Kennish, 1984). The juvenile stages of both of these species are dependent on estuaries such as Barnegat Bay and other shallow water habitats for their growth and survival. In this project we studied the effects of marinas on species composition, abundance, and habitat utilization of fish and decapod crustaceans. Of special concern were blue crabs and winter flounder, particularly their abundance, juvenile recruitment, and the size distribution in marina and control areas.

METHODS and MATERIALS

Study Sites

Fishes and decapod crustaceans were quantitatively sampled in shallow water at two marina sites and two nearby controls in Barnegat Bay. The Viking Village site is 3 km south of Barnegat Inlet (Fig. 1), one of the major inlets on the New Jersey shore. The Long Quay site is

8 km west of the inlet, across the bay, and is more likely to be affected by freshwater runoff from upland sources. These marinas were chosen because they possessed many of the characteristics necessary for this study, including large numbers of boats, gas pumps, availability of shallow water sampling, and tidal flow. Control sites were chosen because of their proximity to the marinas and their similarity in bottom type. Long Quay control (sand and eelgrass) sites are located on the bay, between the channel and the Waretown municipal pier. The control sites for Viking Village marina (sand and eelgrass) are located northwest from the marina across the channel near red bouy number six. Eelgrass (Zostera marina) was not present in either Viking Village or Long Quay marina. However, at Viking Village eelgrass occurred immediately outside a wooden bulkhead that had continuous water exchange through it to the marina. This specific location was designated as the marina eelgrass site. The Viking Village marina site had both eelgrass and sand available for sampling; Long Quay marina had only sand in shallow water areas (Table 1).

Sampling Techniques

Decapod crustaceans and fishes were collected with a one m^2 aluminium throw trap that quantitatively samples the enclosed water column and epibenthos (Kushlan, 1981). The trap was constructed of light aluminium sheeting attached to an aluminium frame (1 m x 1 m x 0.75 m deep). Netting (3 mm mesh) attached to the top of the trap floated and enclosed the water column. In a typical sampling event the trap was thrown onto the area to be sampled; it sank rapidly, and settled into the sediment (approximately 2 cm) preventing escape of the animals. Trapped animals were collected by repeated sweeping of the inside of the trap with a bar seine (1 m x 0.5 m) until no decapod crustaceans or fishes were caught in three consecutive sweeps.

Samples were collected in four different periods from September 1988 to November 1988 and in seven monthly periods from April 1989 to October 1989 (Table 2). One to four replicates were taken in the habitats dependent on weather conditions and water depth. A total of 241 samples were taken from September 1988 to October 1989 (Table 1). After collection each sample was frozen until ready for processing in the laboratory. All blue crabs and winter flounder were identified, counted and measured. All other fishes and decapod crustaceans were identified and counted; a subsample of twenty individuals per sample was measured. Temperature and salinity were measured at all sites during each sample period with a glass thermometer and a refractometer.

Above and below ground vegetation biomass was estimated by the dry weight of 10 cm diameter vegetation cores taken during regular sampling. Two replicate cores were taken for each vegetated throwtrap sample. Cores were frozen after collection and later thawed and rinsed in fresh water and separated into eelgrass rhizomes, and shoots before drying. Samples were dried to a constant weight at 80 °C.

RESULTS

Physical Characteristics of the Study Sites

The study sites varied in several characteristics. Most obvious were the average higher mean salinity and lower mean temperatures at the Viking Village location (Table 2). These differences are likely related to the proximity of the Viking Village site to Barnegat Inlet (Fig. 1). The lower salinities at the Long Quay site may have resulted from freshwater runoff and the lower average salinities on the western side of the bay (Chizmadia et al. 1984). Eelgrass biomass varied among sample locations (Table 3). Aboveground biomass tended to be least at the Long Quay control site and belowground biomass tended to be least at Viking Village marina. In general, aboveground biomass followed a similar seasonal pattern at all sites with low spring values, followed by peak values during the summer and declining again in autumn. Seasonal trends in belowground biomass differed between marina and control sites. Marina samples followed a similar pattern to that of aboveground biomass while the control sites showed high spring values that tended to decline over the summer.

Comparison of Species Composition and Abundance

During the study period over 2200 fishes and 8100 decapod crustaceans representing 28 species of fish and 13 species of decapod crustaceans were collected with throwtraps (Table 4, 5). The fauna was typical of New Jersey estuaries including strays from more southern waters (*Chaetadon ocellatus*, *Chasmodes bosquianus*, *Hypsoblennius hentzi*, *Lactophrys sp.*, *Lutjanus griseus*, *Monacanthus sp.*, *Callinectes similis*, and *Penaeus aztecus*). These were not surprising during 1989 because a large number of subtropical forms occurred in other southern New Jersey estuaries (K. Able, pers. observ.). The vast majority of fish species were represented by the juveniles and adults of resident species or the juveniles of species that utilized the area as nurseries (Table 4). Almost all decapod crustaceans were resident species (Table 5).

Species richness and composition varied between study locations (Table 6, 7). More species of fish (24) and decapod crustaceans (12) were collected at the Viking Village site than at Long Quay where only 17 fish and 9 decapod species occurred in the collections. A number of species occurred exclusively or were much greater in abundance at only one of the locations. At Viking Village these included the fishes *Centropristis striata*, *Etropus microstomus*, *Lactophrys sp.*, *Myoxocephalus aeneus*, *Prionotus evolans*, *Tautoga onitis*, *Tautogolabrus adspersus* and the decapod crustaceans *Crangon septemspinosa*, *Hippolyte pleuracanthus*, *Libinia emarginata*, *Ovalipes ocellatus* and *Penaeus aztecus*. The fishes *Anchoa mitchilli*, *C. bosquianus*, *Cyprinodon variegatus*, *Lucania parva* and the decapod *Cancer irroratus* were unique to the Long Quay location. Fish abundance was much greater at the Long Quay study location in 1988 with the densities greatest at the marina-unvegetated habitat and also relatively high at the control-vegetated habitat (Table 8). The same trend was not evident from the more extensive collections in 1989 with the highest densities occurring in both vegetated and unvegetated control sites at Viking Village and the marina-unvegetated site at Long Quay. The pattern is much different for the decapod crustaceans (Table 8). The density of decapods was almost always greater than fishes in any habitat. In addition, the value for decapods was lowest in 1988 at the Long Quay marina-unvegetated habitat. Also, decapod densities were much greater at every habitat at both study locations in 1989. During that year the highest density of decapods occurred at the Viking Village control-vegetated site.

Species composition also varied with habitat type, irrespective of location or marina effects. Several species of fishes (Apeltes quadracus, C. striata, M. aeneus, Syngnathus fuscus) and decapod crustaceans (C. sapidus, Carcinus maenas, H. pleuracanthus) were more abundant in the eelgrass habitat. A few species of fish (C. variegatus, E. microstomus) and one decapod (Pagurus longicarpus) appeared most abundant in unvegetated habitats.

There were no obvious differences in the species composition and relative abundance between the marinas and controls (Table 6, 7). The only possible difference was the low density of C. septemspinosa in the unvegetated habitat at the Long Quay marina. Palaemonetes vulgaris was most abundant at the unvegetated-marina habitat at Long Quay relative to the unvegetated-control there and at Viking Village.

Seasonal Patterns of Abundance

The seasonal patterns of fish abundance varied between study locations and habitat type (Fig. 2). Fish density at the Long Quay location was much greater during fall 1988 than at the Viking Village location. This was due to greater abundance of fish in the marina-unvegetated and control-vegetated sites. Alternatively, fish density at Viking Village, particularly the control-unvegetated habitat, was much higher in June than at the Long Quay location.

Comparisons between the marinas and control habitats suggested some differences. During 1988 at the Viking Village location the control-vegetated habitats had a greater density of fish from June-September than at the marina-vegetated habitat (Fig. 2). This same comparison was not possible for the Long Quay location. Similarly, at the period of peak fish density in June the density at the control-unvegetated habitat was much greater than at the marina-unvegetated. The opposite trend occurred at the Long Quay location where fish density was often greater at the marina-unvegetated habitat than at the control-unvegetated (Fig. 2). This difference is due to the greater density of C. variegatus and Fundulus heteroclitus in the marina (Table 3).

The seasonal pattern of decapod crustacean abundance, at least in 1988, differed from the fishes with the greatest abundance of decapods occurring in late summer and early fall (Fig. 3). Decapod density was highest at the Viking Village location, especially at the vegetated habitats. There were no clear differences for decapods between marina and controls for any habitats.

Comparisons for winter flounder between marina and control habitats

Winter flounder (P. americanus) was one of the dominant components of the fish fauna and ranked fifth in overall abundance (Table 6). This species was clearly most abundant at the Viking Village location but there were no obvious differences in density between the habitats sampled. It was most abundant at the marina-unvegetated habitat at the Long Quay location.

Winter flounder abundance varied at the Viking Village location both seasonally and with life history stage (Fig. 4). Winter flounder reached the highest density in July 1988 and October 1988. The former peak was due to the recruitment of young-of-the-year individuals. These were first apparent in the May collections and the year class is obvious through August. The fall peak in abundance in 1988 is represented by presumed one year old individuals ranging from 75-125 mm TL (Fig. 5). There were no obvious differences in habitat use by size except that the marina habitats (vegetated and unvegetated) were the source of most of the larger individuals while all of the newly recruited individuals (<10 mm TL) were collected in the vegetated habitats (Fig. 6).

Comparisons for blue crabs between marina and control habitats

Blue crabs (C. sapidus) were one of the dominant components of the decapod fauna and ranked fourth in overall abundance (Table 7). Blue crabs reached their highest densities in the fall of 1988 at the Long Quay location and at the Viking Village location in 1989 (Fig. 7). In both years, the preponderance of individuals were recent recruits (<10-25 mm carapace width (Fig. 8). This occurred independent of habitat with the trend for the largest numbers of individuals collected from vegetated habitats regardless if located in marinas or control areas (Fig. 9).

DISCUSSION

Species Composition

The fish and decapod crustacean fauna collected during this study was typical of New Jersey estuaries (Able, in press) and Barnegat Bay in particular (Marcellus, 1972; Vouglitois, 1983; Tatham et al., 1984). The preponderence of juvenile forms, especially among the fishes, reiterates the importance of New Jersey estuaries, and estuaries elsewhere (Cronin and Mansueti, 1971; McHugh 1967, 1977), as nurseries for a variety of species. One of the most pronounced differences in species composition was apparently related to the location of the study sites. A number of forms collected at Viking Village were unique to that location (Table 6, 7). These occurrences were likely due to the proximity to Barnegat Inlet (Fig. 1) and the resulting cooler water and higher salinity at this site. As a result of the rather pronounced differences due to location effects further comparisons are location specific.

This study presents the first quantitative values for the shallow water macrofauna from Barnegat Bay. Prior studies, utilizing similar techniques in Little Egg Harbor and Great Bay, immediately to the south, provided a basis for comparison (Able et al., 1989; Sogard, 1989; Wilson et al., in prep.). In general, species composition was very similar for vegetated and unvegetated habitats and densities for most species were of the same order of magnitude.

Habitat preferences or differential survival accounted for some differences in species composition. The greater abundance of some fishes in vegetated habitat has been documented in other studies especially for A. quadracus and S. fuscus (Briggs and O'Connor, 1971; Heck et al., 1989; Wilson et al., in review), M. aeneus (Lazzari et al. 1989), and H. pleuracanthus (Thayer et al., 1984; Heck and Orth, 1980; Wilson et al., in review).

Habitat and life history of winter flounder and blue crabs

Winter flounder were most abundant at the Viking Village location but the lack of pronounced habitat differences at that site gives no real insight into the decreased average density that occurred at the Long Quay location (Table 6). Perhaps the slightly higher temperatures and lower salinities were responsible. Recruitment of small juveniles for the study sites and the rate of growth observed (Fig. 4, 5, 6) is similar to that for Little Egg Harbor-Great Bay (Able et al. 1989).

Blue crab recruitment to Barnegat Bay occurred in the fall, although it was more apparent at the Viking Village location than at Long Quay (Fig. 7). Abundance did not vary much between habitat types as we have previously observed in other New Jersey estuaries (Wilson et al., 1990).

Marina effects

In this preliminary attempt to examine for secondary impacts of marinas (i.e. those resulting from marina operation and use) we determined that, with a few possible exceptions, the differences in species composition and abundance were not marked. Where differences in abundances of selected species were apparent we attributed these to differences in habitat utilization. However, there may have been negative effects on the abundance of C. septemspinosa at the Long Quay marina. At the marina-unvegetated site the density was much lower than at the control sites and relative to similar sites at the Viking Village location (Table 7). This species typically buries in the substrate (Able, pers. observ.) and would be susceptible to contamination by heavy metals (Bryan, 1971; LaPorte and Talbott, 1977; Callahan and Weis, 1983; Krishneja et al., 1987), hydrocarbons (Anderson et al., 1977; Griffin and Calder, 1977; Stokall et al., 1980; McDonald and Thomas, 1982), and high biochemical oxygen demand if the sediments in this marina were heavily impacted as occurs in other areas. Certainly these effects and others have been identified in other marinas in New Jersey (Vernam and Connell in press). Impacted sediments could also affect the abundance of C. septemspinosa in more subtle ways. If individuals choose not to bury in the substrate and are thus more available to predation the net result would be decreased survival in areas where the sediments are impacted. This scenario is possible because this species is an important prey item in New Jersey estuaries (Festa, 1979). The pattern of decreased abundance in the Long Quay marina is not obvious for blue crabs even though this species buries in the substrate also.

Another potential difference between marina and control sites was the reduced biomass of eelgrass rhizomes at the Viking Village marina. A number of factors may have contributed to this observation, including natural variation in eelgrass patchiness or age, as well as, variation introduced by the sampling method (small cores with small numbers of replicates). However, impacts typical of marinas (i.e. higher levels of hydrocarbons and heavy metals are known to negatively influence eelgrass occurence and growth (Lyngny and Brix, 1984) and may have played a role as well.

Future studies

The scope of this study, and therefore the determination of the impacts of marinas, is limited by several factors. First, this study was originally proposed for three years. This is probably the minimum duration necessary to define how annual variation affects the occurrence of fishes and decapod crustaceans in each study site. Second, the throwtrap sampling technique, although offering several advantages, limits sampling to waters less than 1.5 m. Most of the area occupied by marinas is deeper; thus this component of the fauna may not have been adequately sampled. Third, sampling was limited to daytime periods. Nocturnal patterns of utilization of the marinas and control habitats may be quite different, especially by shrimp and crabs. Fourth, the possibility that marina sediments might adversely affect *C. septemspinosa* abundance, either through changes in habitat use, predation or direct mortality, is significant because of the trophic importance that this species plays in New Jersey estuaries. Fifth, the presence, absence or relative abundance of a species is a rather crude measure (albeit a necessary first step) to determine the effects of marinas. More detailed studies of the toxicology and behavior of species that utilize marinas is necessary before the full impact can be ascertained.

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Table 1. Number of samples collected and processed at each site in Barnegat Bay during 1988 - 1989. See Figure 1 for sampling sites.

	Long Quay			Viking Village			
	Marina	Control		Marina		Control	
	sand	grass	sand	grass	sand	grass	sand
Sampling periods	11	9	11	10	11	11	11
Total samples	40	29	42	31	32	34	33
Samples processed	40	29	42	31	32	34	33

Table 2. Physical characteristics of marina and control sites. See Figure 1 for sampling sites. Temperatures expressed as °C, salinity as parts per thousand

	Long Quay		Viking Village	
	Marina	Control	Marina	Control
Mean Temperature	19.0	19.8	17.5	17.6
Temperature Range	9-28	10-28	8-25	8.5-26
Mean Salinity	22.6	24.3	29.7	28.4
Salinity Range	16-28	20-30	26-32	26-32
Bottom Type	muddy sand	muddy sand	sand	sand
Vegetation	none	eelgrass	eelgrass	eelgrass
Sampling Depth	30-100 cm	30-150 cm	100-150 cm	80-150 cm

Table 3. Mean dry weight (g/m^2) of eelgrass (*Zostera marina*) from vegetated sites during April 1989 - October 1989. Dashes indicate no samples were taken.

	Viking Village				Long Quay	
	Marina		Control		Control	
	Belowground	Aboveground	Belowground	Aboveground	Belowground	Aboveground
April	5.10	7.64	403.60	7.64	244.45	0.01
May	71.30	45.84	389.60	56.02	481.27	71.30
June	155.33	105.68	134.96	100.58	421.43	11.46
July	146.42	134.96	221.54	29.28	301.75	35.65
August	-	-	-	-	-	-
September	42.02	6.37	218.99	70.03	152.78	24.19
October	-	-	165.52	30.56	-	-

Table 4. List of common and scientific names of the fishes collected in Barnegat Bay. Mode of utilization: R = resident, N = nursery, C = catadromous, T = transient (S = southern, N = northern). Life history stage: L = larvae, J = juvenile, A = adult. Classification of mode of utilization and life history stage is based on this study and prior experience.

	Mode of Utilization Of Study Area	Life History Stages
Family Engraulidae		
Anchoa mitchilli - bay anchovy	N	L,J,A
Family Anguillidae		
Anguilla rostrata - American eel	C	J,A
Family Gasterosteidae		
Apeltes quadracus - fourspine stickleback	R	L,J,A
Family Serranidae		
Centropristis striata - black seabass	N	
Family Chaetodontidae		
Chaetodon ocellatus - spotfin butterflyfish	T-S	J
Family Blenniidae		
Chasmodes bosquianus - striped blenny	T-S	J,A
Hypsoblennius hentzi - feather blenny	T-S	J,A
Family Congridae		
Conger oceanicus - conger eel	N	J,A
Family Cyprinidontidae		
Cyprinodon variegatus - sheepshead minnow	R	L,J,A
Fundulus heteroclitus - mummichog	R	L,J,A
Lucania parva - rainwater killifish	R	L,J,A
Family Bothidae		
Etropus microstomus - smallmouth flounder	N	J,A
Paralichthys dentatus - summer flounder	N	L,J,A
Family Gobiidae		
Gobiosoma bosci - naked goby	R	L,J,A
Family Syngnathidae		
Hippocampus erectus - lined seahorse	N	J,A
Syngnathus fuscus - northern pipefish	N	L,J,A
Family Ostraciidae		
Lactophrys sp. - trunkfish	T-S	J
Family Lutjanidae		
Lutjanus griseus - gray snapper	T-S	J

Table 4. cont.

Family Atherinidae		
Menidia beryllina - inland silverside	N	L,J,A
Menidia menidia - Atlantic silverside	N	L,J,A
Family Balistidae		
Monacanthus sp. - filefish	T-S	J
Family Mugilidae		
Mugil curema - white mullet	N	J
Family Cottidae		
Myoxocephalus aeneus - grubby	N	L,J,A
Family Batrachoididae		
Opsanus tau - oyster toadfish	R	L,J,A
Family Pleuronectidae		
Pseudopleuronectes americanus - winter flounder	N	L,J,A
Family Labridae		
Tautogolabrus adspersus - cunner	N	L,J
Tautoga onitis - tautog	N	L,J,A

Table 5. List of common and scientific names of the decapod crustaceans collected in Barnegat Bay. Mode of utilization: R = resident, T = transient (S = southern, N = northern). Life history stage: L = larvae, J = juvenile, A = adult.

	Mode of Utilization Of Study Area	Life History Stages
Family Portunidae		
<u>Callinectes</u> <u>sapidus</u> - blue crab	R	L,J,A
<u>Callinectes</u> <u>similis</u> - lesser blue crab	T-S	J,A
<u>Carcinus</u> <u>maenas</u> - green crab	R	L,J,A
<u>Ovalipes</u> <u>ocellatus</u> - lady crab	R	L,J,A
Family Cancridae		
<u>Cancer</u> <u>irroratus</u> - rock crab	R	L,J,A
Family Crangonidae		
<u>Crangon</u> <u>septemspinosa</u> - sand shrimp	R	L,J,A
Family Xanthidae		
<u>Dyspanopeus</u> <u>sayi</u> - mud crab	R	L,J,A
Family Hippolytidae		
<u>Hippolyte</u> <u>pleuracanthus</u> - broken-back shrimp	R	L,J,A
Family Majidae		
<u>Libinia</u> <u>dubia</u> - spider crab	R	L,J,A
<u>Libinia</u> <u>emarginata</u> - common spider crab	R	L,J,A
Family Paguridae		
<u>Pagurus</u> <u>longicarpus</u> - long-clawed hermit crab	R	L,J,A
Family Palaemonidae		
<u>Palaemonetes</u> <u>vulgaris</u> - grass shrimp	R	L,J,A
Family Penaeidae		
<u>Penaeus</u> <u>aztecus</u> - brown shrimp	T-S	J

Table 6. Mean density (N/m^2) of fishes collected in each site from September to November 1988 and April to October 1989. No samples were taken in the Viking Village marina vegetated site on October 1989 or in the Long Quay control vegetated site on October 1988 and 1989.

Species	Viking Village				Long Quay			Total Number of Individuals
	Marina		Control		Marina	Control		
	Vegetated	Unvegetated	Vegetated	Unvegetated	Unvegetated	Vegetated	Unvegetated	
Anchoa mitchilli	0	0	0	0	0	1.6	0.1	52
Anguilla rostrata	0.1	0	<0.1	<0.1	0.1	<0.1	<0.1	13
Apeltes quadracus	3.3	0.5	4.1	0.1	<0.1	1.3	0.2	307
Centropristis striata	<0.1	0	<0.1	0	0	0	0	2
Chaetodon ocellatus	0	0	0.1	0	0	0	0	5
Chasmodes bosquianus	0	0	0	0	0	0.1	<0.1	3
Conger oceanicus	<0.1	0	0	<0.1	0	0	0	2
Cyprinodon variegatus	0	0	0	0	6.2	0	0	249
Etropus microstomus	0	0.1	0	0.1	0	0	0	4
Fundulus heteroclitus	0.1	0	0.3	<0.1	2.3	0	<0.1	107
Gobiosoma bosci	0.1	0.2	<0.1	0.1	2.1	3.1	0.9	228
Gobiosoma sp.	0	0	0	0	0	0	0.1	5
Hippocampus erectus	0	<0.1	<0.1	0	0	0	0	2
Hypsoblennius hentzi	0	0	0.1	0	0	0	0	2
Lactophrys sp.	<0.1	<0.1	<0.1	<0.1	0	0	0	4
Lucania parva	0	0	0	0	1.4	0.1	0.4	77
Lutjanus griseus	0	0	0	0	0	<0.1	0	1
Menidia beryllina	0	0.1	0	0	1.8	0	0	74
Menidia menidia	0.2	3.2	3.0	6.9	4.2	0.6	0.5	639
Menidia sp.	<0.1	<0.1	0.1	1.3	<0.1	0	0	49
Monacanthus sp.	0.1	0	<0.1	0	0	0	0	3
Mugil curema	0	0	0	0	0.1	0	0	3
Myoxocephalus aeneus	1.1	0.4	0.5	0.1	0	0	0	63
Opsanus tau	0.1	0	0.1	0	0	0.1	0	6
Paralichthys dentatus	0	<0.1	0	0	0	0	0	1
Prionotus evolans	<0.1	0	0	0	0	0	0	1
Pseudopleuronectes americanus	1.0	1.4	1.8	0.2	0.4	<0.1	0	152
Syngnathus fuscus	0.6	0.4	1.1	0.2	0	0.7	0.1	100
Tautogolabrus adspersus	0.1	0.1	0.2	0	0	0	0	12
Tautoga onitis	0.2	0.1	0.1	0	0	0	0	11
								2177

Table 7. Mean density (N/m^2) of decapod crustaceans in each site sampled from September to November 1988 and April to October 1989. No samples were taken in the Viking Village marina vegetated site on October 1989 or in the Long Quay control vegetated site on October 1988 and 1989.

Species	Viking Village				Long Quay			Total Number of Individuals
	Marina		Control		Marina	Control		
	Vegetated	Unvegetated	Vegetated	Unvegetated	Unvegetated	Vegetated	Unvegetated	
Callinectes sapidus	1.8	1.1	2.9	0.8	1.8	4.3	1.8	488
Callinectes similis	0	0	0	0.1	0	0	<0.1	5
Cancer irroratus	0	0	0	0	0	<0.1	0	1
Carcinus maenas	0.7	0.2	0.6	0	0	0	0	51
Crangon septemspinosa	13.0	21.2	30.0	30.5	3.1	12.2	14.9	4209
Dyspanopeus sayi	0.2	<0.1	<0.1	0	0	0.1	0.1	16
Hippolyte pleuracanthus	15.2	1.5	27.7	1.2	0.1	4.0	0.3	1632
Libinia dubia	<0.1	0	0.1	0	0	0.1	0	9
Libinia emarginata	0	0	0.1	<0.1	0	0	0	3
Libinia sp.	0.2	<0.1	<0.1	0	0	0	0	7
Ovalipes ocellatus	0	0	0	0.2	0	0	0	7
Pagurus longicarpus	0	<0.1	0	<0.1	0	0	<0.1	3
Palaemonetes vulgaris	4.4	0.8	9.2	0.2	19.4	8.6	0.9	1547
Penaeus aztecus	0	0	0	<0.1	0	0	0	1
								7979

Table 8. Density (N/m^2) and percent of total density by year for fishes and decapod crustaceans collected by habitat at each study site. Sampling occurred September - November 1988 and April - October 1989.

	1988				1989			
	Fishes		Decapods		Fishes		Decapods	
	N/m^2	%	N/m^2	%	N/m^2	%	N/m^2	%
Viking Village								
Marina-vegetated	7.0	6.9	12.7	12.3	7.0	11.8	43.3	13.9
Marina-unvegetated	6.9	6.7	9.6	9.3	6.3	11.1	30.0	10.1
Control-vegetated	7.2	7.1	13.6	13.1	12.7	24.2	88.2	32.1
Control-unvegetated	5.7	5.6	11.4	11.0	10.0	18.4	40.1	14.0
Long Quay								
Marina-unvegetated	29.0	53.4	3.9	7.0	12.5	22.9	36.7	12.8
Control-vegetated	16.0	9.8	51.4	30.9	5.9	10.4	24.8	8.3
Control-unvegetated	5.7	10.4	9.1	16.5	0.6	1.2	23.0	8.7

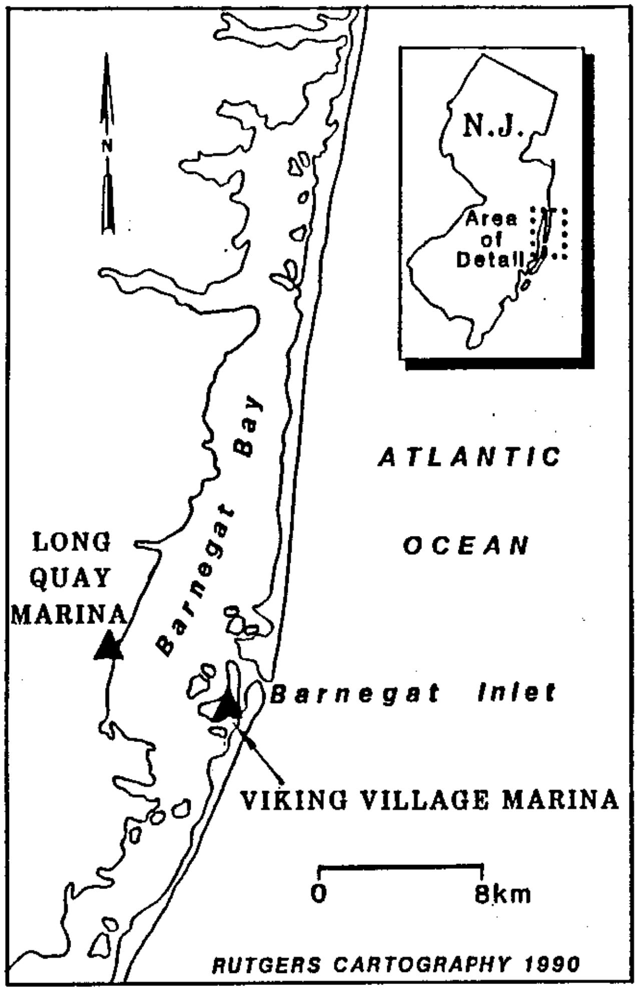

Figure 1. Locations of Barnegat Bay sampling sites.

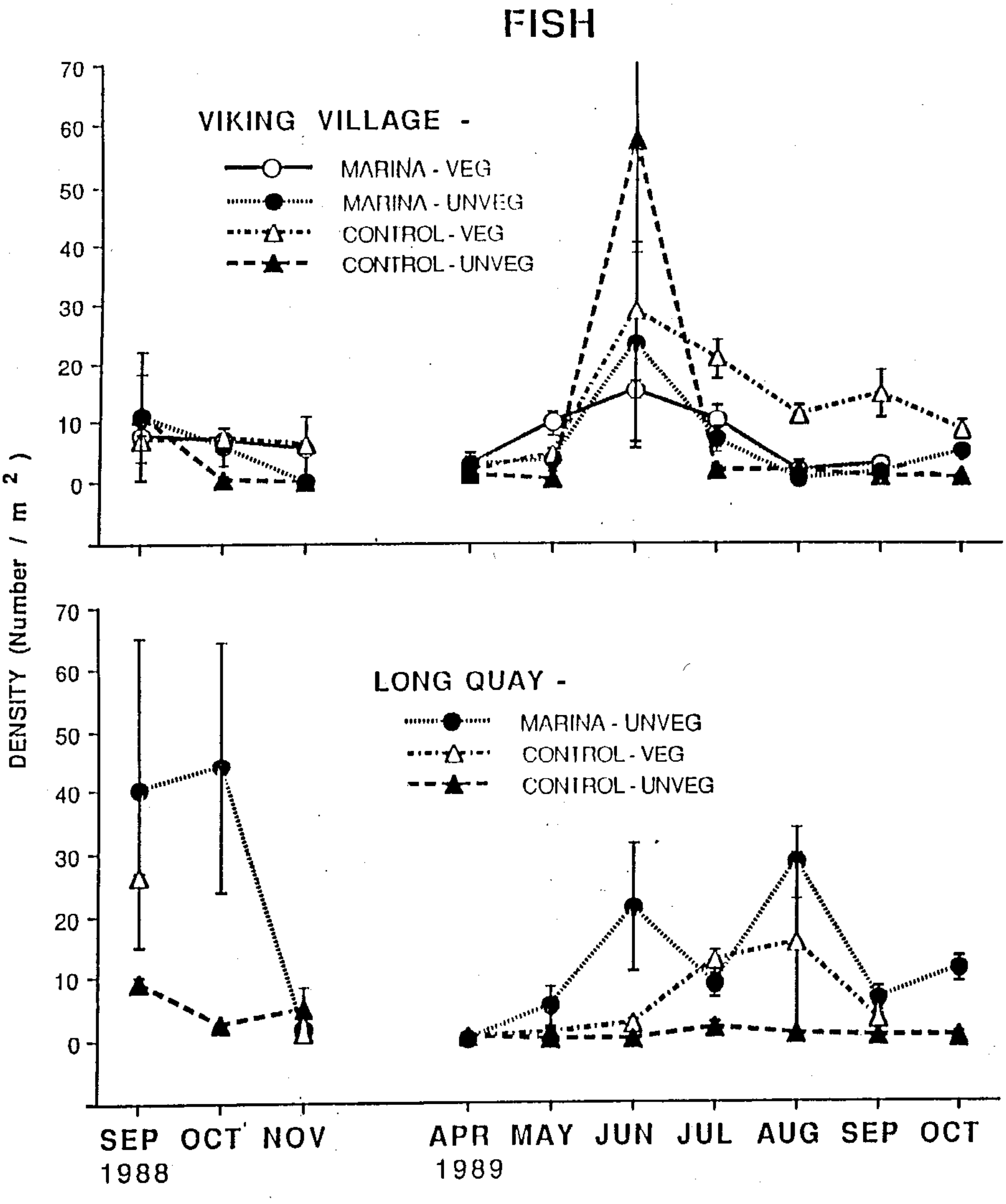

Figure 2. Density (N/m^2) of all fishes collected by month and habitat in Barnegat Bay sampling sites.

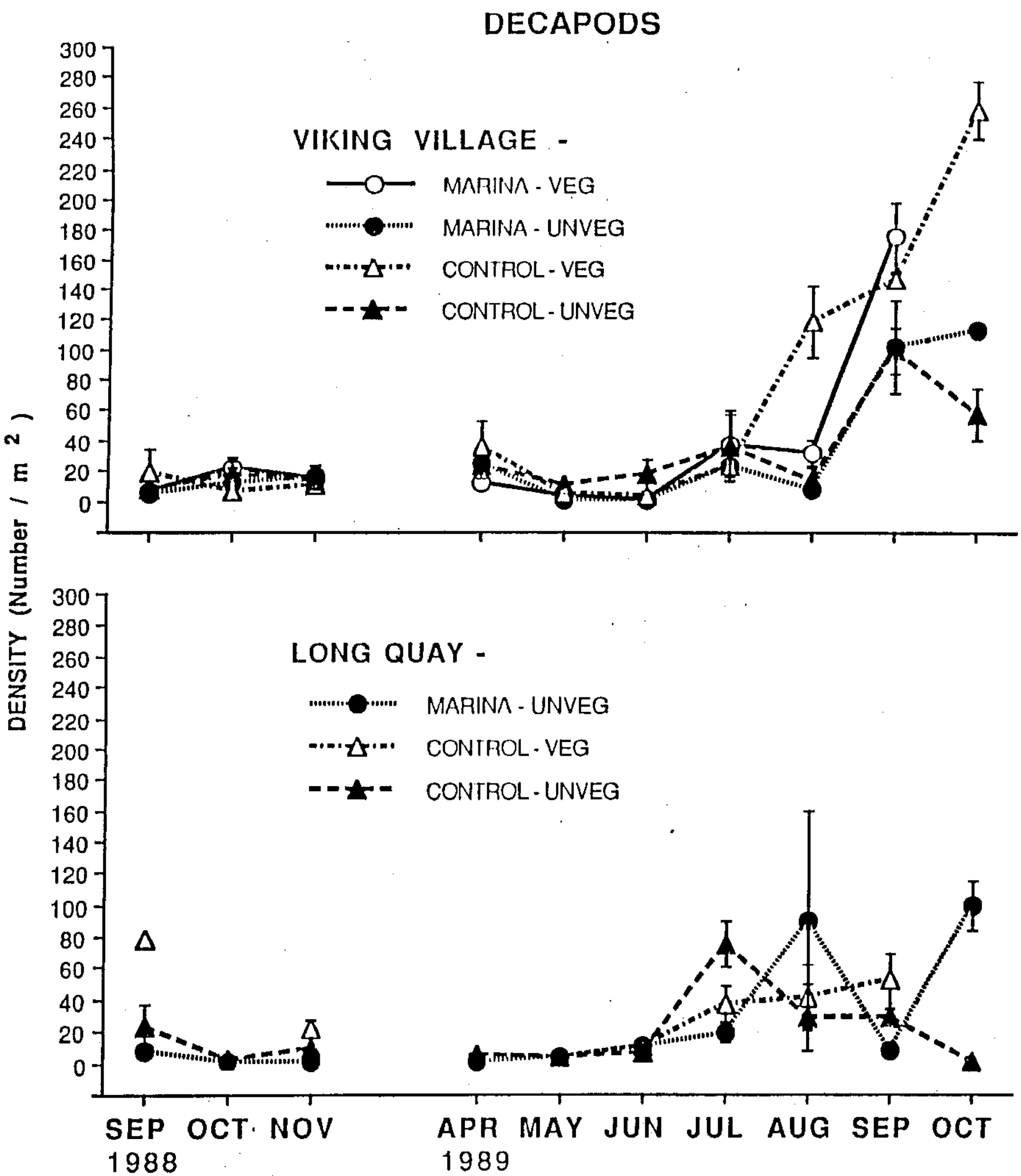

Figure 3. Density (N/m^2) of all decapod crustaceans collected each month by habitat in Barnegat Bay sampling sites.

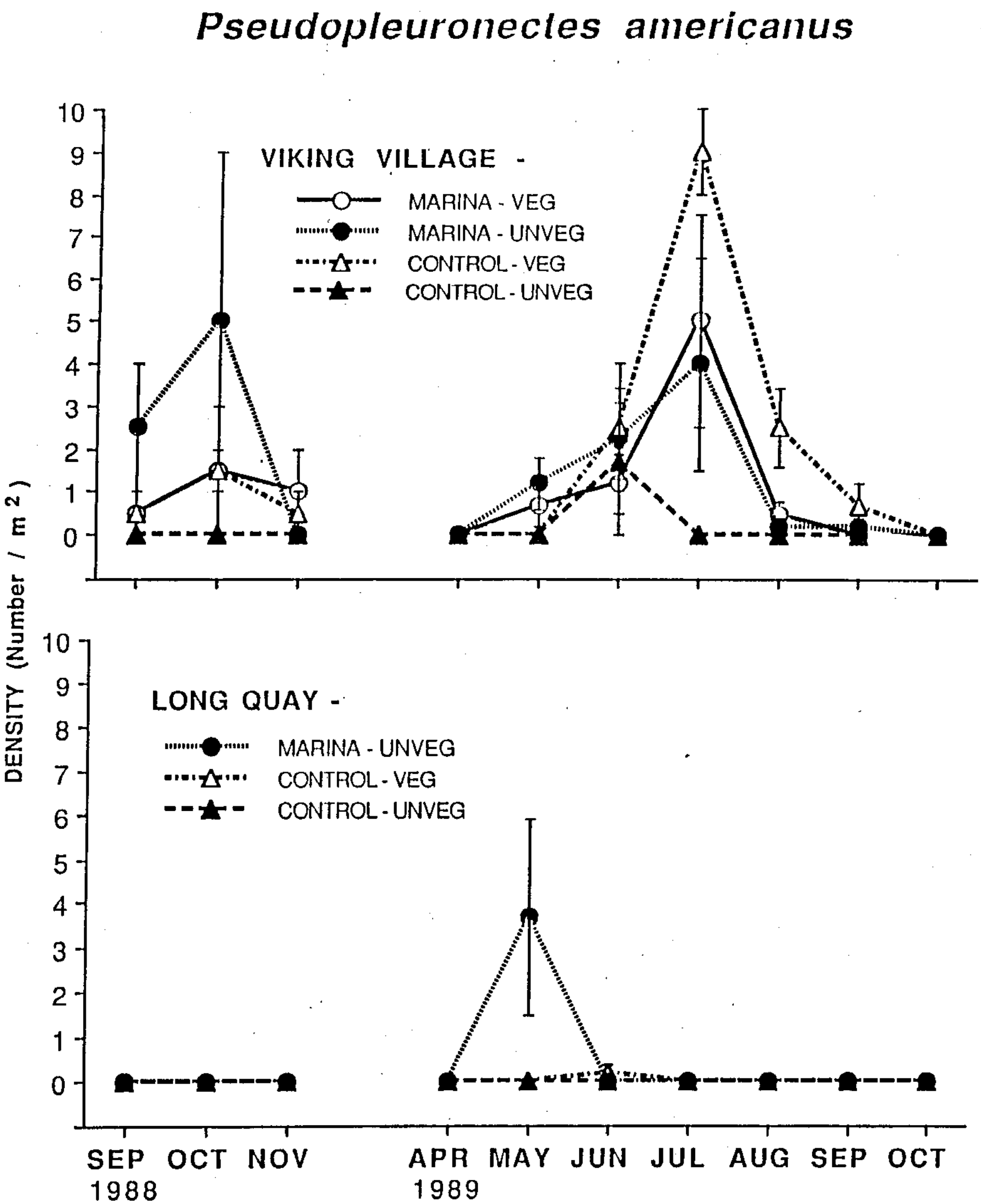

Figure 4. Monthly density (N/m^2) of winter flounder, Pseudopleuronectes americanus, at each site.

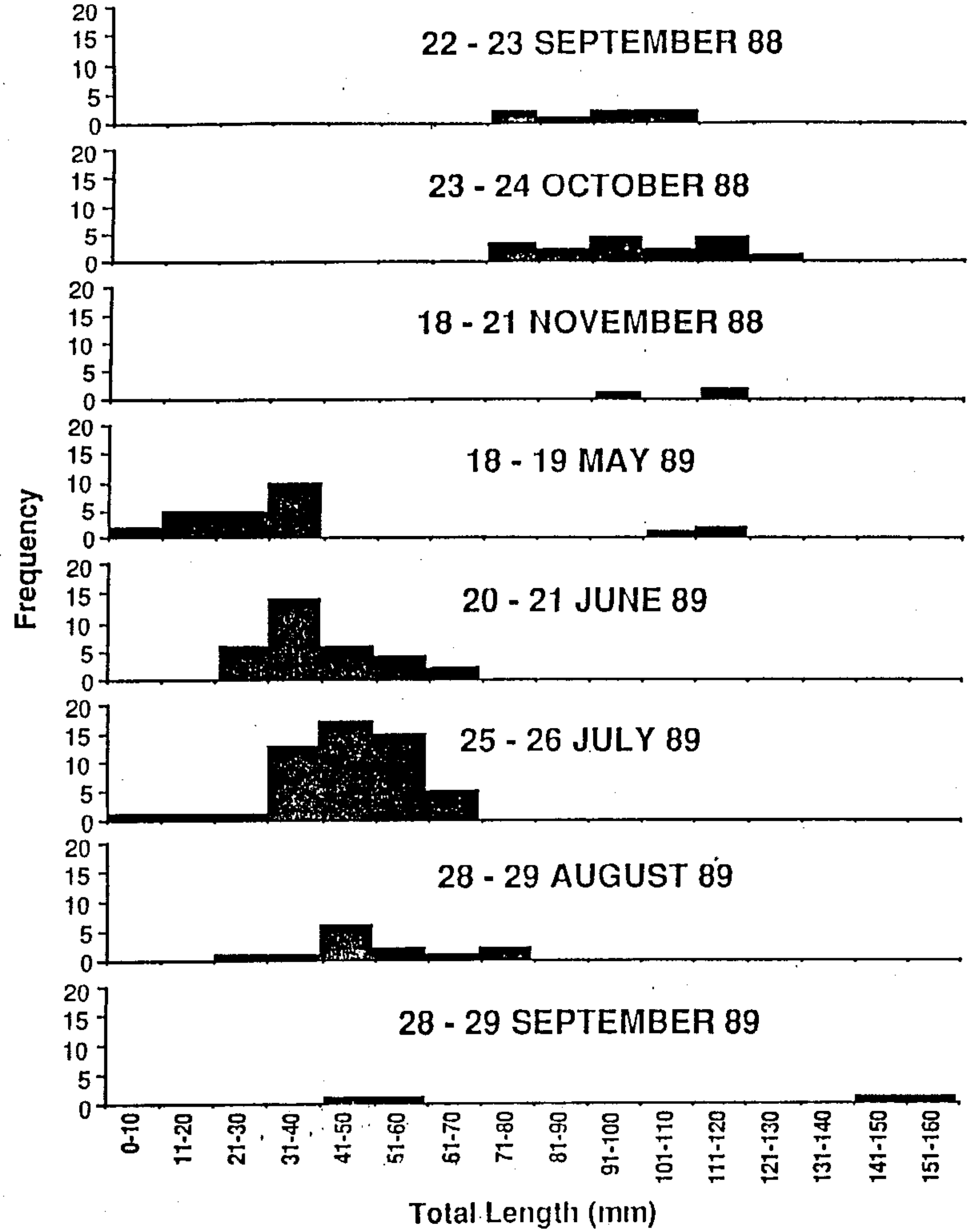

Figure 5. Length frequency distribution of winter flounder, Pseudopleuronectes americanus, by month at both study sites.

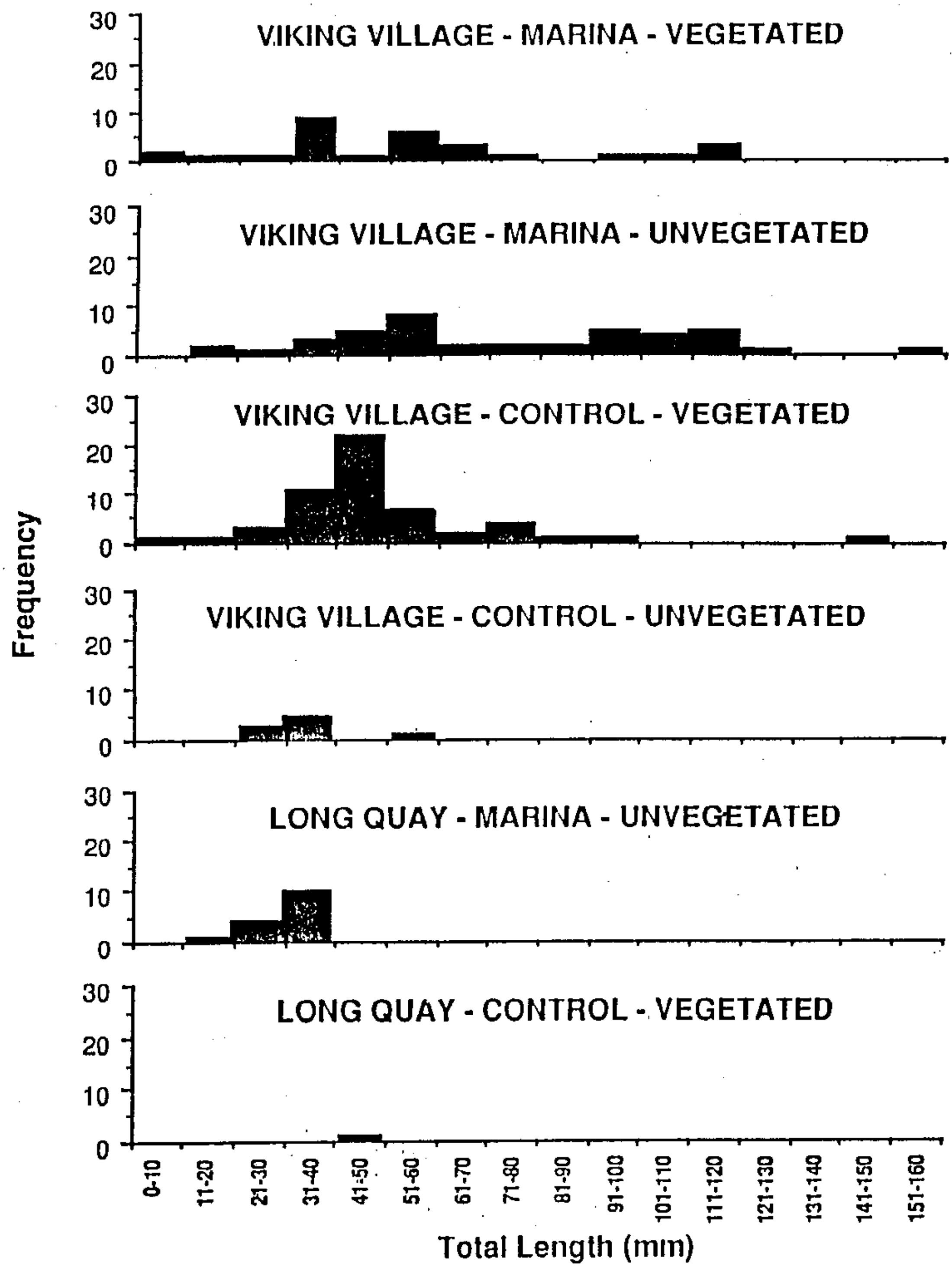

Figure 6. Length frequency distribution of winter flounder, Pseudopleuronectes americanus, by habitat.

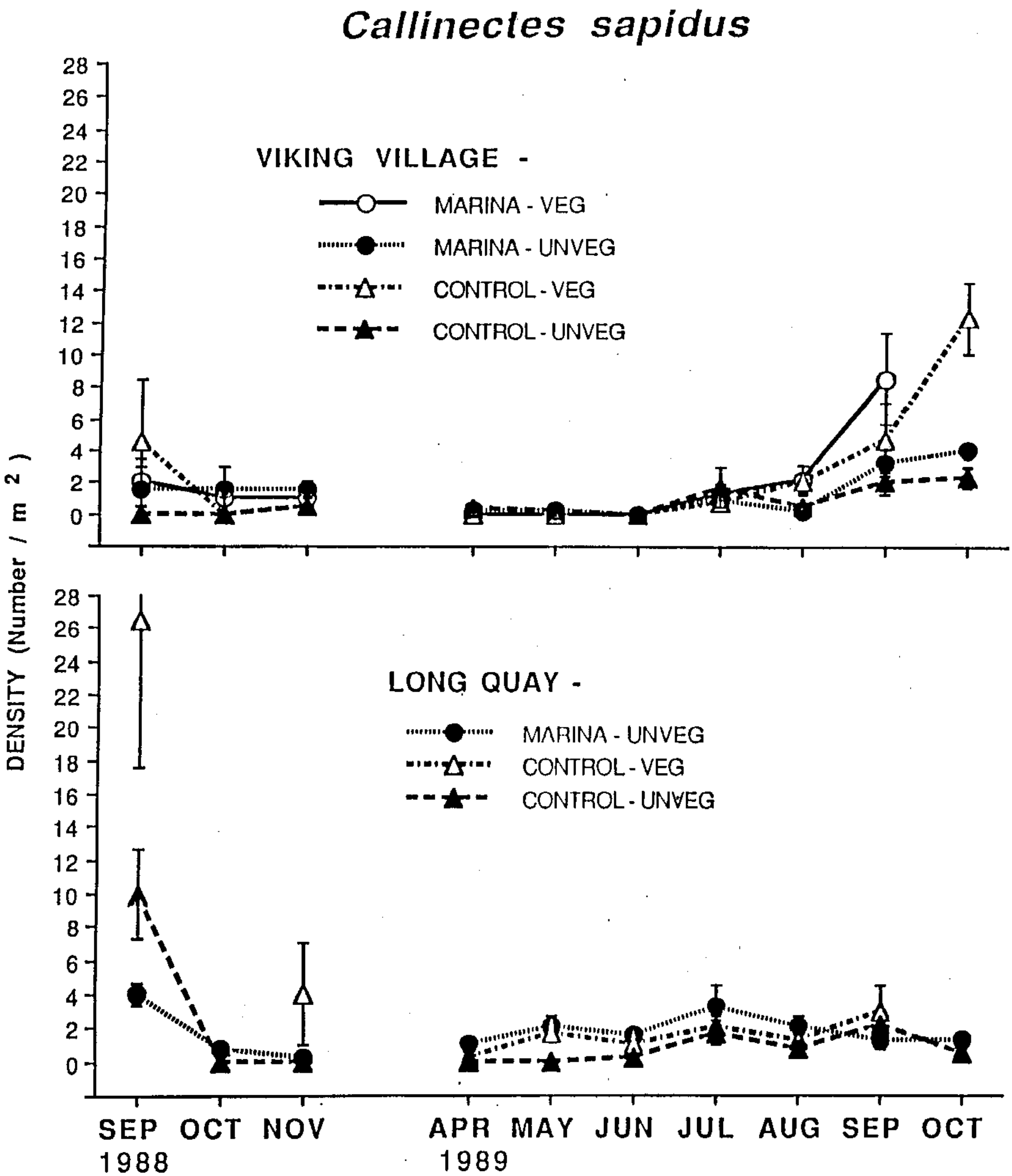

Figure 7. Monthly density (N/m^2) of blue crabs, Callinectes sapidus, at each habitat.

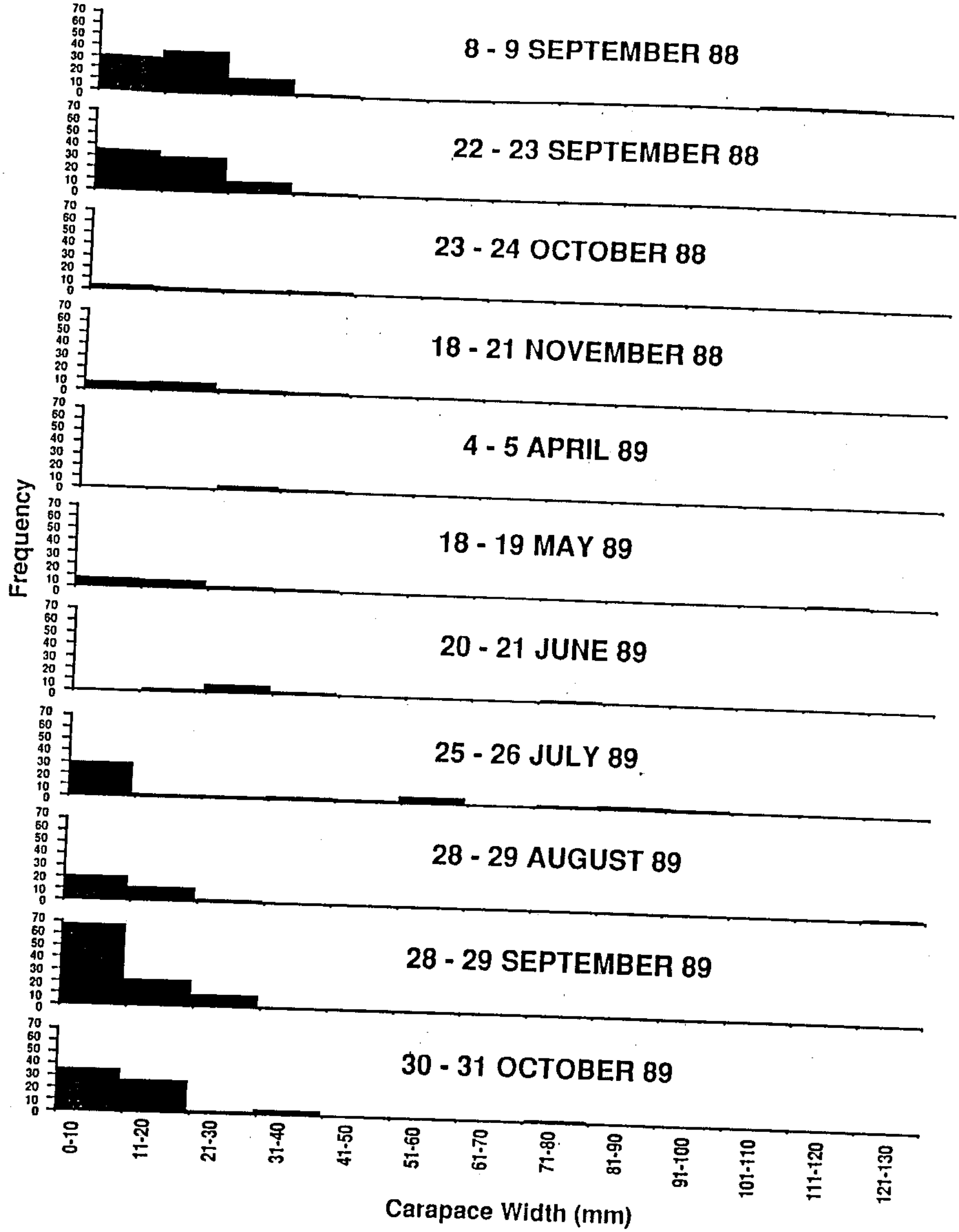

Figure 8. Length frequency distribution of blue crabs, Callinectes sapidus, by month at both study sites combined.

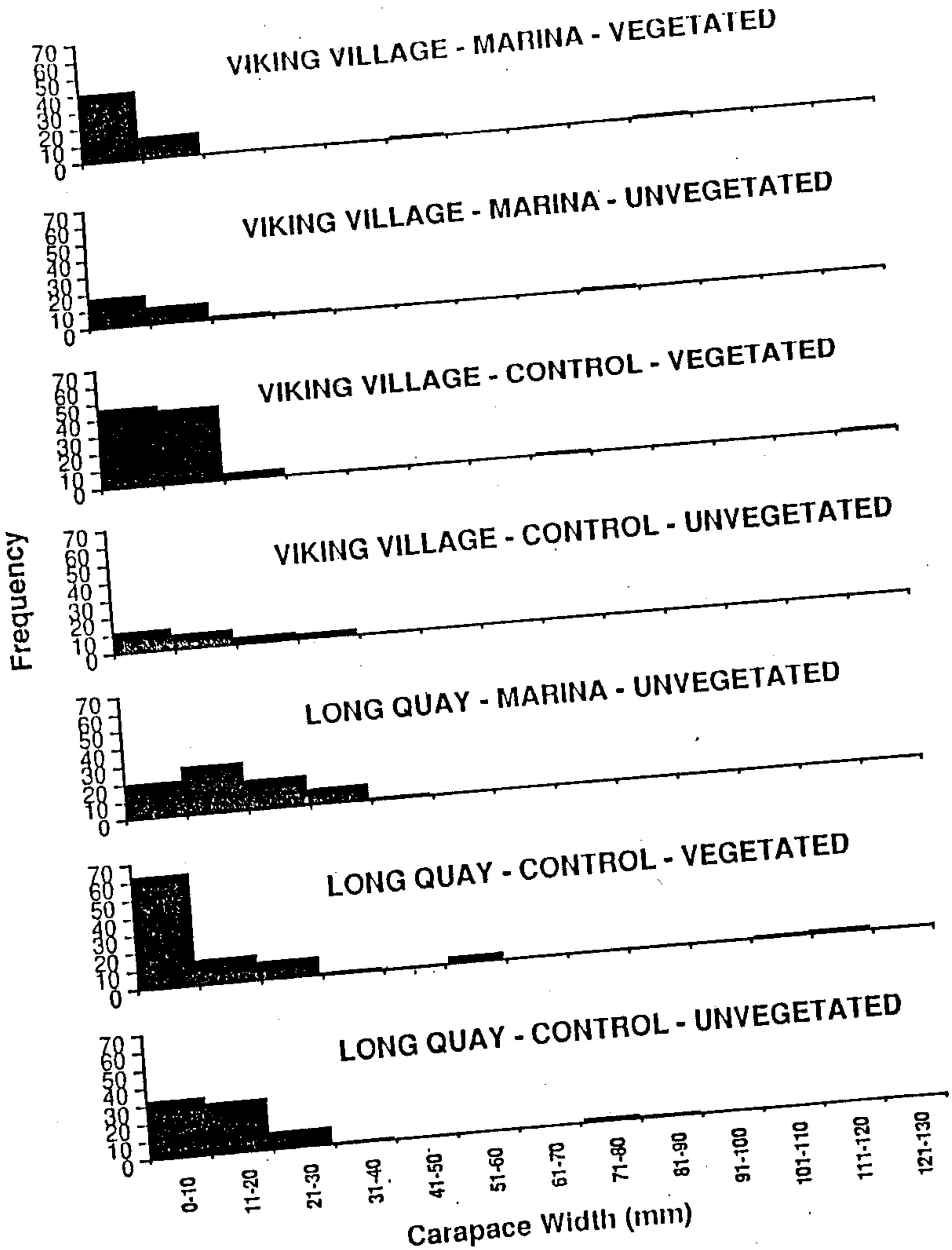

Figure 9. Length frequency distribution of blue crabs, Callinectes sapidus, by habitat at each study site.