PSEG

Estuary Enhancement Program

Public Service Enterprise Group
Biological Monitoring Program
2008 Annual Report

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2008 BIOLOGICAL MONITORING PROGRAM ANNUAL REPORT
EXECUTIVE SUMMARY

IMPINGEMENT ABUNDANCE MONITORING

Impingement abundance and initial survival sampling at the circulating water intake structure was conducted by diverting timed subsamples of flow from combined fish and trash troughs into fish counting pools. Sampling was scheduled during three 24-hour collection events per week from January through December. A total of 1,570 samples were collected. Sample duration can vary with fish and detritus abundance, and ranged from one to five minutes, with 58% of the collections in 2008 being one minute. Individual finfish and blue crabs were collected from the pools by dip net and categorized as "live", "dead", or "damaged". Debris (vegetative matter) was examined for fish and any found were included in the collection. Specimens were sorted by condition category and species, and were counted, weighed, and measured. Ancillary parameters, including weight of detritus in the subsampled water volume, pump and screen conditions, tide, weather, water temperature and salinity, were measured during every sampling event.

A total of 35,292 finfish and 9,775 blue crabs were taken in 1,570 samples (total sample time of 2,303 minutes) during 2008. Findings specific to target finfish species include:

- Blueback herring (*Alosa aestivalis*). A total of 112 individuals were taken from 74 of 1,570 samples. Abundance was highest in March; individuals were in January through April, November and December. The proportion of live individuals on an annual basis was 87%.

- Alewife (*A. pseudoharengus*). A total of 10 individuals were taken from 9 of 1,570 samples. Abundance was highest in March; individuals were collected in January through May and December. The proportion of live individuals on an annual basis was 80%.

- American shad (*A. sapidissima*). A total of 26 individuals were taken from 24 of 1,570 samples. Abundance was highest in November; individuals were collected in January, May and October through December. The proportion of live individuals on an annual basis was 96%.

- Atlantic menhaden (*Brevoortia tyrannus*). A total of 883 individuals were taken from 338 of 1,570 samples. Abundance was highest in June; individuals were collected during all months of 2008. The proportion of live individuals on an annual basis was 69%.

- Bay anchovy (*Anchoa mitchilli*). A total of 1,103 individuals were taken from 466 of 1,570 samples. Catches were highest in April; individuals were collected during all months of 2008. The proportion of live individuals on an annual basis was 83%.

- Atlantic silverside (*Menidia menidia*). A total of 859 individuals were taken from 284 of 1,570 samples. Abundance was highest in December; individuals were collected during all months of 2008. The proportion of live individuals on an annual basis was 96%.

- White perch (*Morone americana*). A total of 10,106 individuals were taken from 796 of 1,570 samples. Abundance was highest in December; individuals were collected during all months of 2008. The proportion of live individuals on an annual basis was 97%.

- Striped bass (*M. saxatalis*). A total of 497 individuals were taken from 250 of 1,570 samples. Abundance was highest in November; individuals were collected during all months of 2008 except May. The proportion of live individuals on an annual basis was 98%.

- Bluefish (*Pomatomus saltatrix*). A total of 87 individuals were taken from 57 of 1,570 samples. Abundance was highest in May; individuals were collected May through November. The proportion of live individuals on an annual basis was 82%.

- Weakfish (*Cynoscion regalis*). A total of 4,652 individuals were taken from 450 of 1,570 samples. Abundance was highest in July; individuals were collected in May through December. The proportion of live individuals on an annual basis was 95%.

- Spot (*Leiostomus xanthurus*). A total of 361 individuals were taken from 230 of 1,570 samples. Abundance was similarly high in October and November; individuals were also collected in May through December. The proportion of live individuals on an annual basis was 95%.

- Atlantic croaker (*Micropogonias undulatus*). A total of 8,322 individuals were taken from 756 of 1,570 samples. Abundance was highest in January; individuals were collected during all months of 2008. The proportion of live individuals on an annual basis was 97%.

ENTRAINMENT ABUNDANCE MONITORING

Entrainment abundance sampling was conducted in the Salem Generating Station's circulating water intake structure by pumping river water out of the intake bay of Circulating Water Pumps 12B or 22A into a plankton net having a 0.5-mm mesh. A typical sample filtered 50 m^3 of intake water. During the months of January through March and August through December, routine entrainment sampling was scheduled during three 24-hour events per week with seven collections at approximately equal intervals during each event. During the months of April through July, intensive entrainment sampling occurred during four events scheduled each week with 14 samples scheduled at equal intervals during each event. Each event monitored a complete diel period encompassing two tidal cycles. A total of 1,633 out of 1,716 scheduled entrainment abundance samples were collected during 2008. Each concentrated sample was preserved, and the ichthyoplankton identified. For each species collected, the life stage was determined, the total number counted, and the lengths of a subsample were measured.

During the 2008 Salem Entrainment Abundance Monitoring program, totals of 19,839 fish eggs, 33,029 larvae, 18,206 juveniles, and 162 adults representing at least 26 species were collected in 1,633 entrainment abundance samples, with 83,299 m^3 of sample water filtered. Results specific to the target species are discussed in phylogenic order:

- Blueback herring - A total of one juvenile blueback herring was taken during November.

- Alewife – A total of 1 larval alewife was collected during May.

- *Alosa* spp. - A total of 1 larval *Alosa* spp. was collected during May.

- Atlantic menhaden - A total of 13,500 Atlantic menhaden, including 4,213 larvae and 9,287 juveniles, was taken during all months other than August and September. The abundance of Atlantic menhaden was highest in April, with juveniles being the predominant life stage.

- Bay anchovy - A total of 34,878 bay anchovy, including 19,810 eggs, 13,194 larvae, 1,788 juveniles and 86 adults was collected during all months except March. Bay anchovy were most abundant in June, with eggs being the predominant lifestage.

- *Menidia* spp. – A total of 698 *Menidia* spp., including 15 eggs, 641 larvae, 19 juveniles, and 23 adults, was collected during the months of January, February, May through August, November and December. *Menidia* spp. were most abundant in June, with larvae being predominant.

- White perch - A total of 10 white perch including 3 larvae, and 7 juveniles was collected during the months of February through June. White perch were most abundant in April, with juveniles being the predominant lifestage.

- Striped bass - A total of 1,433 striped bass, including 6 eggs, 1,317 larvae and 110 juveniles, was collected during April through July. Striped bass were most abundant in June, with larvae being the predominant lifestage.
- *Morone* spp**.** - A total of 20 *Morone* spp. larvae was collected during May.
- Bluefish – A total of one juvenile bluefish was taken during May.
- Weakfish - A total of 430 weakfish, including 5 eggs, 163 larvae and 262 juveniles, was collected during the months of May through October. Weakfish were most abundant in June, with juveniles being predominant lifestage.
- Spot – A total of 114 spot, including one larva and 113 juveniles was collected during the months of April through June. Spot were most abundant in June, with juveniles being the most predominant lifestage.
- Atlantic croaker - A total of 6,444 Atlantic croaker, including 33 larvae and 6,411 juveniles was collected in all months except July and August. Atlantic croaker was most abundant in October, with juveniles being the predominant lifestage.

BOTTOM TRAWL PROGRAM

The 2008 bottom trawl effort was conducted within the Delaware River Estuary from the mouth of the Delaware Bay to just north of the Delaware Memorial Bridge (rkm 0-117) at 40 randomly selected stations allocated from sampling Zones 1-8. The number of sampling stations designated within each of the eight sampling zones was allocated using a Neyman allocation procedure based on the proportional area of each zone and historical fisheries data. One daytime bottom trawl event was completed at each station each month from April through November 2008 using a 4.9m (16-ft) semi-balloon otter trawl. Eight monthly surveys were completed, resulting in the collection of 320 bottom trawls. Target species for this project were alewife, American shad, Atlantic menhaden, blueback herring, bay anchovy, Atlantic silverside, striped bass, white perch, bluefish, Atlantic croaker, spot, weakfish, and blue crab (*Callinectes sapidus*). All finfish and blue crabs were identified to the lowest practicable taxonomic level, enumerated, and recorded on field data sheets. Length measurements for all target species were recorded to the nearest millimeter. Surface, mid-depth and bottom water quality were recorded for each sample as well as pertinent field observations such as water clarity, weather, and tidal stage.

In the 320 bottom trawls that were completed in 2008, 32,729 specimens (31,418 finfish and 1,311 blue crabs) were collected. Total catch per unit effort (CPUE) was 102.3 for all zones. The results for target species were as follows:

- Alewife: Two specimens were collected during the bottom trawl effort accounting for <0.1% of the total finfish catch. They were collected in Zones 4 in April and May. The CPUE for alewife was <0.1.

- American shad: Eight specimens were caught in bottom trawls, comprising <0.1% of the total finfish catch. They were taken in April, May, October and November catches in Zones 2,3 and 58. The CPUE for American shad was <0.1.

- Atlantic croaker: A total of 7,027 specimens were captured in bottom trawls, accounting for 22.4% of the total finfish collected. They were found in all zones and were more evenly distributed than they had been in prior studies prior to 2006. The largest monthly catch was in July, the second largest was in June, the third largest in November and the fourth largest in October. These four months accounted for 80.62% of the Atlantic croaker caught in 2008. The CPUE for Atlantic croaker was 22.0.

- Atlantic menhaden: One hundred fourteen Atlantic menhaden were collected during the 2008 Baywide bottom trawl effort, representing 0.4% of the total finfish catch. They were found in all zones except Zone 1, and during all months except July. The CPUE for Atlantic menhaden was 0.4.

- Atlantic silverside: Three Atlantic silverside were collected during the bottom trawl effort, comprising <0.1% of the total finfish catch. They were caught in Zones 2 and 3 during October and November. The CPUE for Atlantic silverside was <0.1.

- Bay anchovy: A total of 11,759 specimens were captured during the 2008 Baywide bottom trawl effort comprising 37.4% of the total finfish catch. Bay anchovy were captured in every sampling month, but approximately 32% were found in July. They were taken in every zone, but most of them (96%) were taken in Zones 2-5. The CPUE for bay anchovy was 36.7.

- Blueback herring: One specimen wase collected during the bottom trawl effort accounting for <0.1% of the total finfish catch. It was collected in Zones 3 during October. The CPUE for blueback herring was <0.1.

- Bluefish: A total of two specimens were collected during the bottom trawl effort, representing <0.1% of the total finfish catch. They were found in Zones 3 and 6 in July and August. The CPUE for bluefish was <0.1.

- Spot: A total of 1,453 specimens were captured in bottom trawls, comprising 4.6% of the total finfish collected. Most of them were collected from July through November and, although they were collected in all eight zones, the greatest numbers were found in Zones 2 through 5. The CPUE for spot was 4.5.

- Striped bass: A total of 38 specimens were collected during the bottom trawl effort, accounting 0.1% of the total finfish collected. Striped bass were taken in Zones 3, 4 and 6-8, and were captured in every sampling month, except May and June. The CPUE for striped bass was 0.1.

- Weakfish: A total of 2,191 specimens were caught in bottom trawls, representing 7.0% of the total finfish catch. Weakfish were collected in all eight zones and were evenly distributed throughout. They were captured in every month except April. However, most of them were found from July through September. The CPUE for weakfish was 6.8.

- White perch: A total of 406 specimens were captured during the bottom trawl effort, comprising 1.3% of the total finfish catch. White perch were present in all eight zones, except Zone 1, and were most abundant in Zones 5-8. They were taken in all months and were most abundant in April. The CPUE for white perch was 1.3.

- Blue crab: A total of 1,311 specimens were collected in all eight zones and were collected in every month. They were most abundant in Zones 3, 5,6 and 7 and the heaviest catches were in May, July and October. The CPUE for blue crab was 4.1.

BAYWIDE BEACH SEINE PROGRAM

The Baywide Beach Seine Survey was conducted on a monthly basis in June and November, and twice monthly from July through October 2008. During the design phase of the study in 1995, the perimeter of the Delaware Bay from Cape May, NJ (rkm 0) to the lower Delaware River at the Chesapeake and Delaware Canal (rkm 100) was divided into 32 equal-length regions. Each region was further partitioned into 0.1-nautical mile segments. One fixed station was established within each of the 32 regions. Eight additional stations were established at bay front locations adjacent to PSEG marsh restoration sites. These 40 fixed stations have been annually sampled since 1995. The gear was a 100- x 6-ft (30.5- x 1.8-m) bagged haul seine with a 1/4-inch (6.25 mm) nylon mesh, identical to the gear employed by New Jersey Department of Environmental Protection (NJDEP) in their beach seine program conducted upstream of the present study. The seine was set at high tide by boat from the shore and pulled in the direction of the prevailing tidal current, wind or surf as conditions required, resulting in the most effective deployment of the gear. Water quality parameters, including water temperature, salinity, dissolved oxygen and water clarity were measured with each collection.

The Baywide Beach Seine Survey yielded 15,559 individuals of 38 finfish species from 400 samples. Atlantic silverside and bay anchovy represented 72.9% of the catch. Nearly

45 percent (17 of 38) of the species taken were represented by 10 or fewer specimens. Of the target species only Atlantic silverside, bay anchovy, striped bass, spot, Atlantic croaker and striped bass were taken during all sampling events, in all regions and at all beach types.

Findings specific to target species include:

- American shad. A total of four American shad was taken in beach seine collections in 2008.
- Blueback herring. A total of 3 blueback herring was taken in beach seine collections in 2008.
- Alewife. No alewife were taken in beach seine collections in 2008.
- Atlantic menhaden. A total of 778 Atlantic menhaden was taken, comprising 5.0% of the 2008 seine catch. Their abundance was highest during the second half of June. Although taken in all regions, Atlantic menhaden abundance was highest in region rkm 21-40.
- Bay anchovy. A total of 4,015 bay anchovy was taken, comprising 25.8% of the 2008 seine catch. Bay anchovy was collected during all sampling events; abundance was highest during the second half of September. Bay anchovy was most abundant in region rkm 81-100.
- Atlantic silverside. A total of 7,329 Atlantic silverside was taken, comprising 47.1% of the 2008 seine catch. Atlantic silverside was collected during all sampling events; abundance was highest during the first half of November. Atlantic silverside catches were highest in region rkm 21-40.
- White perch. A total of 50 white perch was taken in the 2008 seine catch. Their abundance was highest in the first half of November. White perch abundance was highest in regions rkm 41-60.
- Striped bass. A total of 98 striped bass was taken in beach seine collections in 2008. Individuals were taken during all collection events; abundance was highest during the first half of July and August. Striped bass were most abundant in region rkm 41-60.
- Bluefish. A total of 71 bluefish was taken in beach seine collections in 2008. Bluefish were taken during all sampling events except the first half of November and were most abundant during the second half of June. They were most abundant in region rkm 0-20.
- Weakfish. A total of 467 weakfish was taken, comprising 3.0% of the 2008 seine catch. Their abundance was highest during the first half of July. Weakfish were most abundant in regions rkm 0-20.

- Spot. A total of 1,037 spot was taken, comprising 6.7% of the seine catch. They were most abundant during the second half of August and in region rkm 21-40.

- Atlantic croaker. A total of 285 Atlantic croaker was taken, comprising 1.8% of the 2008 seine catch. Atlantic croaker abundance was highest in the first half of November and in region 0-20.

FISH LADDER MONITORING

PSEG Nuclear LLC (PSEG) has constructed and maintains fish ladders on Delaware River estuary tributaries for spawning run restoration of the alewife (*Alosa pseudoharengus*) and the blueback herring (*Alosa aestivalis*), collectively known as river herring. Alaska Steeppass fish ladders have been constructed at twelve sites: Sunset Lake, Stewart Lake, Newton Lake, and Cooper River Lake in New Jersey, and Noxontown Pond, Silver Lake (Dover), Silver Lake (Milford), McGinnis Pond, Coursey Pond, McColley Pond, Garrisons Lake and Moores Lake in Delaware.

Adult passage monitoring, employing a fish ladder exit trap net, occurred from March 26 to June 11, 2008. No sampling of adult passage was conducted at McGinnis Pond during 2008, as this ladder has consistently passed adult herring and monitoring was discontinued to avoid potentially impacting spawning behavior. No stocking occurred during 2008 due to the limited availability of adult herring for trap and transfer.

The following lists the number of adult herring counted, counted passing through the ladder, stocked, and total spawning run adult herring, for each of the monitored fish ladder sites:

Ladder Location	Counted	Counted Passing	Stocked	Total Into Pond
Noxontown Pond	**1**	**1**	**0**	**1**
Garrisons Lake	**0**	**0**	**0**	**0**
Silver Lake (Dover)	**9**	**8**	**0**	**8**
Moores Lake	**653**	**639**	**0**	**639**
Coursey Pond	**1,147**	**1,096**	**0**	**1,096**
McColley Pond	**682**	**652**	**0**	**652**
Silver Lake (Milford)	**0**	**0**	**0**	**0**
Cooper R. Lake	**2**	**1**	**0**	**1**
Newton Lake	**3**	**3**	**0**	**3**
Stewart Lake	**3**	**2**	**0**	**2**
Sunset Lake	**170**	**168**	**0**	**168**

In 2008, adult river herring migrated upstream to spawn in the creeks, spillpools, and ponds beginning in early March and the run continued through early June. As expected, the adult herring movement appeared to be associated with rising creek water temperature and sunny days. The occurrence of adult herring at the fish ladder sites generally coincided with reported spawning temperatures.

FISH ASSEMBLAGE MONITORING

To evaluate the faunal response to salt marsh restoration in Delaware Bay, fish assemblages are monitored in small and large creek habitats of reference and restored marshes in upper and lower regions of the bay. Sampling was conducted monthly from May to November 2008 with otter trawls (4.9 m headrope, 6 mm mesh) in large marsh creeks (1.2 – 2.8 m mean depth at high tide) and with weirs (1.8 x 1.2 x 1.2 m with 4.5 x 1.2 m wings, 0.175 mm mesh) in small intertidal marsh creeks draining the marsh surface.

In the Lower Bay Region, totals of 126 trawl tows and 14 weir sets were conducted at the Moores Beach Reference Site, and 126 trawl tows and 14 weir sets were conducted at the Commercial Township Restoration Site. At the Moores Beach Site, a total of 23 fish species was collected; of these, 26% were considered residents of salt marshes and 74% were transients. In the large marsh creek habitat, fish abundance was highest in June, and Atlantic menhaden was the predominant species. In the small marsh creek habitat, fish abundance was highest in August, and mummichog (*Fundulus heteroclitus*) was the predominant species. At the Commercial Township Site, a total of 20 fish species was collected; of these, 35% were considered residents of salt marshes and 65% were transients. In the large marsh creek habitat, fish abundance was highest in August. Bay anchovy was the predominant species. In the small marsh creek habitat, fish abundance was highest in August, and mummichog was the predominant species. In the large marsh creek habitats of the Lower Bay Region, total fish abundance was higher at the Commercial Township Restoration Site than at the Moores Beach Reference Site, resulting from the disproportionate catches of bay anchovy. In the large marsh creek habitats of the Lower Bay Region, fish species richness was similar at both sites, with over 80% of the species in common. In the small marsh creek habitats, total fish abundance was similar at both the Moores Beach Reference Marsh and at the Commercial Township Restoration Site. The abundance of the target species was unremarkable at both sites. Fish species richness was equal at the two sites, with seven of ten species in common.

In the Upper Bay Region, totals of 126 trawl tows and 14 weir sets were conducted at the Mad Horse Creek Reference Site; in the Alloway Creek Restoration Site totals of 126 trawl tows and 14 weir sets were conducted at the Mill Creek Sampling Area, and 42 weir sets were conducted at Alloway Creek Sampling Area. At the Mad Horse Creek Site, a total of 20 fish species was collected; of these, 30% were considered residents of salt marshes and 70% were transients. In the large marsh creek habitat, fish abundance was highest in July, bay anchovy and Atlantic menhaden were the predominant species. In the small marsh creek habitat, fish abundance was highest in May, and mummichog was the predominant species. At the Alloway Creek Sampling Area, a total of five fish species was collected; three were considered residents of salt marshes and two were transients. In the small marsh creek habitat fish abundance was highest in September, and mummichog was the predominant species. At the Mill Creek Sampling Area, a total of 21 fish species was collected; 43% were considered residents of alt marshes and 57% were transients. In the large marsh creek habitat, fish abundance was highest in June, and spot was the predominant species. In the small marsh creek habitat, fish abundance was highest in August, and mummichog was the predominant species.

In the large marsh creek habitats of the Upper Bay Region, total fish abundance was higher at the Mill Creek Sampling Area of the Alloway Creek Restoration Site than at the Mad Horse Creek Reference Site, resulting not from the predominance of one or two species, but rather reflecting an assemblage-wide contribution to higher abundance at Mill Creek. Contributions to this abundance by the target species, white perch, bay anchovy and spot were of note. However, the contributions made by the other target species, weakfish, was more dubious. In the large marsh creek habitats of the Upper Bay Region, fish species richness was similar at Mad Horse Creek and at the Mill Creek Area. In the small marsh creek habitats of the Upper Bay Region, total fish abundance was higher at both restoration sampling areas than at the Mad Horse Creek Reference Site. Regarding species rank order, the three sites shared the same top two species, mummichog and Atlantic menhaden. All species taken at Mad Horse Creek were common to Mill Creek, and all species taken at Alloway Creek were common to Mill Creek.

VEGETATIVE COVER AND GEOMORPHOLOGY MONITORING

Vegetative cover monitoring is performed annually during the peak growing season at the reference marshes and all restoration sites that have not met the final success criteria as follows:

- Commercial Township Salt Hay Farm Wetland Restoration Site (CT Site)
- Moores Beach West Reference Marsh (MBW)
- Alloways Creek *Phragmites*-dominate Wetland Restoration Site (ACW Site)
- The Rock *Phragmites*-dominate Wetland Restoration Site (The Rocks)
- Cedar Swamp *Phragmites*-dominate Wetland Restoration Site (Cedar Swamp)
- Mad Horse Creek Reference Marsh (MHC)

To evaluate production of these marshes, cover type mapping and field sampling is conducted to assess community abundance and composition for vascular plants. During 2008, geomorphological monitoring was conducted at all four restoration sites to assess changes associated with the restoration process.

Analyses of the 2008 vegetative cover type mapping indicates that *Spartina alterniflora* and other desirable marsh species is the dominant cover type at all four restoration sites and the two reference marshes. *S. alterniflora* comprised approximately 81 and 74 percent of the MBW and MHC reference marshes, respectively. At the three *Phragmites*-dominated restoration sites, *S. alterniflora* and other desirable vegetation ranged between nearly 75 to 86 percent the total marsh at the restoration sites. Approximately 51% of the CT Site marsh was mapped as *S.alterniflora* during 2008.

Other cover type categories evaluated at the restoration sites and reference marshes include *Phragmites*-dominated vegetation, non-vegetated marsh plain, internal water areas and open water. Non-vegetated marsh plain comprised approximately 37 percent of the CT Site.

Quantitative monitoring and sampling of the vascular vegetation provides data on percent cover, vegetation height, and a calculation of above ground biomass for the vascular plants. *S.alterniflora* was the most common dominant species present at the reference marshes and restoration sites. For each site, means were calculated for *Spartina* spp. dominated quadrats, non-*Spartina* spp. dominated quadrats, and for all quadrats.

Geomorphology monitoring during the 2008 season indicated that drainage densities (linear feet of channel/acre of marsh) ranged from 537 ft/acre to 690 ft/acre at the *Phragmites*-dominated restoration sites, and 1150 ft/acre at the CT Site.

CHAPTER 1 - BIOLOGICAL MONITORING ANNUAL REPORT

INTRODUCTION

This report summarizes results of ongoing ecological monitoring programs conducted by PSEG Nuclear, LLC (PSEG, formerly PSE&G) of New Jersey. These studies are being conducted in relation to the operation of the Salem Generating Station (SGS), a two-unit nuclear power plant. The basis for conducting these studies is the New Jersey Pollutant Discharge Elimination System (NJPDES) Permit No. NJ0005622 issued by the New Jersey Department of Environmental Protection (NJDEP), with an effective date of September 1, 1994. This permit allows the SGS to discharge cooling water into the Delaware River in accordance with NJPDES Regulations N.J.A.C. 7:14A-1 et. Seq.. In 2001, the NJPDES Permit for the SGS was renewed with an effective date of August 1, 2001. Custom requirement G.6 of the renewed permit provided for the continuation and expansion of the studies included in the report.

STUDY AREA

The Delaware Estuary is a continuum of environments: freshwater, tidal fresh water, tidal brackish water and marine. The characteristics of these varying environments determine species composition and abundance, temporal and spatial distribution, functional dynamics and resiliency of the population and communities in this system.

The study area extends from the mouth of the Bay to River Mile 211, just south of the fall line in Trenton, NJ. Approximately 308 square miles of tidal marshes surround the Estuary, which play a significant role in water exchange and retention, and in chemical and biological functions within the system. An important interactive component of the Estuary is the contiguous ocean water of the Middle Atlantic Bight (Cape Cod to Cape Hatteras), which exists outside the entrance to the Bay. Pape and Garvine (1982) established that bottom ocean water from at least 40 km offshore is involved in residual flows into the Bay.

The Delaware Bay is composed of three regions: a shallow flats area on the New Jersey side, a central channel and alternating shoals with zones of deep water on the Delaware side. The deep water ranges from 12 - 90 feet with a deep hole reaching 143 feet at the mouth of the Bay off Lewes, DE. The deep zone is interspersed with long, finger like shoals 0 - 12 feet deep, which radiate out to the west and north from the mouth of the Bay. Broad expanses of shallow flats from 9-17 feet deep extend from the deeper water to the shoreline. Beyond the shoreline and extending up the many tidal creek tributaries are wide expanses of salt marsh.

The water movements within the Delaware Estuary affect the occurrence, distribution, and abundance of organisms both directly (as a result of net water transport, turbulent mixing, and exchange of water among the system's components) and indirectly (as a result of its influence on biologically important water quality parameters such as salinity, temperature, dissolved oxygen, and turbidity). Tidal circulation, freshwater discharge from the drainage basin and upstream impoundments, wind-induced flushing, and salinity-induced density gradients are major forces that influence the water circulation patterns in the system and result in its highly dynamic physical and chemical environment.

Tidal transport of water between the ocean and the Delaware Estuary dominates flow and circulation throughout the Estuary (Polis and Kupferman, 1973). The total flux during each tidal cycle, 11.02 billion cubic yards, is equivalent to about 23- 24 percent of the standing volume of the Estuary measured at mean tide level. Tidal flow past the Salem Station is approximately 448,000 to 472,000 cubic feet per second.

Current speed and direction throughout the Delaware Estuary are primarily dominated by the tide. Surface tidal currents generally are directed along the longitudinal axis of the Estuary except in near shore areas of river bends and coves. At maximum ebbing or flooding tide, local currents at any point within the Estuary may reach speeds of 3.3 to 4.3 feet per second (Polis and Kupferman, 1973).

Salinity in the Delaware Estuary varies from fresh water at Trenton (River Mile 132), to typical ocean water concentrations of about 34 parts per thousand on the continental shelf off the mouth of Delaware Bay. Variables such as freshwater discharge, tidal phase, basin morphology, and meteorological conditions affect salinity. In the vicinity of Salem, salinity ranges seasonally from about 0.5 to 20 parts per thousand.

SALEM GENERATING STATION

Location

Salem Generating Station is located on a peninsula known as Artificial Island on the eastern shore of the Delaware Estuary, 50 miles northwest of the mouth of the Bay and 30 miles southwest of Philadelphia, PA. Artificial Island was created from the deposition of dredge spoil material by the Army Corps of Engineers during the first half of the last century. It is bordered by the River on two sides and by extensive marshes and uplands on the other two sides. The Salem Units 1 and 2 are identical pressurized -water reactors; each with a net rated electrical output of 1,162 Mwe. Units 1 and 2 began commercial operation in 1977 and 1981, respectively.

The Station was sited on the Delaware Estuary to take advantage of the large volume of relatively low temperature cooling water. This once through cooling water is used to condense the steam produced by the Units during the process of electric generation. The rated flow for both units with all twelve pumps operating is 3,168 million gallons per day. Under Special Condition IV-B/C.H. I of the 1994 NJPDES Permit, Salem is limited to "...a monthly average rate not to exceed 3,024 million gallons per day". Water is withdrawn from the River through a shoreline intake structure divided into 12 intake bays. Each bay is 11.5 feet wide at the entrance with a designed water depth ranging from 31 - 50 feet depending on tide (and factors influencing tides). This configuration results in an average intake bay entrance design velocity of 0.87 feet per second at mean high tide and 1.0 foot per second at mean low tide.

Intake System

The traveling screens are equipped with buckets to catch most impinged organisms and prevent them from becoming re-impinged. Each screen basket base is fitted with a lip, which creates a water-filled bucket. The screens rotate continuously to minimize the time during which organisms may be impinged. Estuarine organisms are captured in the water-filled buckets at the base of each ascending screen panel to prevent re-impingement. The buckets are emptied into a sluiceway (part of the fish return system) behind the screens, which return the fish to the Estuary north of the circulating water intake system (CWS) intake on flood tide and south of the CWS intake on ebb tide, to prevent re-impingement.

In June of 1996, PSE&G, in compliance with Special Condition IV-B/C.H.2 of the 1994 NJPDES permit, completed the installation of six newly modified traveling screens into the Unit 2 intake system. Composite material was used in place of stainless steel for the construction of the fish buckets. This reduced the weight of each screen by 100 pounds (6,200 pounds total). Composite material was also used to construct the individual basket frames, further saving weight. The lighter weight has enabled the maximum speed of the traveling screens to double from 17.5 to 35 feet per minute. The leading edge of the bucket is formed into a hydrodynamic inward bending shape that eliminates turbulence in the bucket, which could damage fish. New screen mesh with a flat smooth mesh face and 0.25 x 0.5-inch openings has been installed. The size of the wire in the mesh was reduced from 12 down to 14 gauge, increasing the open area by 25 percent. Mounting and structural hardware for the basket have been relocated behind the new screen mesh. Eight spray nozzles were added to the inside spray wash headers to provide a more efficient and even spray pattern. Debris shields were added to the above the spray nozzles to keep them free of debris. Fish and debris trough flap seals were redesigned to maintain a closer fit to the traveling screens. All of these modifications were designed to improve fish survival on the traveling screens.

Discharge

Both CWS water and service water systems (SWS) water are discharged through six 10-foot diameter pipes (3 per unit) which extend 500 feet into the Estuary. Water depth at the discharge is approximately 31 feet to the centerline of the pipe. When Salem is operating at full load, approximately 16 billion BTU/hr are released into the Estuary. The discharge pipes were designed to minimize the thermal effect on the Estuary by maintaining the discharge velocity at about 10 feet per second.

Heated effluent from the cooling water discharge is characterized by a difference in temperature (ΔT) from the ambient River water and results in a thermal plume. The ΔT normally varies from approximately 15°F to 21°F depending upon the CWS flow. Thus, the discharge water temperature can range from about 45°F in winter to about 100°F in summer. The ΔT is reduced by approximately one-half between the time the CWS water is discharged through the pipes until it reaches the surface approximately 40-50 seconds later. This is due to the fact that the water discharged (at 10 feet per second) is turbulently mixed with ambient River water. During this time, the plume buoyantly rises in the water column. The characteristics of the thermal plume are determined by convective spread, mass transport by ambient currents, diffusion and dispersion, and loss of heat to the atmosphere. These processes are affected by the temporal and spatial variations within tidal cycles, meteorological conditions, and plant operations.

MONITORING PROGRAMS

Special Condition IV-B/C.H.6 (a) of the 1994 NJPDES Permit required PSEG to develop and implement a biological monitoring program for the Delaware Estuary. The results presented herein are from programs conducted per the approved 2006 Improved Biological Monitoring Work Plan.

This report contains a separate section for each of the Improved Biological Monitoring Work Plan (IBMWP) programs that were performed during 2008. Programs discussed include; fish utilization of restored wetlands, elimination of impediments to fish migration, bay-wide trawl survey, beach seine survey, entrainment abundance monitoring, impingement abundance monitoring, and vegetative cover and geomorphology mapping of the restored wetlands.

CHAPTER 2: IMPINGEMENT MONITORING

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IMPINGEMENT MONITORING

INTRODUCTION

Impingement monitoring is conducted annually as stipulated in the New Jersey Pollutant Discharge Elimination System (NJPDES) permit issued for the Salem Generating Station (SGS). The specified monitoring was performed in 2008 as described in the Procedures Manual for Biological Monitoring Program for the Delaware Estuary (PSEG 2002). The objectives of this monitoring program are to estimate the temporal occurrence and abundance of each fish species impinged at Salem Units 1 and 2, and to estimate their initial survival. These estimates are important parameters for assessing the effects of Salem on the Delaware Estuary's fish populations.

During 2008, there were refueling and maintenance outages at Salem Unit 2 from March 11, 2008 through May 6, 2008 and at Salem Unit 1 from October 12, 2008 through November 9, 2008, when a reduced number of circulating water pumps were in service. However, during the remainder of the year, nearly 85% of the impingement samples were collected when 11 or 12 circulating pumps were in operation. This chapter presents the overall results of sampling and specific findings regarding the occurrence of SGS finfish target species: blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), Atlantic menhaden (*Brevoortia tyrannus*), bay anchovy (*Anchoa mitchilli*), Atlantic silverside (*Menidia menidia*), white perch (*Morone americana*), striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*).

MATERIALS AND METHODS

Impingement abundance sampling during 2008 was scheduled three days per week during January through December. Sampling consisted of ten (10) samples taken at approximately 2½-hr intervals during each 24-hr period. The 24-hr sampling event provided for monitoring over a complete diel period and two full tidal cycles. The three 24-hr periods were chosen randomly within the seven-day weekly sampling time frame. During 2008, all of the 1,570 scheduled samples were collected.

Organisms impinged on the continuously rotating traveling screens at Salem are lifted from the river in water-filled buckets or troughs fitted at the bottom of each screen panel (Figure 2-1). These buckets provide a temporary environment during the vertical transport of the screen, and are designed to prevent most organisms from falling back into the screen well and becoming re-impinged. As the bucket travels over the head or top sprocket, organisms slide onto the screen face and are spray-washed into the fish trough by a low-pressure spray. The screen continues its downward movement and debris on the screen mesh is washed into the debris trough by a high-pressure wash. These fish and debris troughs converge and discharge to the Delaware River either to the north or south of the circulating water intake structure depending on tidal current direction to reduce re-impingement. To collect impingement samples, a timed sub-sample of total flow from the converged fish and debris troughs was diverted into the appropriate north or south fish counting pool (Figure 2-2) as dictated by tide and trough discharge direction. Sample duration ranged from one to five minutes, and was dependent largely on specimen and detrital abundance. Sample duration was one minute for 58% of the collections in 2008. At the end of the timed interval, trough flow was returned to the river discharge mode, and the sample was allowed a five-minute acclimation period before the pool was drained. As the pool was drained, debris (vegetative matter) was examined for finfish and blue crab, and any found were included in the collection. The condition of the specimens collected was determined according to the following criteria:

Live -	Swimming vigorously, no apparent orientation problems, behavior normal
Dead -	No vital signs, no body or opercular movement, no response to gentle probing
Damaged -	Struggling or swimming on side, evidence or indication of abrasion or laceration

Specimens in each category were sorted by species, and the total number and weight of each was determined. All specimens or a representative subsample (at least 100 specimens) of each species, drawn equally from each condition category, if possible, were measured to the nearest millimeter. Weights were determined to the nearest 0.1 g with an Acculab® Model 121 electronic scale.

The following parameters were recorded with all samples: the number of pumps and screens in operation, screen speed, tidal stage and elevation, air temperature, sky condition, wind direction, wave height, water temperature, and salinity. Air and water temperatures were measured with a field thermometer, and salinity was measured using a refractometer. Detritus taken with the sample was weighed to the nearest 0.1 kg with a Chatillon® suspended scale.

RESULTS AND DISCUSSION

Collection totals of 35,292 finfish of at least 61 species and 37 families, and 9,775 blue crab were taken in 1,570 samples (2,303 min sampled) at the Salem CWIS during 2008 (Table 2-1). All SGS designated finfish target species were taken, and summaries on the period of occurrence and abundance (expressed as a density in terms of the number/million cubic meters of intake water or $n/10^6m^3$), initial survival (species catches of < 5 individuals in a given month are not considered in the discussion), and length for each of these species are presented below in phylogenetic order. Target species include: blueback herring, alewife, American shad, Atlantic menhaden, bay anchovy, Atlantic silverside, white perch, striped bass, bluefish, weakfish, spot, and Atlantic croaker.

Blueback herring - A total of 112 specimens was taken in impingement samples during 2008; collection frequency was 74 out of 1,570 samples (Table 2-1). They were collected during January through April, November and December (Figure 2-4). During their period of occurrence, monthly mean water temperatures and salinities ranged from 4.8 to 12.4ºC and from

1.7 to 10.0 ppt, respectively (Figure 2-3). Blueback herring were most abundant in March with a mean density of 47.32 (Figure 2-4). During the other months in which they occurred, densities ranged from 2.98 in December, to 23.83 in November. Annual percent live and dead was 87 and 13, respectively; monthly (≥ 5 specimens taken) initial survival ranged from 72% in February to 100% in November (Tables 2-1 and 2-2). Length range was 48-108 mm FL, however individuals ranging from 53 to 83 FL comprised 91% of the subsample measured (Figure 2-5).

Alewife - A total of 10 specimens was taken; collection frequency was 9 out of 1,570 samples (Table 2-1). They were collected during January through May and December (Figure 2-6). During their period of occurrence, monthly mean water temperatures and salinities ranged from 4.8 to 16.6ºC and from 1.7 to 5.9 ppt, respectively (Figure 2-3). Alewife were most abundant in March with a mean density of 3.15 (Figure 2-6). In the other months of their occurrence, densities ranged from 0.75 in December, to 2.59 in February. Annual percent live and damaged was 80 and 20, respectively (Tables 2-1). Length range was 53-228 mm FL, and all but two of the individuals measured were ≤ 93 mm (Figure 2-7).

American shad - A total of 26 specimens was taken; collection frequency was 24 out of 1,570 samples (Table 2-1). They were collected during January, May, and October through December (Figure 2-8). During their period of occurrence, monthly mean water temperatures and salinities ranged from 5.4 to 17.0ºC and from 3.8 to 11.4 ppt, respectively (Figure 2-3). American shad were similarly abundant in four out of the five months in which they occurred. Monthly mean density was highest in November at 5.78, and in January, October, and December, mean densities were secondarily and similarly high at 4.78, 3.80, and 4.48, respectively (Figure 2-8). During May, density was 1.04. Annual percent live and dead was 96 and 4, respectively; monthly (≥ 5 specimens) initial survival ranged from 80% in January to 100% in all other months of occurrence (Tables 2-1 and 2-2). Length range was 53-103 mm FL, and all but three of the individuals measured were ≤ 93 mm (Figure 2-9).

Atlantic menhaden – A total of 883 specimens was taken; collection frequency was 338 out of 1,570 samples (Table 2-1). They were collected during all months of 2008, when monthly mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively (Figures 2-3 and 2-10). Atlantic menhaden were most abundant in June with a density of 276.99 (Figure 2-10). During the other months in which they occurred, monthly mean densities ranged from 3.73 in December to 98.14 in May. Annual percent live, dead and damaged was 69, 24 and 7, respectively; monthly (≥ 5 specimens) initial survival ranged from 8% in August to 97% in June (Tables 2-1 and 2-2). During late August of 2008, Atlantic menhaden with lesions caused by the protozoan *Kudoa* spp. (identification based on pers. comm. with Roy Miller and John Clark of DE/DNREC) were observed. During the period from August 27, 2008 through the remainder of the year, 71% of the Atlantic menhaden collected had these lesions. Initial survival of these infected specimens was 17%, as compared with initial survival of 74% of those not visibly infected (n=50) during the same period. Length range was 28-333 mm FL, and specimens ranging from 33 to 113 FL comprised >92% of the individuals measured (Figure 2-11). The modal length in June, the month of highest abundance, was 38 mm.

Bay anchovy - A total of 1,103 specimens was taken; collection frequency was 466 out of 1,570 samples (Table 2-1). They were collected during all months of 2008 when monthly mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively (Figures 2-3 and 2-12). Bay anchovy exhibited two periods of abundance. The first and highest period occurred in April and May when the mean densities were 259.49 and 150.34, respectively (Figure 2-12). The second period of abundance occurred in October and November when mean densities were 103.17 and 148.00, respectively. In all other months of their occurrence, abundance ranged from 1.91 in January to 78.91 in June. Annual percent live, dead and damaged was 83, 16 and 1, respectively; monthly (≥ 5 specimens) initial survival ranged from 29% in March to 96% in October and November (Tables 2-1 and 2-2). Length range was 28 to 103 mm FL, however individuals ranging from 38 to 78 mm FL comprised > 93% of the subsample measured (Figure 2-13). The modal length in April, the month of highest abundance, was 48 mm.

Atlantic silverside - A total of 859 specimens was taken; collection frequency was 284 out of 1,570 samples (Table 2-1). They were collected during all months of 2008, when monthly mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively (Figures 2-3 and 2-14). Atlantic silverside were most abundant in December with a mean density of 186.56 (Figure 2-14). Atlantic silverside was secondarily abundant in January and November with mean densities of 129.15 and 157.39, respectively. In the other months of their occurrence, density ranged from 1.58 in June to 83.87 in February. Annual percent live, dead and damaged was 96, 3 and 1, respectively; monthly (≥ 5 specimens) initial survival ranged from 83% in May to 100% in April and August (Tables 2-1 and 2-2). The length range was 38-118 mm FL, however individuals ranging from 58 to 98 mm FL comprised > 94% of the subsample measured (Figure 2-15). The modal length in December, the month of highest abundance, was 68 mm.

White perch - A total of 10,106 specimens was taken; collection frequency was 796 out of 1,570 samples (Table 2-1). They were collected during all months of 2008, when monthly mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively (Figure 2-3 and 2-16). White perch were generally abundant during late fall, winter and early spring months, with the highest monthly mean density of 2,503.63 occurring in December (Figure 2-16). During the other months of this aforementioned seasonal abundance, densities ranged from 910.20 in March to 2,188.88 in January. During the other months of their occurrence, densities ranged from 2.58 in September to 56.38 in May. Annual percent live, dead and damaged was 97, 1 and 2, respectively; monthly (≥ 5 specimens) initial survival ranged from 31% in June to 100% in October (Tables 2-1 and 2-2). Length range was 33-298 mm FL, and specimens ranging from 53 to 153 mm FL comprised >96% of the individuals measured (Figure 2-17). The modal length in December, the month of highest abundance, was 63 mm.

Striped bass - A total of 497 specimens was taken; collection frequency was 250 out of 1,570 samples (Table 2-1). They were collected in all months of 2008, except May, when monthly mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively (Figure 2-3 and 2-18). Striped bass were most abundant in November when the mean density was 111.91 and secondarily abundant in December, when the mean density was

95.52 (Figure 2-18). In other months of their occurrence, monthly mean density ranged from 0.79 in June to 66.47 in April. Annual percent live, dead and damaged was 98, 1 and 1, respectively; monthly (≥ 5 specimens) initial survival ranged from 67% in September to 100% in January, February, July, October, and December (Tables 2-1 and 2-2). Length range was 23-468 mm FL, and > 84% of all individuals measured were ≤ 98 mm (Figure 2-19). The modal length in November, the month of highest abundance, was 68 mm.

Bluefish - A total of 87 specimens was taken; collection frequency was 57 out of 1,570 samples (Table 2-1). They were collected from May through November, when monthly mean water temperatures and salinities ranged from 10.7 to 26.8ºC and from 5.8 to 11.4 ppt, respectively (Figures 2-3 and 2-20). Bluefish abundance was highest in May, when the mean density was 34.45 and secondarily abundant in June, when the mean density was 22.89 (Figure 2-20). Monthly mean densities in the other months of occurrence ranged from 0.72 in November to 7.60 in October. Annual percent live, dead and damaged was 82, 16 and 2, respectively; monthly (≥ 5 specimens) initial survival ranged from 63% in September to 100% in October (Tables 2-1 and 2-2). Length range was 48-178 mm FL, and > 83% of all individuals measured were ≤ 98 mm FL (Figure 2-21).

Weakfish - A total of 4,652 specimens was taken; collection frequency was 450 out of 1,570 samples (Table 2-1). They were collected in May through December, when monthly mean water temperatures and salinities ranged from 6.1 to 26.8ºC and from 3.8 to 11.4 ppt, respectively (Figures 2-3 and 2-22). Weakfish abundance was highest in July when the monthly mean density was 1,468.40 and secondarily high in August when the monthly mean density was 903.26. In the remaining months of their occurrence, mean density ranged from 1.04 in May to 270.91 in September. Annual percent live and dead was 95 and 5, respectively; monthly (≥ 5 specimens) initial survival ranged from 70% in December to 99% in October (Tables 2-1 and 2-2). Length range was 8-248 mm TL, however individuals ranging from 38 to 88 mm TL comprised > 93% of the subsample measured (Figure 2-23). The modal length in July, the month of highest abundance, was 63 mm.

Spot - A total of 361 specimens was taken; collection frequency was 230 out of 1,570 samples (Table 2-1). They were collected in May through December, when monthly mean water temperatures and salinities ranged from 6.1 to 26.8ºC and from 3.8 to 11.4 ppt, respectively (Figure 2-3 and 2-24). Spot were similarly abundant in October and November, when monthly mean densities were 42.41 and 40.43, respectively (Figure 2-24). In other months of their occurrence, density ranged from 13.57 in May, to 38.77 in September. Annual percent live, dead and damaged was 95, 1 and 4, respectively; monthly (≥ 5 specimens) initial survival ranged from 90% in July to 100% in May and June (Tables 2-1 and 2-2). Length range was 33-188 mm TL; and specimens ranging from 63 to 163 mm comprised > 91% of the individuals measured (Figure 2-25). The modal length in October, the month of highest abundance, was 123 and 128 mm.

Atlantic croaker - A total of 8,322 specimens was taken; collection frequency was 756 out of 1,570 samples (Table 2-1). They were collected in all months of 2008, when mean water temperatures and salinities ranged from 4.8 to 26.8ºC and from 1.7 to 11.4 ppt, respectively

(Figures 2-3 and 2-26). Atlantic croaker were most abundant in January when monthly mean density was 3,301.50 and secondarily and similarly abundant in May and June, when monthly mean densities were 1,553.49 and 1,382.59, respectively (Figure 2-26). During other months of occurrence, densities ranged from 7.75 in September to 383.57 in December. Annual percent live and dead was 97 and 3, respectively; monthly (≥ 5 specimens) initial survival ranged from 60% in September to 99% in November and December (Tables 2-1 and 2-2). Length range was 13-213 mm TL; individuals ranging from 28 to 88 mm TL comprised 96% of the subsample measured (Figure 2-27). The modal length in January, the month of highest abundance, was 38 mm.

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Table 2-1
Annual catch statistics of finfish and blue crab taken in impingement sampling at the Salem Generating Station circulating water intake structure, January through December 2008

Number of samples = 1,570
Total minutes sampled = 2,303
Total pump volume sampled (cubic meters) = 15,262,588.8
Detritus mean density (kg/million cubic meters) = 881.1

Species		Collection Frequency	Initial Percent			Total Collected	Mean Density (n/10^{6}m^3)
			Live	Dead	Damaged		
Blue crab	*Callinectes sapidus*	865	100			9,775	640.45
Lampreys - Petromyontidae							
Sea lamprey	*Petromyzon marinus*	4	80		20	5	0.33
Freshwater eels - Anguillidae							
American eel	*Anguilla rostrata*	53	64	10	26	58	3.80
Conger eels - Congridae							
Conger eel	*Conger oceanicus*	3	67		33	3	0.20
Herrings - Clupeidae							
American shad	*Alosa sapidissima*	24	96	4		26	1.70
Blueback herring	*Alosa aestivalis*	74	87	13		112	7.34
Alewife	*Alosa pseudoharengus*	9	80		20	10	0.66
Atlantic menhaden	*Brevoortia tyrannus*	338	69	24	7	883	57.85
Gizzard shad	*Dorosoma cepedianum*	357	94	2	4	1,199	78.56
Anchovies - Engraulidae							
Striped anchovy	*Anchoa hepsetus*	7	86	14		7	0.46
Bay anchovy	*Anchoa mitchilli*	466	83	16	1	1,103	72.27
Carps and minnows - Cyprinidae							
Common carp	*Cyprinus carpio*	1	100			1	0.07
Eastern silvery minnow	*Hybognathus regius*	98	98	2		257	16.84
Suckers - Catostomidae							
White sucker	*Catostomus commersonii*	1	100			1	0.07
North American catfishes - Ictaluridae							
Yellow bullhead	*Ameiurus natalis*	4	75		25	4	0.26
Channel catfish	*Ictalurus punctatus*	12	75		25	12	0.79
Pikes - Esocidae							
Redfin pickerel	*Esox americanus*	1	100			1	0.07
Phycid hakes - Phycidae							
Red hake	*Urophycis chuss*	3	100			3	0.20
Spotted hake	*Urophycis regia*	92	96	3	1	230	15.07
Toadfishes - Batrachoididae							
Oyster toadfish	*Opsanus tau*	49	98	2		57	3.73
Mullets - Mugilidae							
Striped mullet	*Mugil cephalus*	17	100			17	1.11
Cusk-eels - Ophidiidae							
Striped cusk-eel	*Ophidion marginatum*	172	99	1		546	35.77
Needlefishes - Belonidae							
Atlantic needlefish	*Strongylura marina*	1	100			1	0.07

Table 2-1 continued.

Species		Collection Frequency	Initial Percent			Total Collected	Mean Density $(n/10^6m^3)$
			Live	Dead	Damaged		
Killifishes - Cyprinodontidae							
Mummichog	*Fundulus heteroclitus*	13	100			15	0.98
Striped killifish	*Fundulus majalis*	2	100			2	0.13
Silversides - Atherinidae							
Atlantic silverside	*Menidia menidia*	284	96	3	1	859	56.28
Stickleback - Gasterosteidae							
Threespine stickleback	*Gasterosteus aculeatus*	3	100			3	0.20
Pipefishes - Syngnathidae							
Lined seahorse	*Hippocampus erectus*	1	100			1	0.07
Northern pipefish	*Syngnathus fuscus*	44	100			47	3.08
Searobins - Triglidae							
Northern searobin	*Prionotus carolinus*	32	96	4		53	3.47
Temperate basses - Percichthyidae							
White perch	*Morone americana*	796	97	1	2	10,106	662.14
Striped bass	*Morone saxatilis*	250	98	1	1	497	32.56
Sea basses - Serranidae							
Black sea bass	*Centropristis striata*	11	100			11	0.72
Sunfishes - Centrarchidae							
Bluegill	*Lepomis macrochirus*	31	94	3	3	35	2.29
Largemouth bass	*Micropterus salmoides*	1	100			1	0.07
Perches - Percidae							
Tessellated darter	*Etheostoma olmstedi*	1	100			1	0.07
Yellow perch	*Perca flavescens*	21	100			23	1.51
Bluefishes - Pomatomidae							
Bluefish	*Pomatomus saltatrix*	57	82	16	2	87	5.70
Jacks - Carangidae							
Crevalle jack	*Caranx hippos*	1	100			2	0.13
Lookdown	*Selene vomer*	1	100			1	0.07
Florida pompano	*Trachinotus carolinus*	1			100	1	0.07
Permit	*Trachinotus falcatus*	2	100			2	0.13
Porgies - Sparidae							
Scup	*Stenotomus chrysop*	2	50	50		2	0.13
Sheepshead	*Archosargus probatocephalus*	5	100			6	0.39
Drums - Sciaenidae							
Weakfish	*Cynoscion regalis*	450	95	5		4,652	304.80
Silver perch	*Bairdiella chrysoura*	70	93	2	5	100	6.55
Spot	*Leiostomus xanthurus*	230	95	1	4	361	23.65
Northern kingfish	*Menticirrhus saxatilis*	12	100			12	0.79
Atlantic croaker	*Micropogonias undulatus*	756	97	3		8,322	545.25
Black drum	*Pogonias cromis*	68	98	1	1	190	12.45

Table 2-1 continued.

Species		Collection	Initial Percent			Total	Mean Density ($n/10^6m^3$)
		Frequency	Live	Dead	Damaged	Collected	
Butterflyfishes - Chaetodontidae							
Spotfin butterflyfish	*Chaetodon ocellatus*	1	100			1	0.07
Wrasses - Labridae							
Tautog	*Tautoga onitis*	1			100	1	0.07
Stargazers - Uranoscopidae							
Northern stargazer	*Astroscopus gattatus*	7	100			7	0.46
Combtooth blennies - Blenniidae							
Feather blenny	*Hypsoblennius hentz*	1	100			1	0.07
Clingfishes - Gobiesocidae							
Skilletfish	*Gobiesox strumosus*	18	100			20	1.31
Sleepers - Eleotridae							
Fat sleeper	*Dormitator maculatus*	1			100	1	0.07
Gobies - Gobiidae							
Naked goby	*Gobiosoma bosc*	35	98	2		41	2.69
Butterfishes - Stromateidae							
Butterfish	*Peprilus triacanthus*	2	50	50		2	0.13
Lefteye flounders - Bothidae							
Smallmouth flounder	*Etropus microstomus*	1	100			1	0.07
Summer flounder	*Paralichthys dentatus*	26	94	3	3	31	2.03
Windowpane	*Scophthalmus aquosus*	2	100			2	0.13
American soles - Achiridae							
Hogchoker	*Trinectes maculatus*	786	100			5,248	343.85
Unknown spp.	Unknown spp.	7	63	38		8	0.52

Table 2-2
Monthly percentages live (L), dead (D), and damaged (D*) for target species taken in impingement sampling at the Salem Generating Station circulating water intake structure during 2008. n=number of individuals sampled. Values represent initial observed condition.

	Blueback herring				**Alewife**				**American shad**			
Month	n	L	D	D*	n	L	D	D*	n	L	D	D*
January	4	100			2	100			5	80	20	
February	25	72	28		3	100						
March	30	80	20		2	50		50				
April	16	88	13		1	100						
May					1			100	1	100		
June												
July												
August												
September												
October									6	100		
November	33	100							8	100		
December	4	100			1	100			6	100		
Total	112				10				26			

	Atlantic menhaden				**Bay anchovy**				**Atlantic silverside**			
Month	n	L	D	D*	n	L	D	D*	n	L	D	D*
January	9	78	22		2	100			135	96	4	1
February	52	79	17	4	21	62	33	5	97	84	9	7
March	27	89	11		7	29	57	14	18	94	6	
April	62	63	37		203	83	16	1	5	100		
May	94	88	11	1	144	85	15		12	83	17	
June	351	97	3		100	49	47	4	2	100		
July	13	62	23	15	40	65	35		4	100		
August	108	8	64	28	69	67	29	4	25	100		
September	104	22	67	11	114	89	11		37	97	3	
October	34	38	32	29	163	96	4		56	98	2	
November	24	79	17	4	205	96	4		218	99	1	
December	5	60		40	35	80	20		250	99	1	
Total	883				1,103				859			

Table 2-2 Continued.
Monthly percentages live (L), dead (D), and damaged (D*) for target species taken in impingement sampling at the Salem Generating Station circulating water intake structure during 2008. n=number of individuals sampled. Values represent initial observed condition.

	White perch				**Striped bass**				**Bluefish**			
Month	n	L	D	D*	n	L	D	D*	n	L	D	D*
January	2,288	97	1	2	64	100						
February	1,203	93	1	5	33	100						
March	577	97	1	3	20	95		5				
April	891	95	1	3	52	96		4				
May	54	67	6	28					33	82	18	
June	36	31	22	47	1		100		29	79	17	3
July	18	50	11	39	12	100			1		100	
August	8	50		50	14	86		14	3	100		
September	5	60		40	6	67	17	17	8	63	25	13
October	29	100			12	100			12	100		
November	1,642	99			155	97	3		1	100		
December	3,355	99	1		128	100						
Total	10,106				497				87			

	Weakfish				**Spot**				**Atlantic croaker**			
Month	n	L	D	D*	n	L	D	D*	n	L	D	D*
January									3,451	95	4	
February									327	85	11	4
March									58	90	9	2
April									254	95	5	
May	1	100			13	100			1,488	98	2	
June	54	81	19		37	100			1,752	98	2	
July	1,994	93	6		31	90	3	6	192	98	1	1
August	1,646	96	4		47	91	2	6	50	94	2	4
September	524	98	2		75	92		8	15	60	13	27
October	401	99	1		67	97		3	20	95		5
November	22	95		5	56	95		5	201	99	1	
December	10	70	30		35	97	3		514	99	1	
Total	4,652				361				8,322			

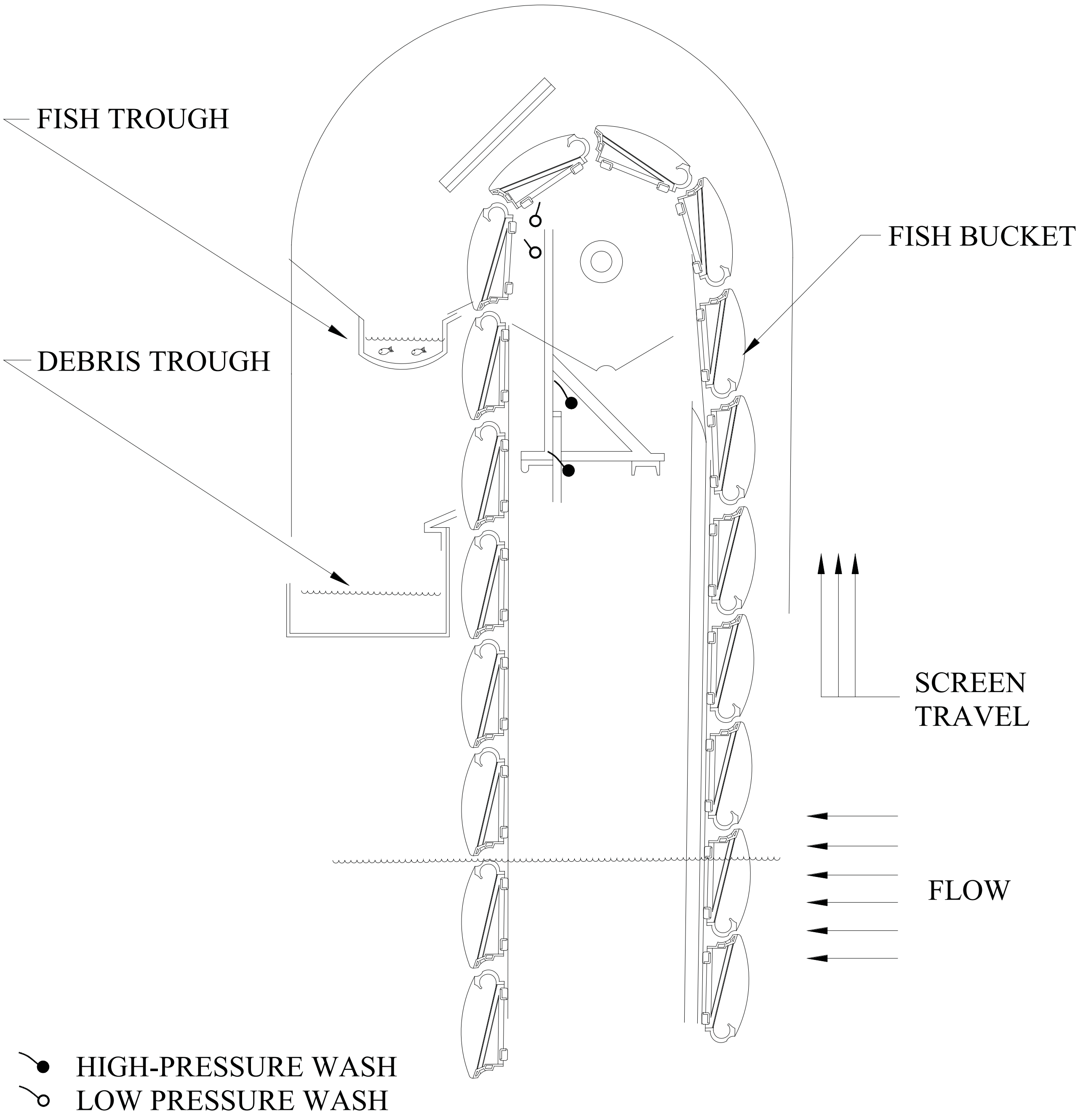


Figure 2-1. Ristroph modified traveling screen.

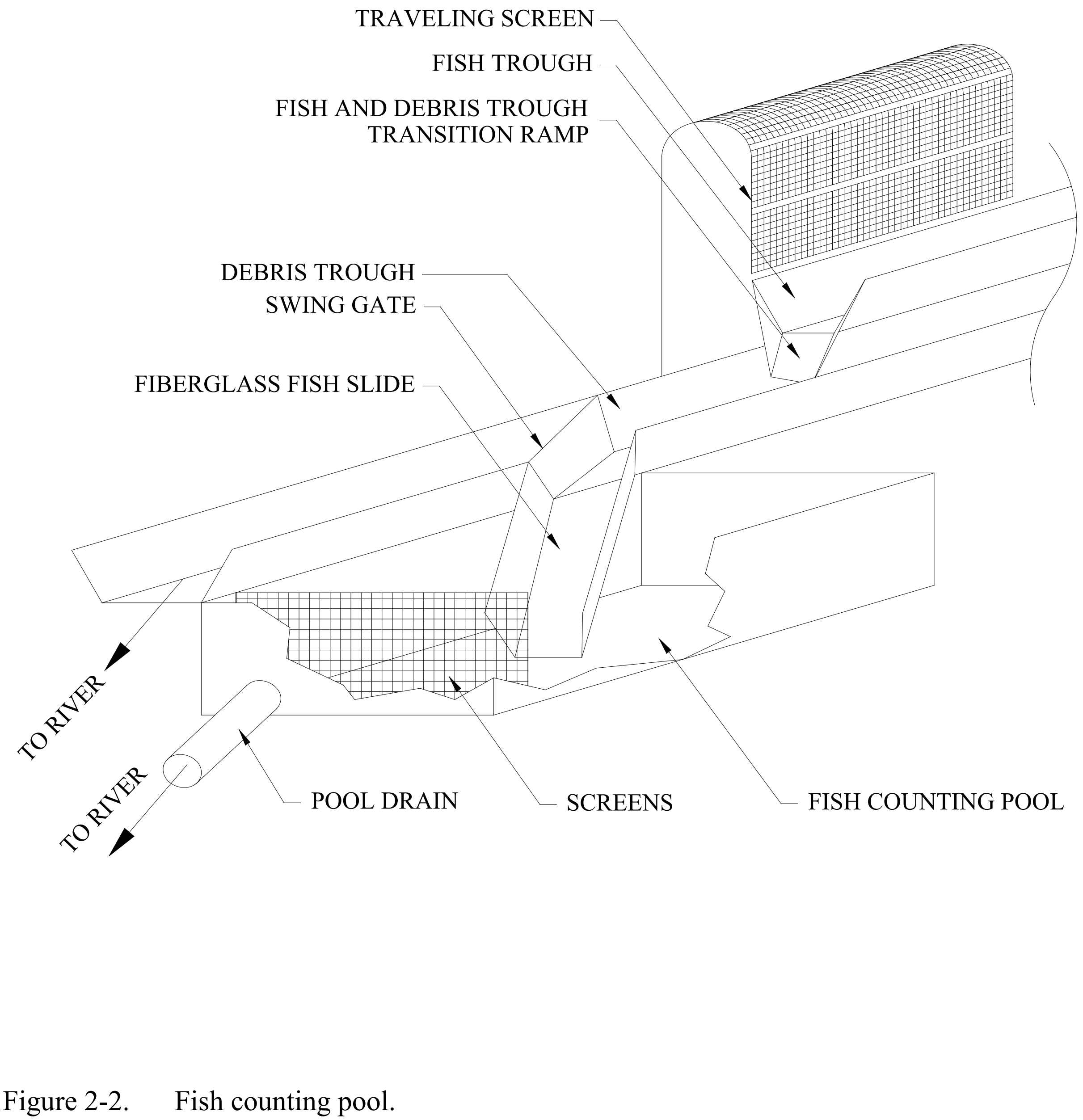


Figure 2-2. Fish counting pool.

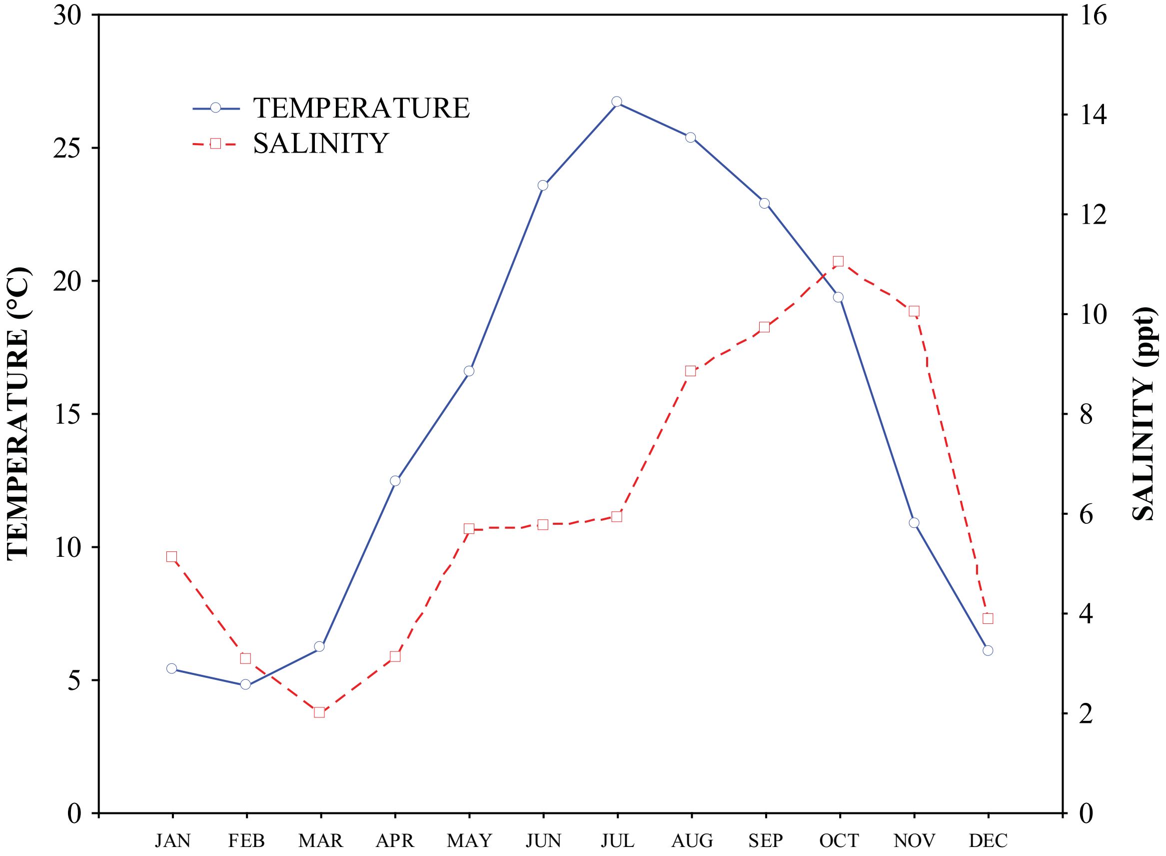


Figure 2-3. Salinity and temperature (mean) by month as observed during 2008 impingement sampling.

BLUEBACK HERRING

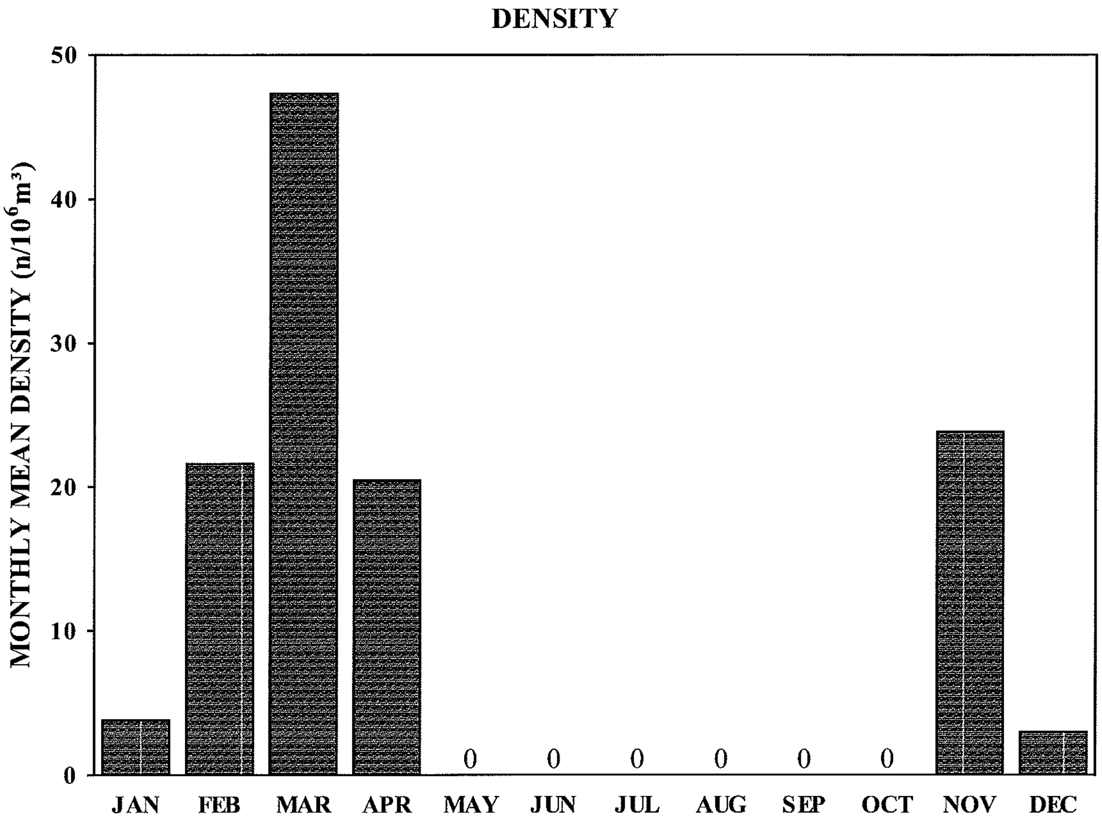
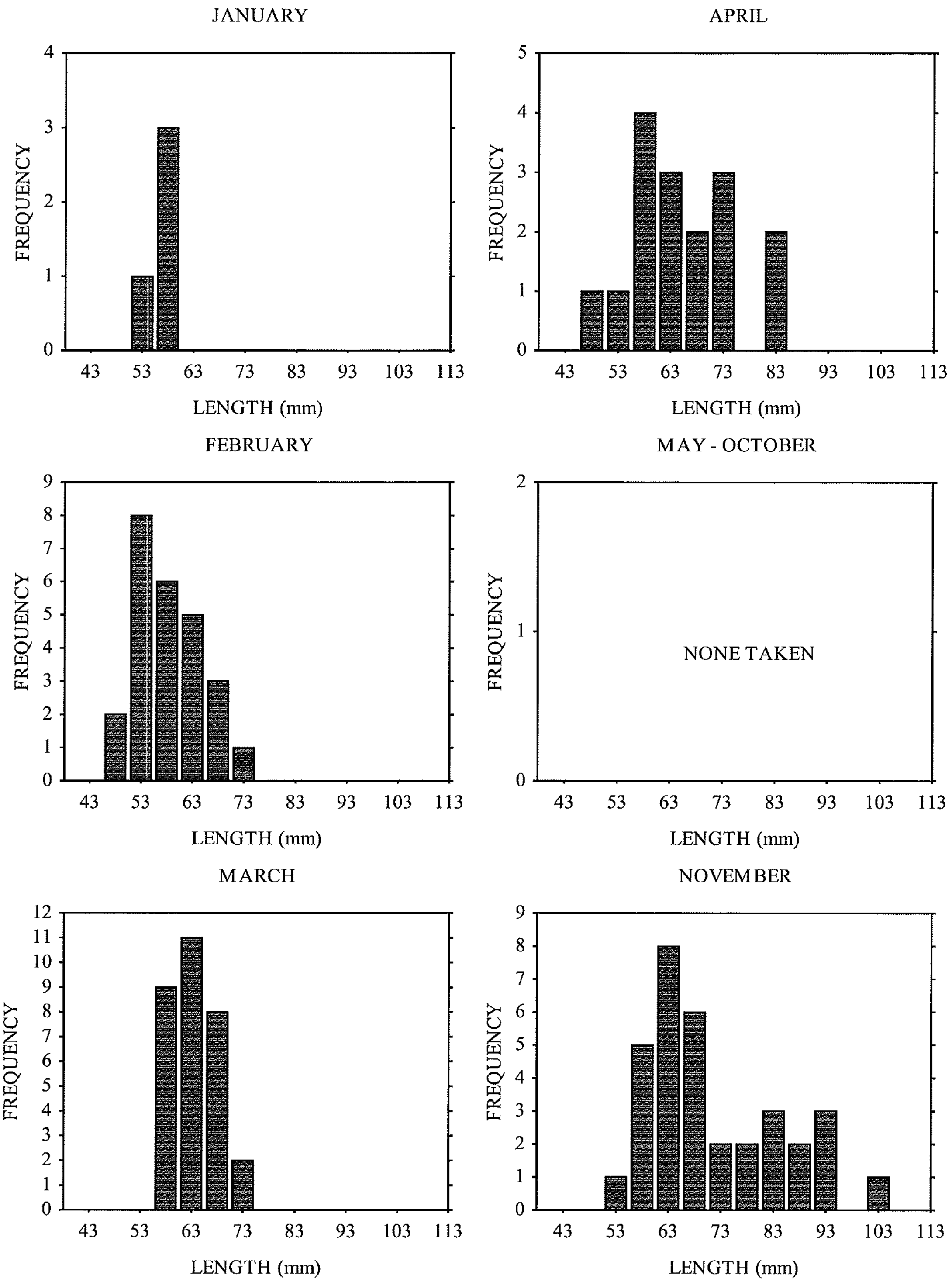


Figure 2-4. Monthly mean density (n/10^6 meters^3) of blueback herring taken in impingement sampling at the Salem circulating water intake structure during 2008

BLUEBACK HERRING


JANUARY

APRIL

FEBRUARY

MAY - OCTOBER

NONE TAKEN

MARCH

NOVEMBER

Figure 2-5. Length frequency of blueback herring taken in impingement sampling at the Salem circulating water intake structure during 2008.

BLUEBACK HERRING

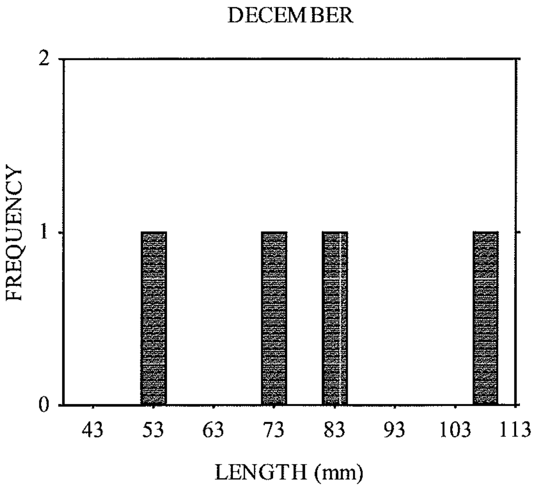


Figure 2-5. Continued.

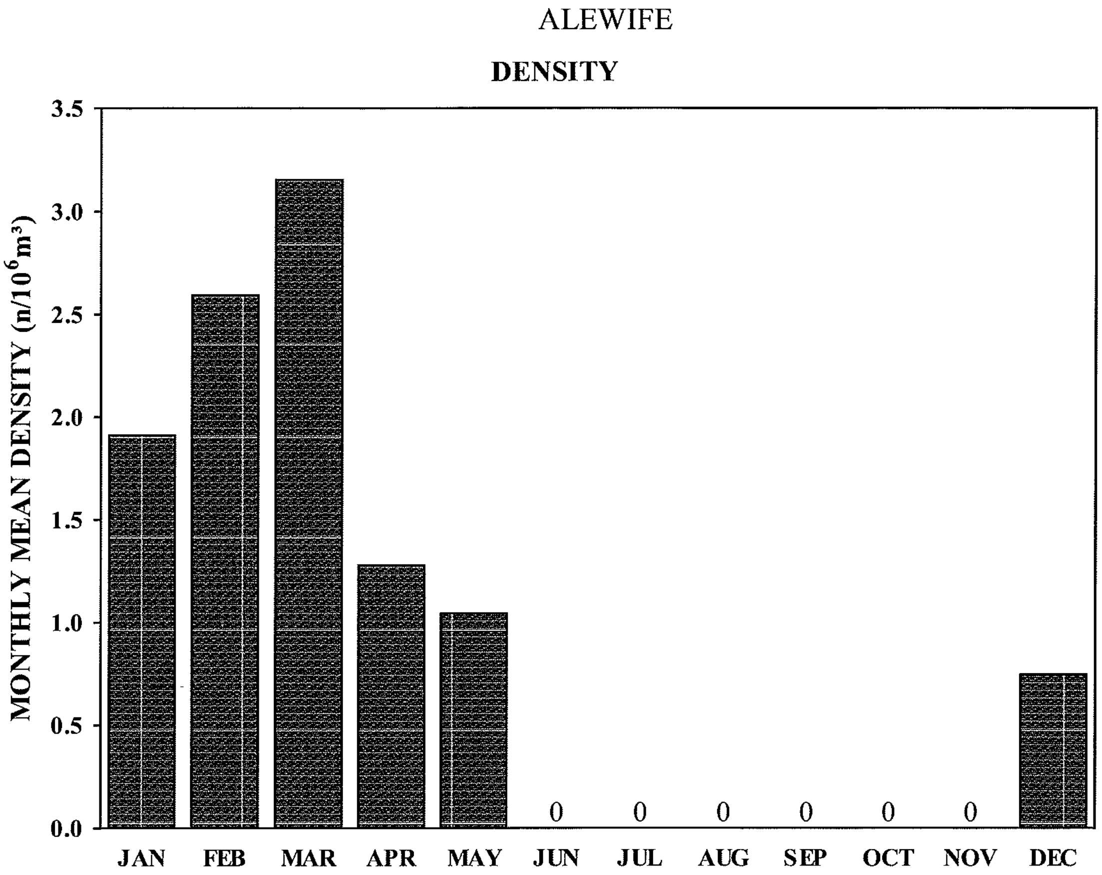


Figure 2-6. Monthly mean density (n/10^6 meters^3) of alewife taken in impingement sampling at the Salem circulating water intake structure during 2008.

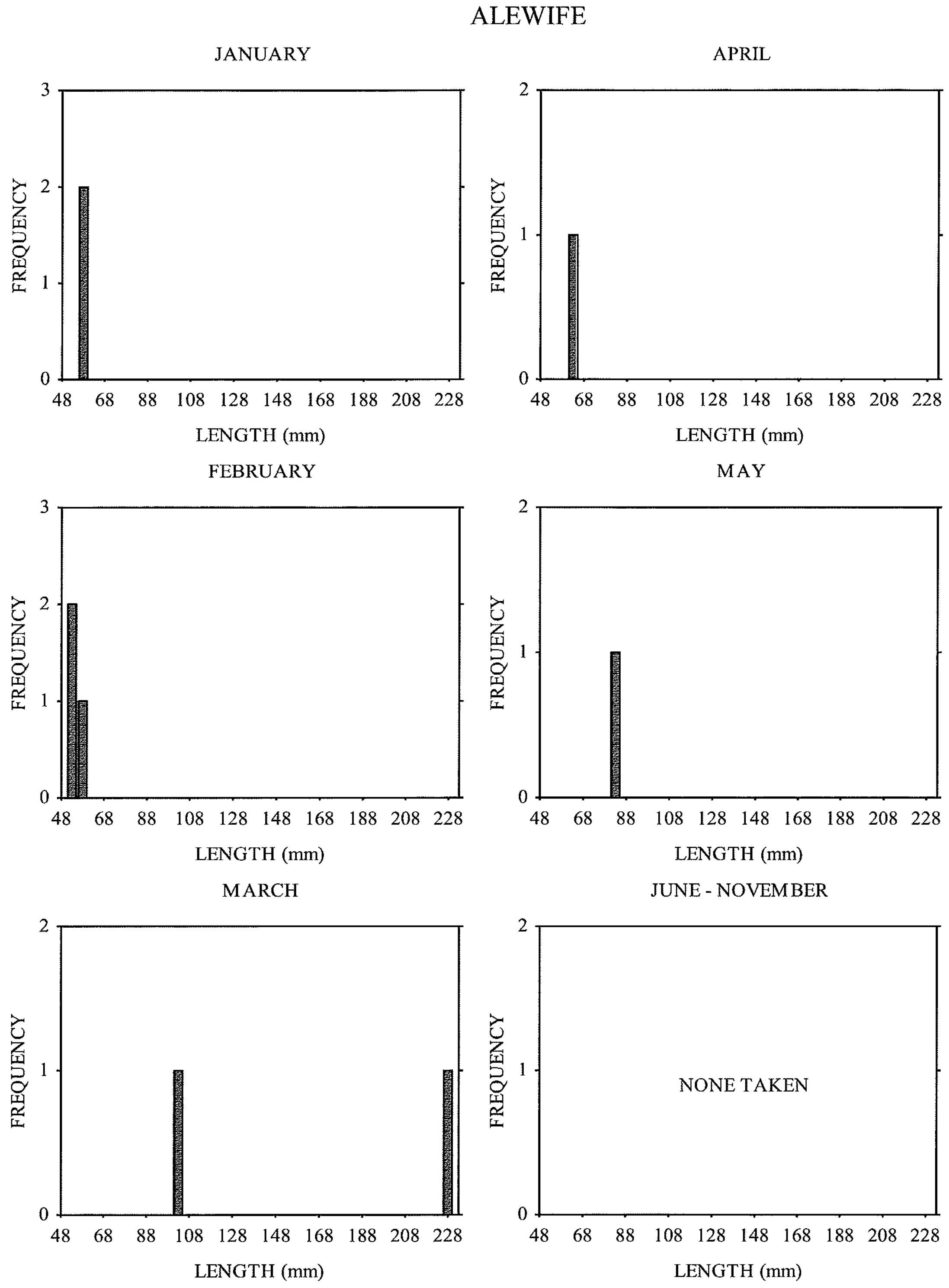
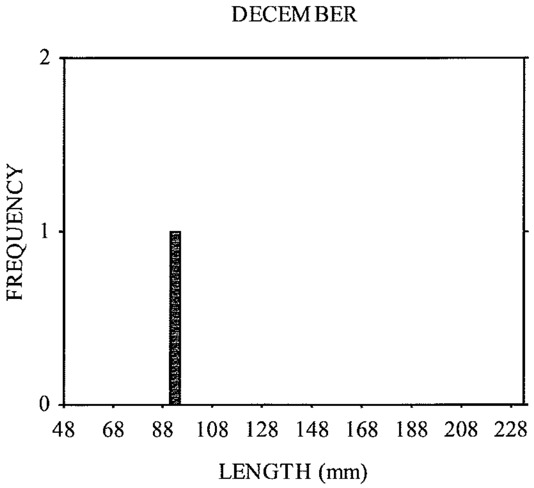


Figure 2-7. Length frequency of alewife taken in impingement sampling at the Salem circulating water intake structure during 2008.

ALEWIFE



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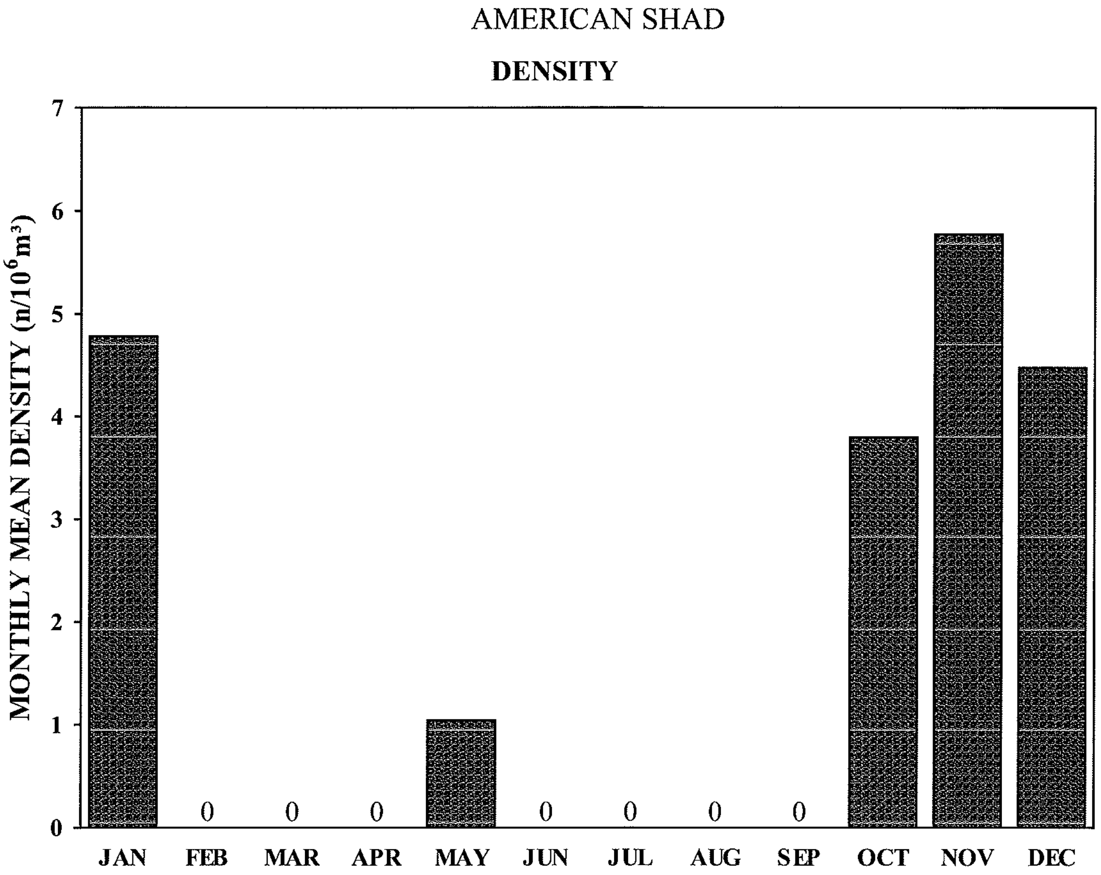


Figure 2-8. Monthly mean density (n/10^6 meters^3) of American shad taken in impingement sampling at the Salem circulating water intake structure during 2008.

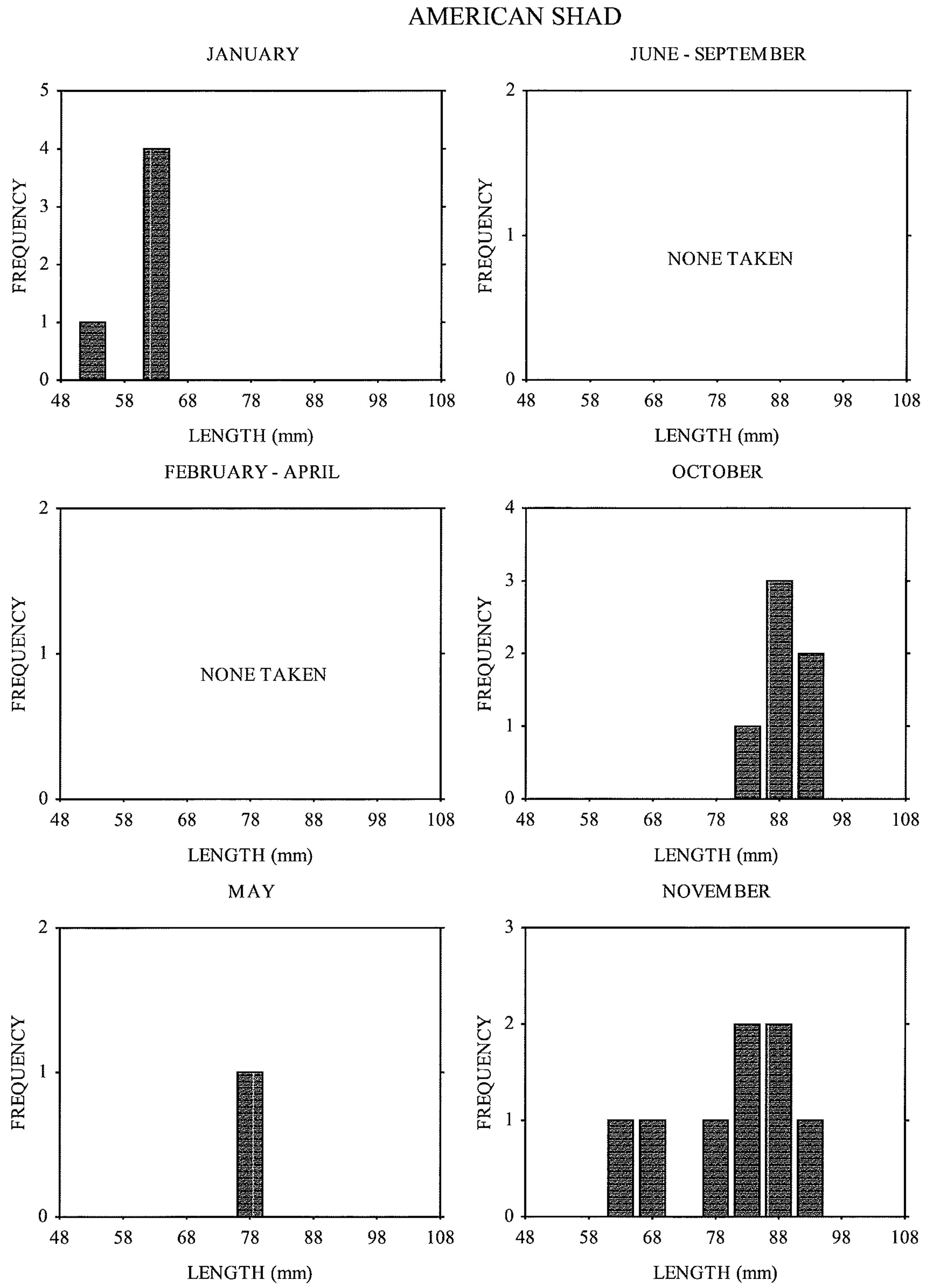


Figure 2-9. Length frequency of American shad taken in impingement sampling at the Salem circulating water intake structure during 2008.

AMERICAN SHAD

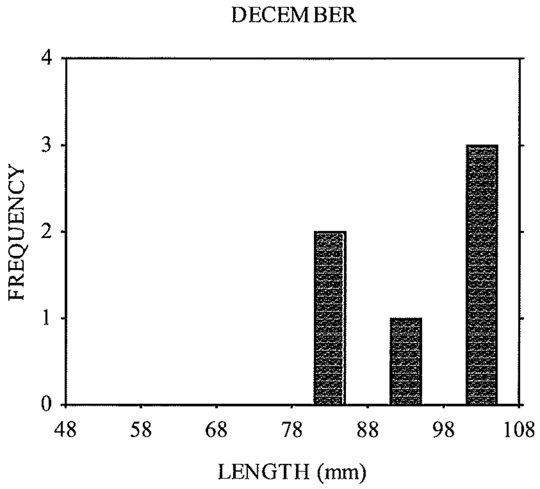


Figure 2-9. Continued.

ATLANTIC MENHADEN

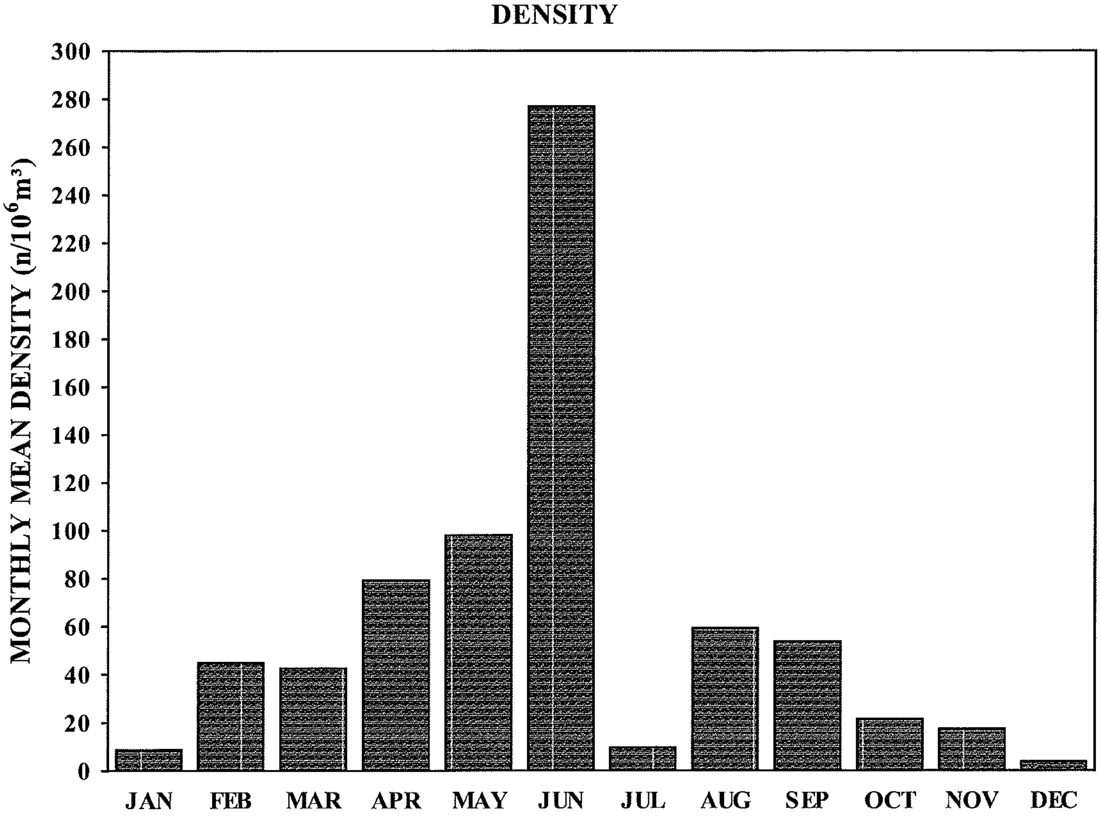


Figure 2-10. Monthly mean density (n/10^6 meters^3) of Atlantic menhaden taken in impingement sampling at the Salem circulating water intake structure during 2008.

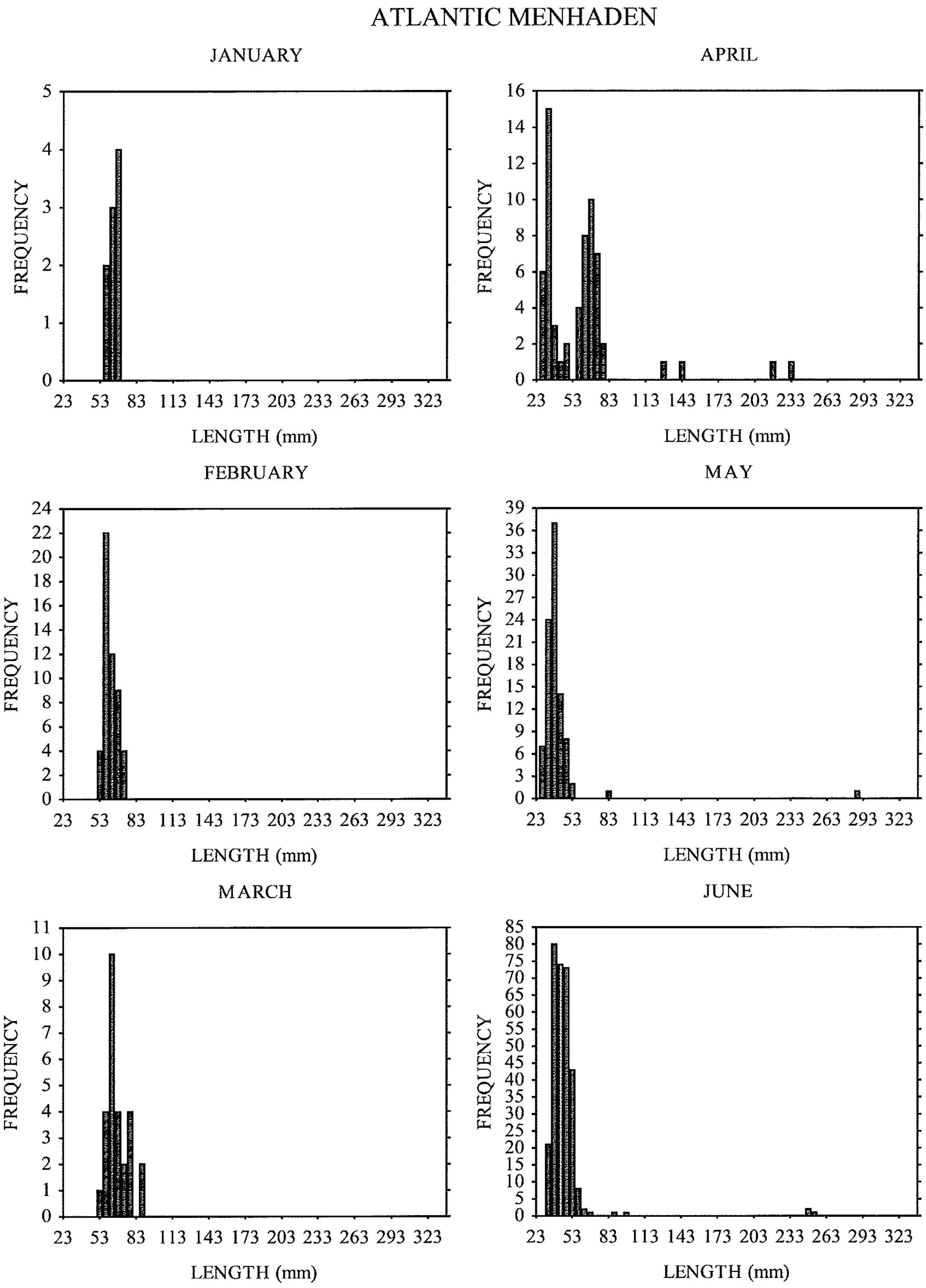


Figure 2-11. Length frequency of Atlantic menhaden taken in impingement sampling at the Salem circulating water intake structure during 2008.

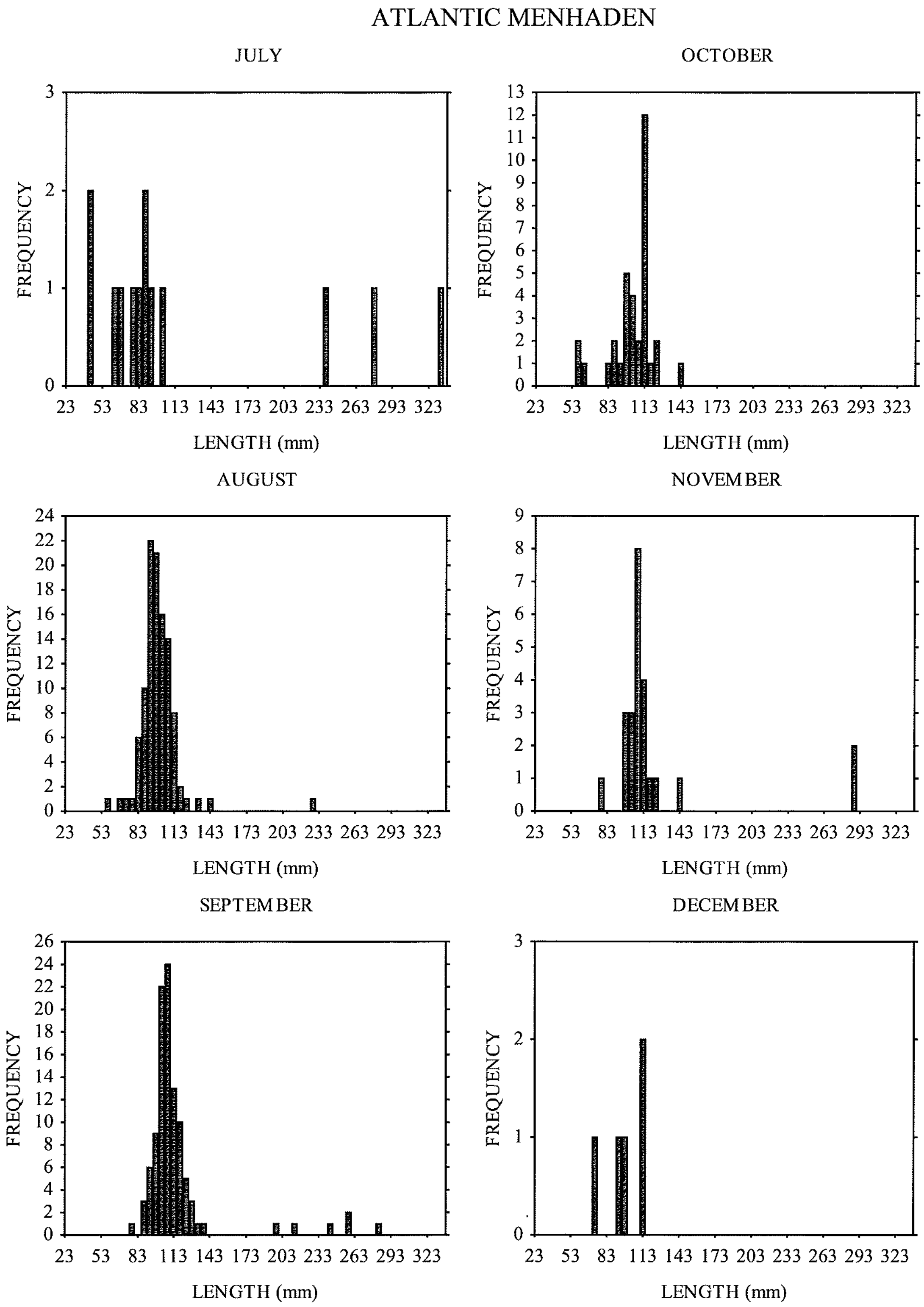


Figure 2-11. Continued.

BAY ANCHOVY

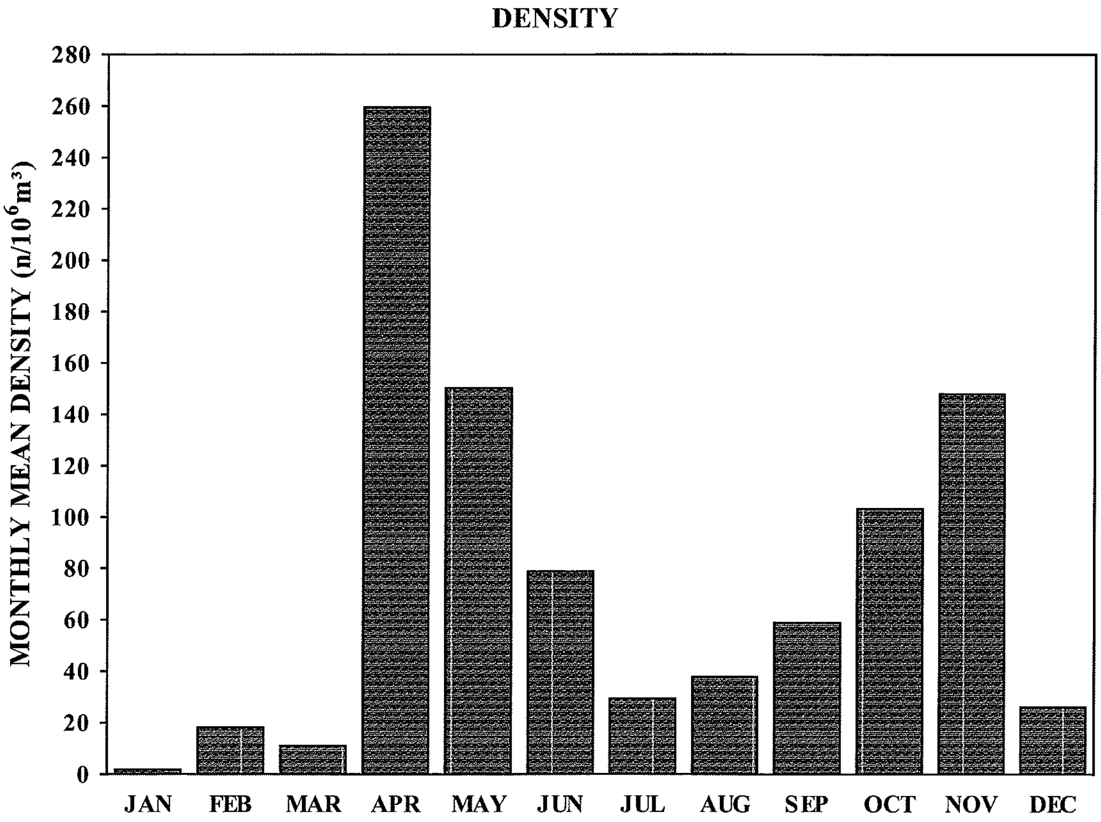
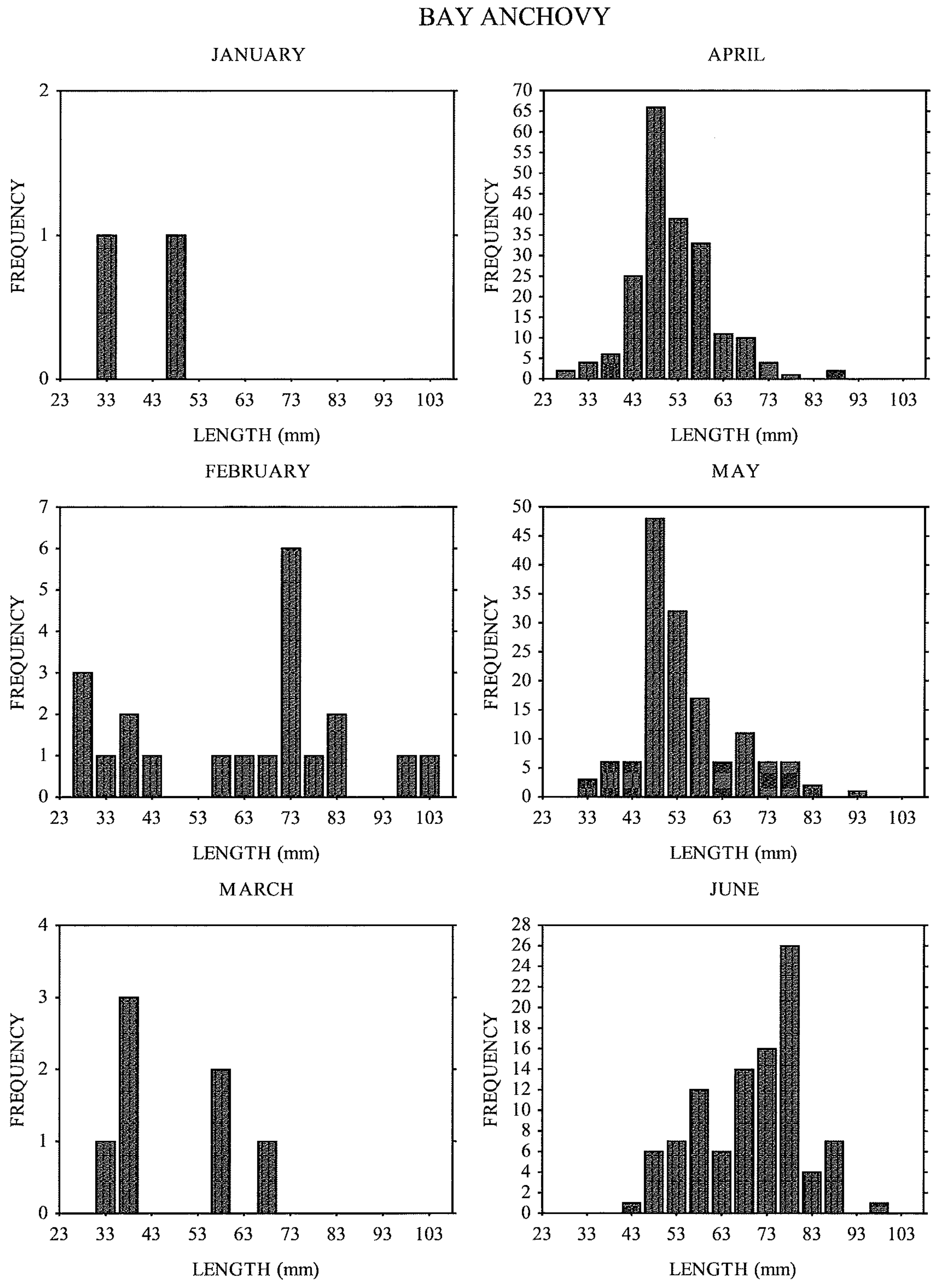


Figure 2-12. Monthly mean density (n/10^6 meters^3) of bay anchovy taken in impingement sampling at the Salem circulating water intake structure during 2008.



BAY ANCHOVY

JANUARY

APRIL

FEBRUARY

MAY

MARCH

JUNE

Figure 2-13. Length frequency of bay anchovy taken in impingement sampling at the Salem circulating water intake structure during 2008.

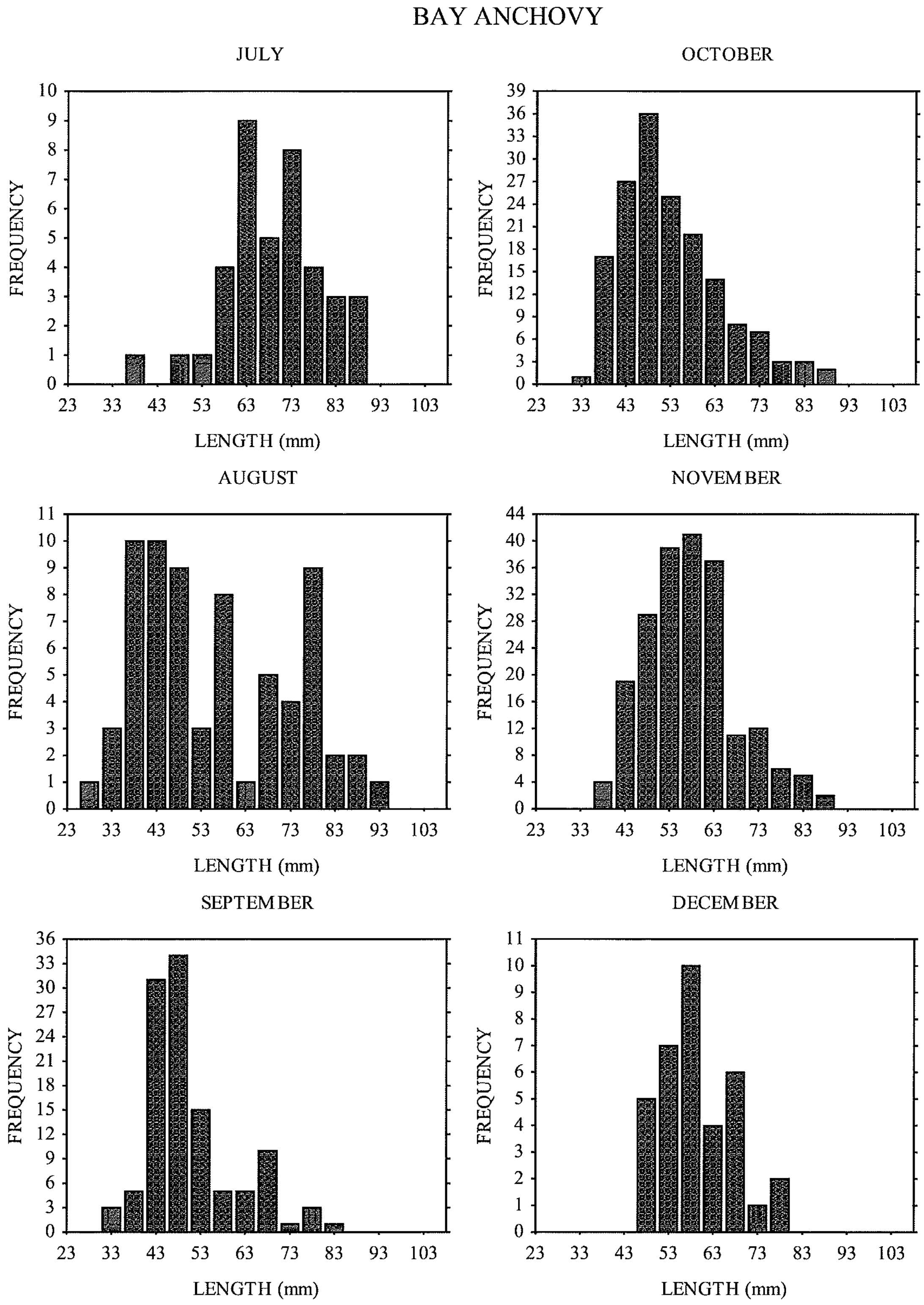


Figure 2-13. Continued.

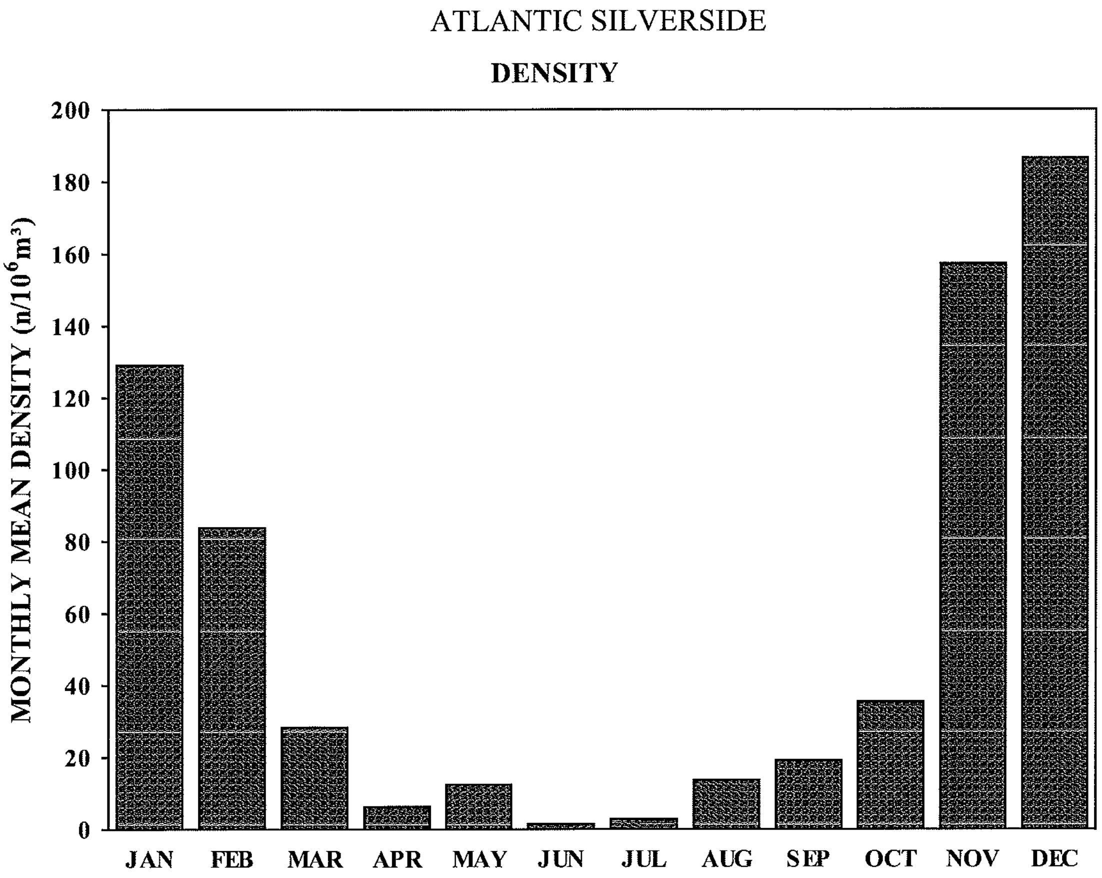


Figure 2-14. Monthly mean density (n/10^6 meters^3) of Atlantic silverside taken in impingement sampling at the Salem circulating water intake structure during 2008.

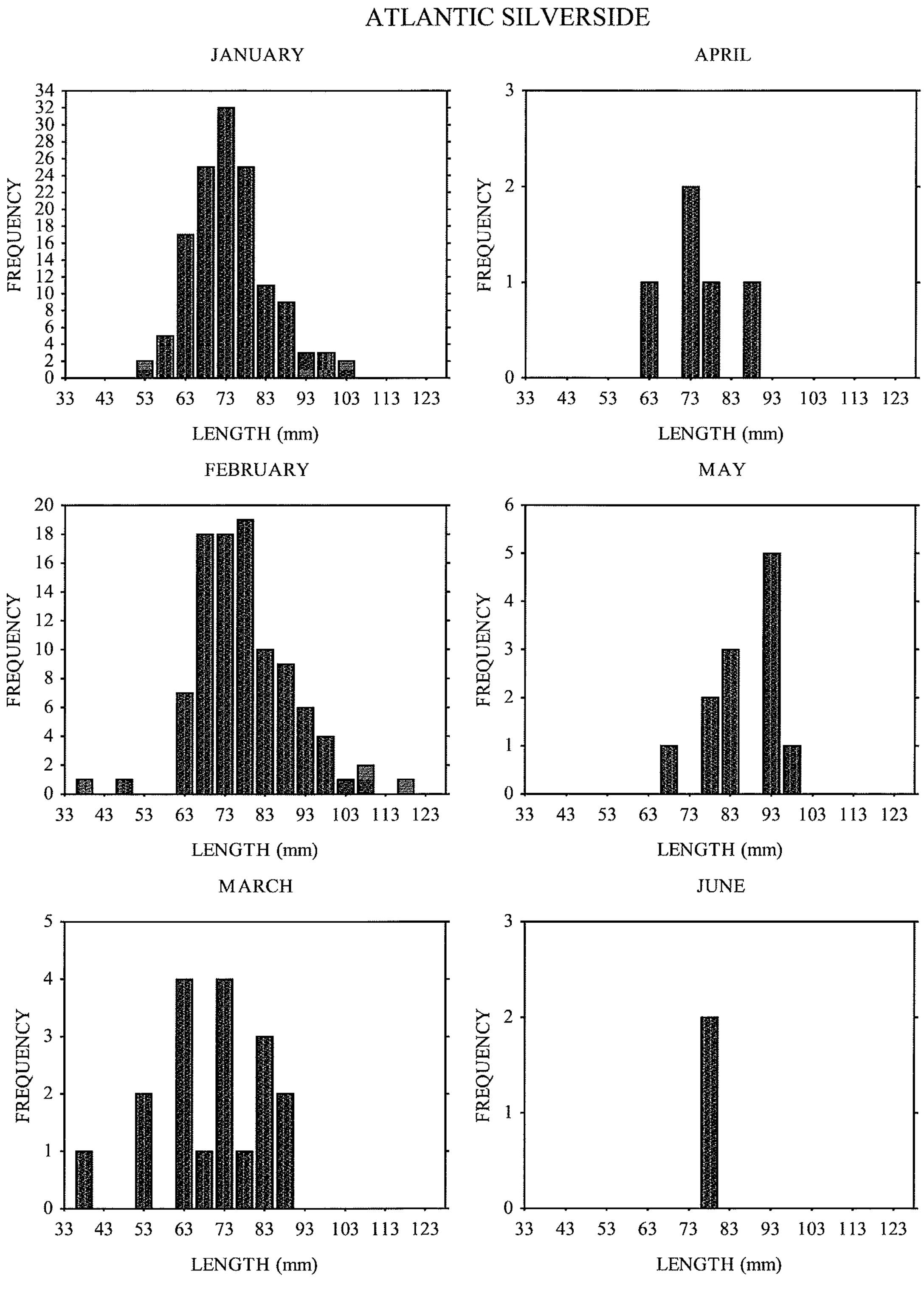
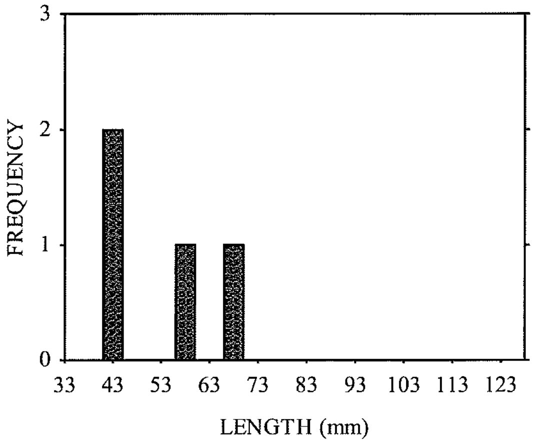


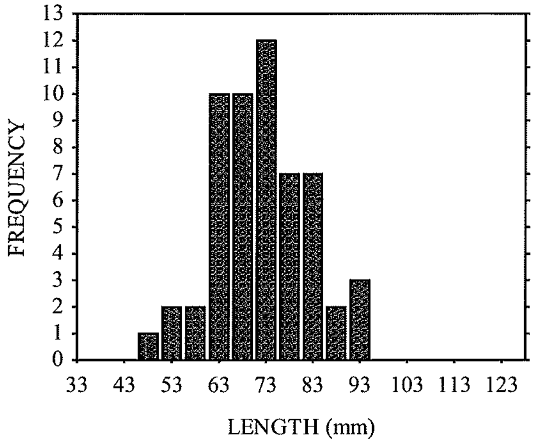
Figure 2-15. Length frequency of Atlantic silverside taken in impingement sampling at the Salem circulating water intake structure during 2008.

ATLANTIC SILVERSIDE

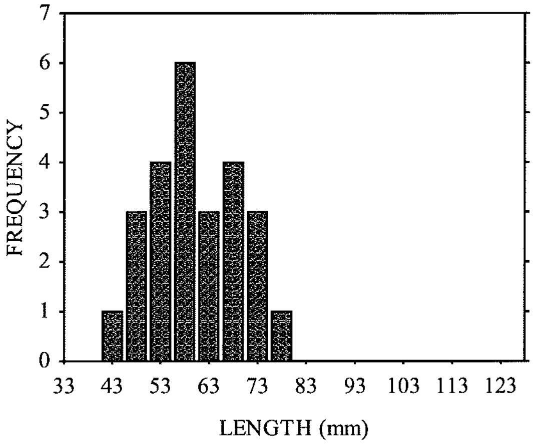
JULY



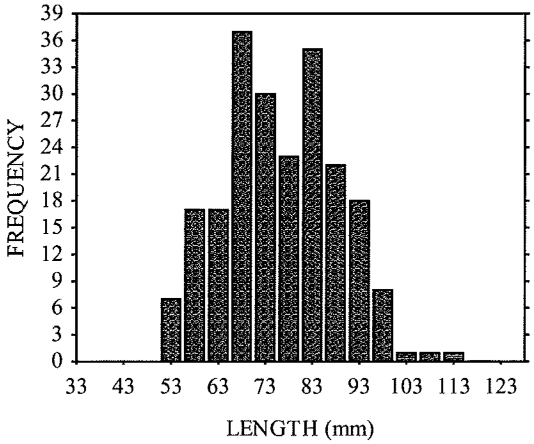
OCTOBER



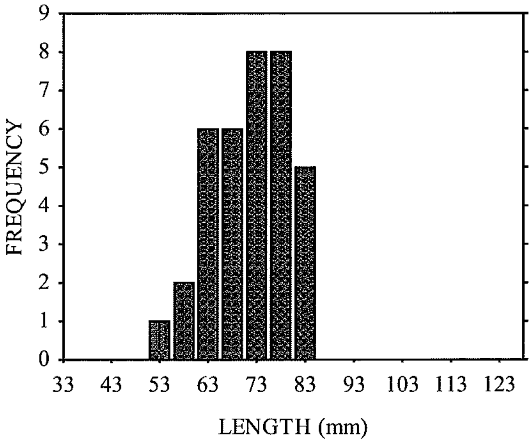
AUGUST



NOVEMBER



SEPTEMBER



DECEMBER

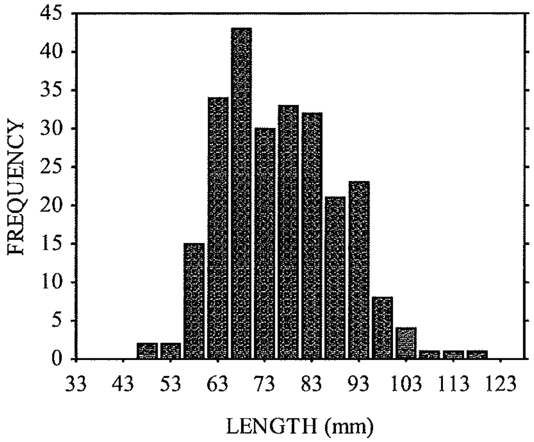


Figure 2-15. Continued.

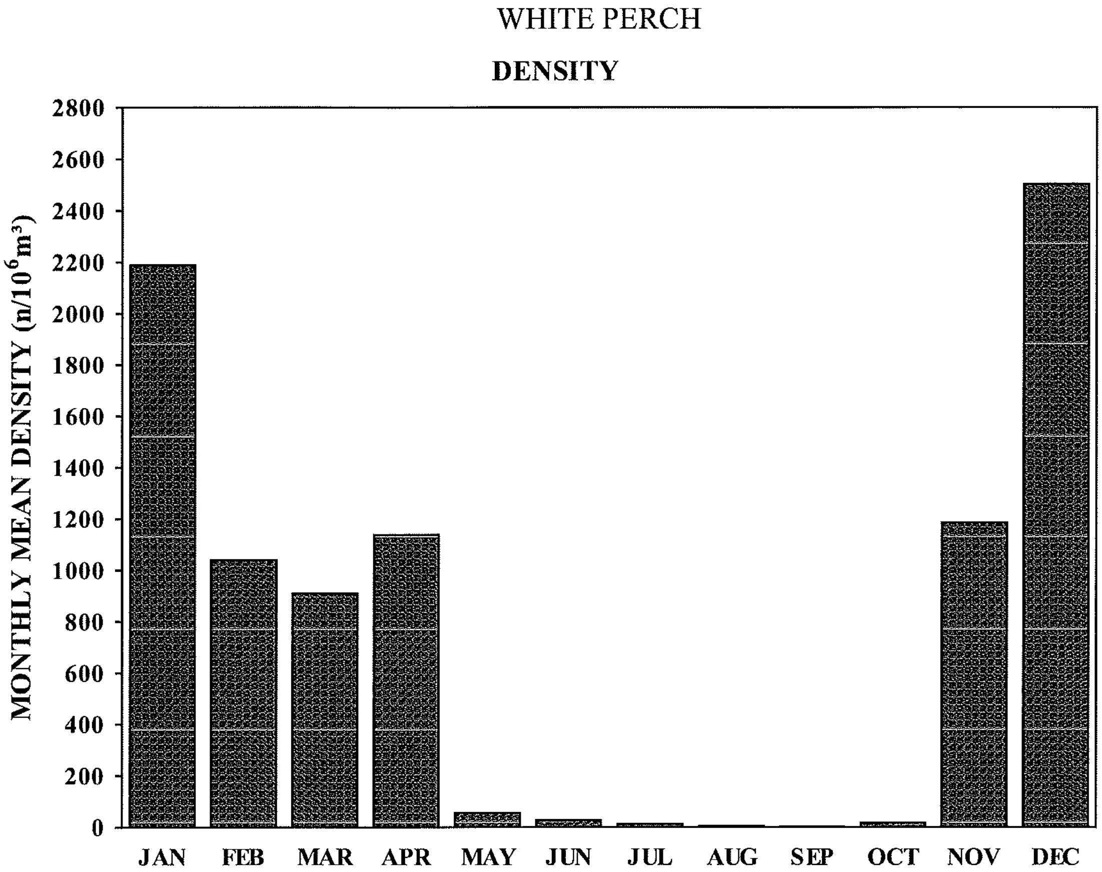


Figure 2-16. Monthly mean density ($n/10^6$ meters^3) of white perch taken in impingement sampling at the Salem circulating water intake structure during 2008.

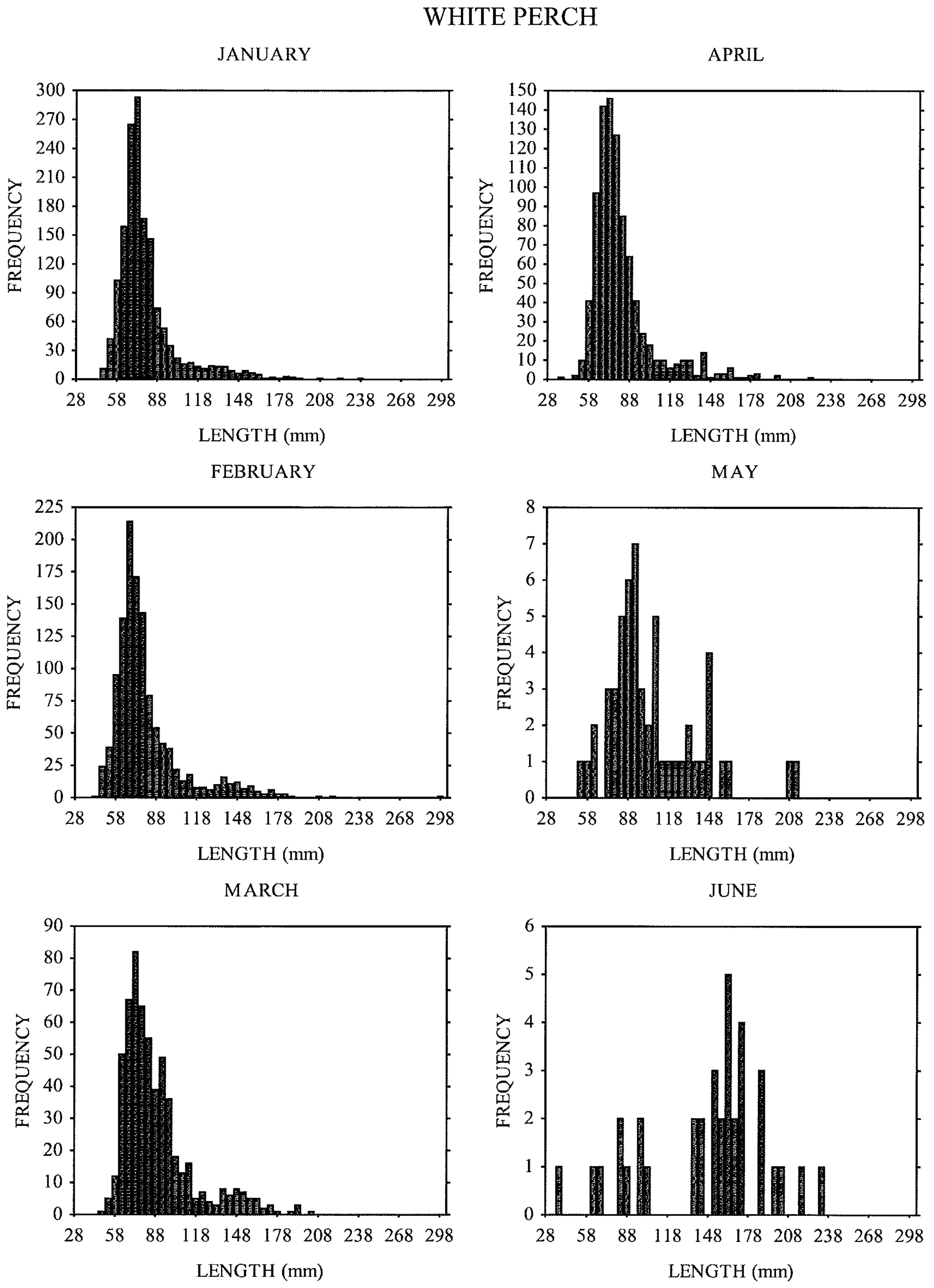


Figure 2-17. Length frequency of white perch taken in impingement sampling at the Salem circulating water intake structure during 2008.

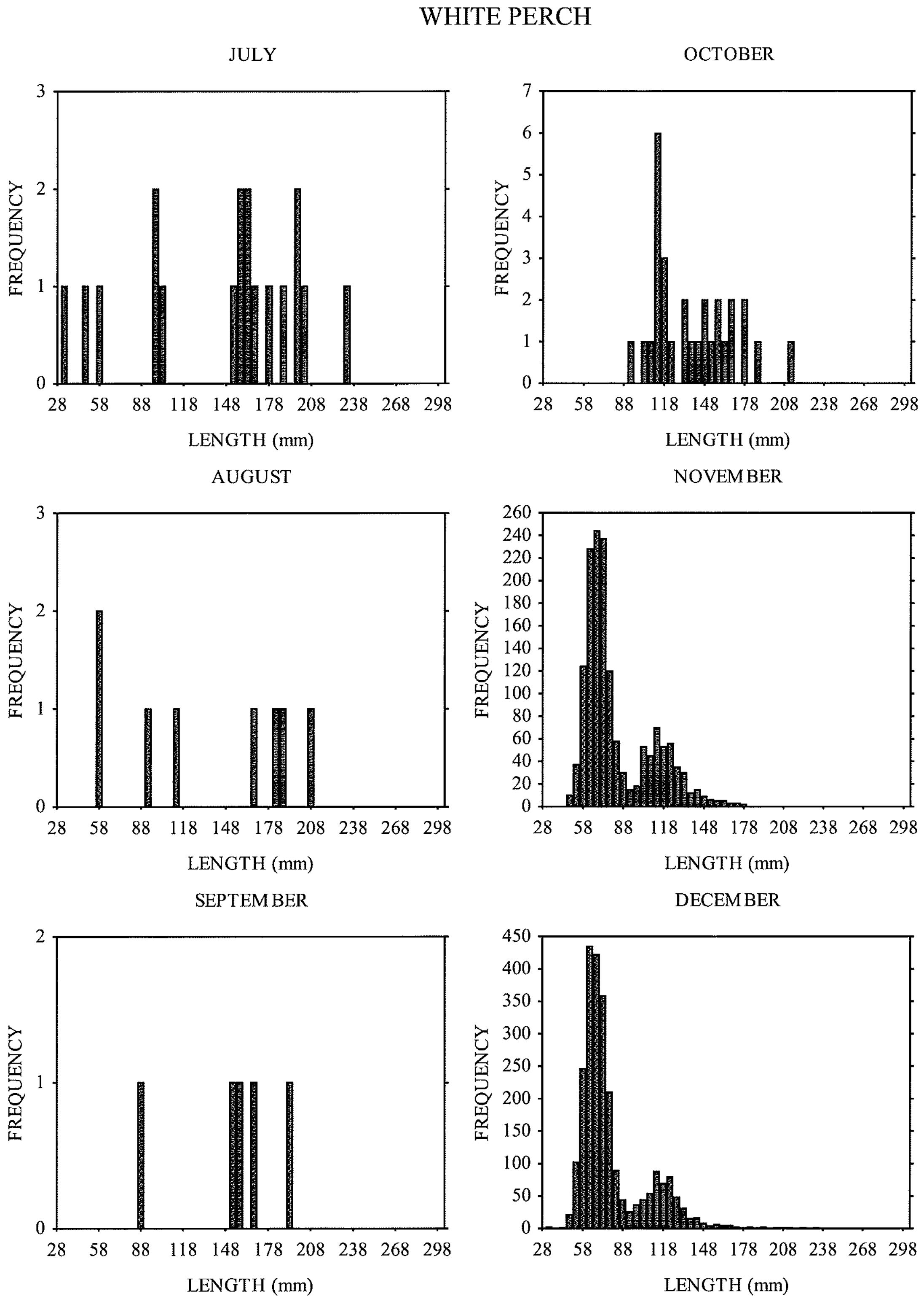


Figure 2-17. Continued.

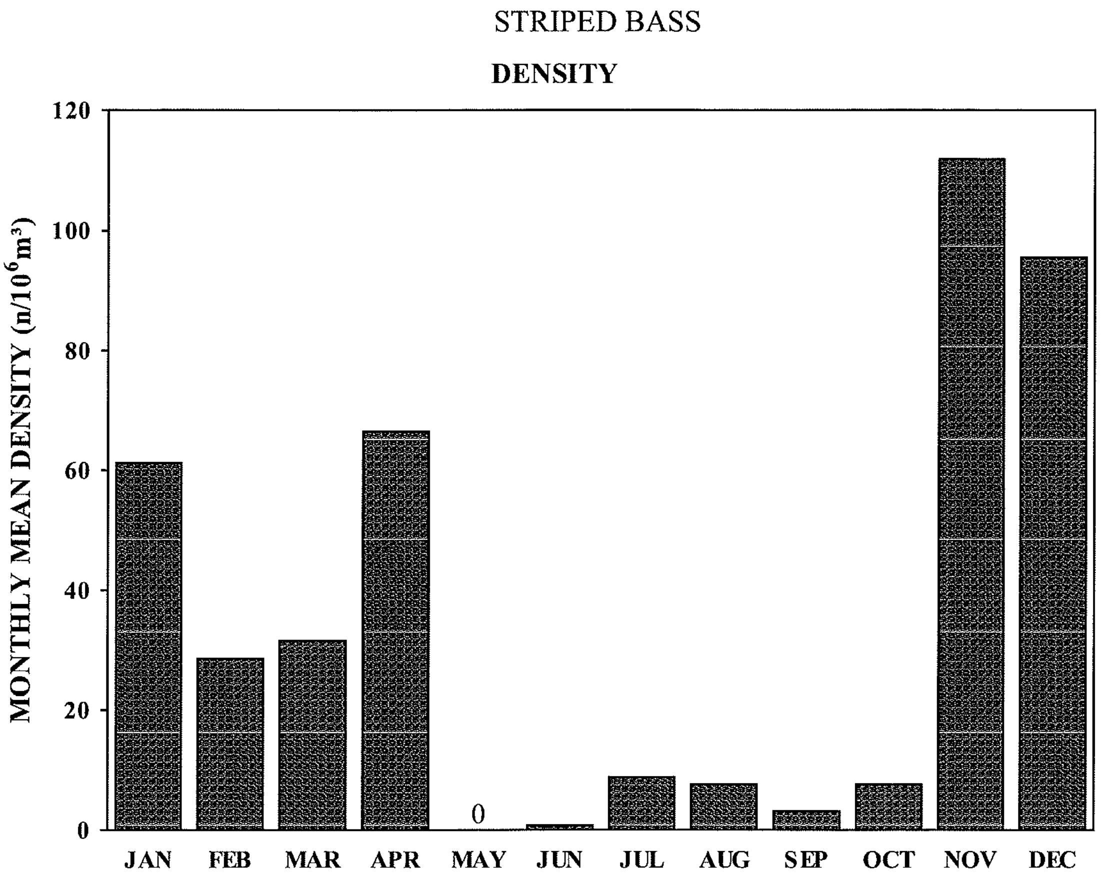


Figure 2-18. Monthly mean density (n/10^6 meters^3) of striped bass taken in impingement sampling at the Salem circulating water intake structure during 2008.

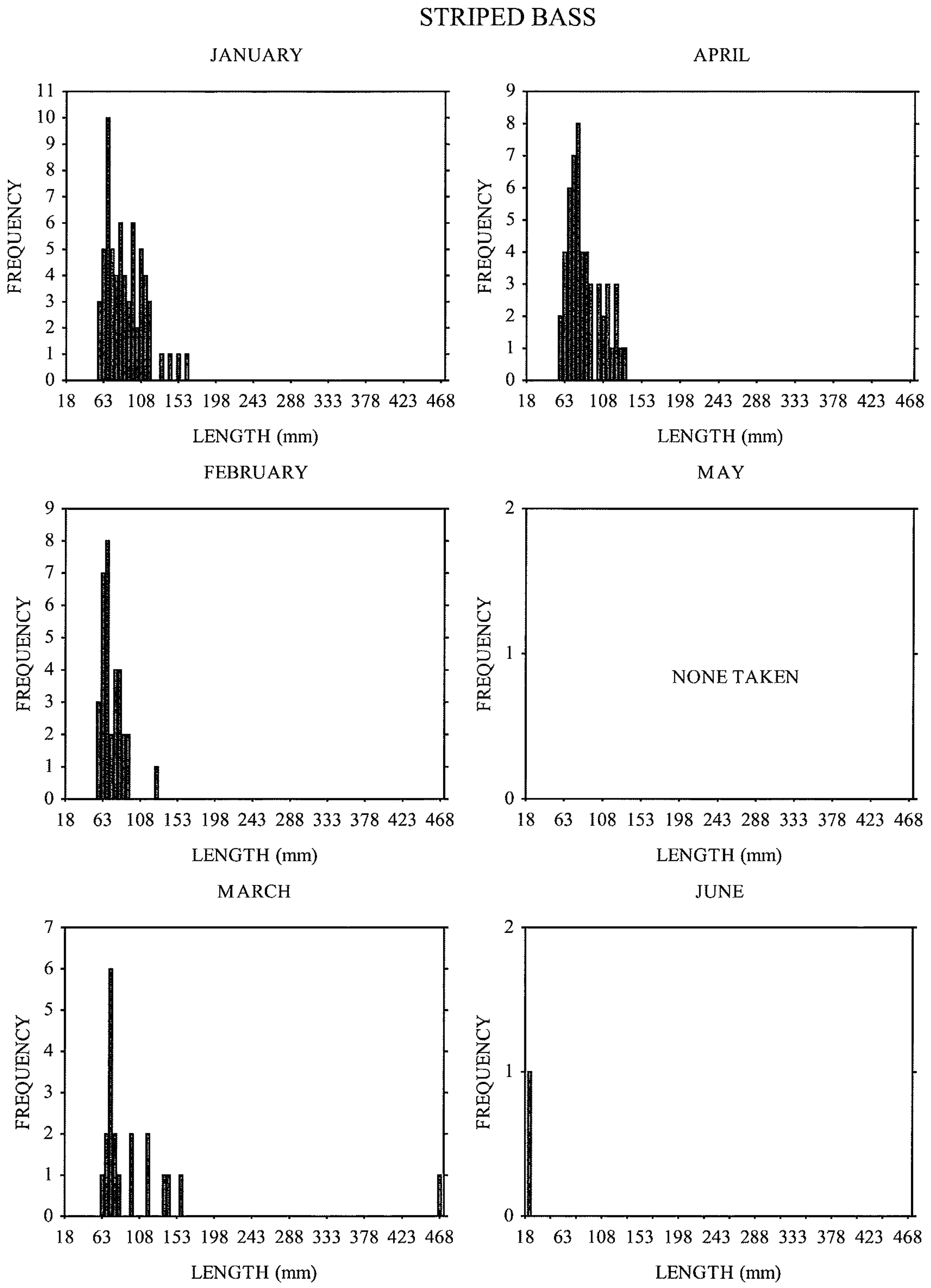


Figure 2-19. Length frequency of striped bass taken in impingement sampling at the Salem circulating water intake structure during 2008.

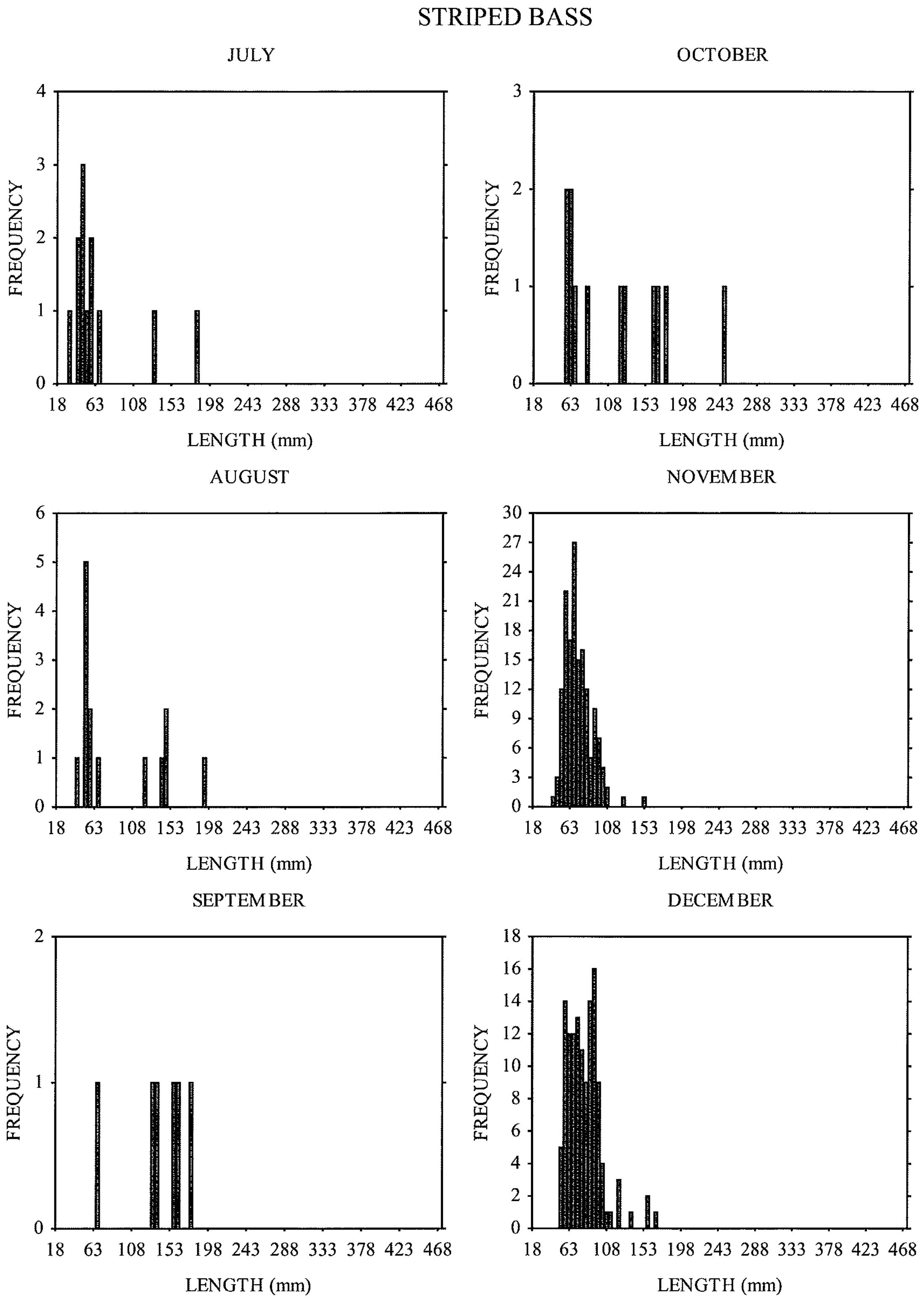


Figure 2-19. Continued.

BLUEFISH

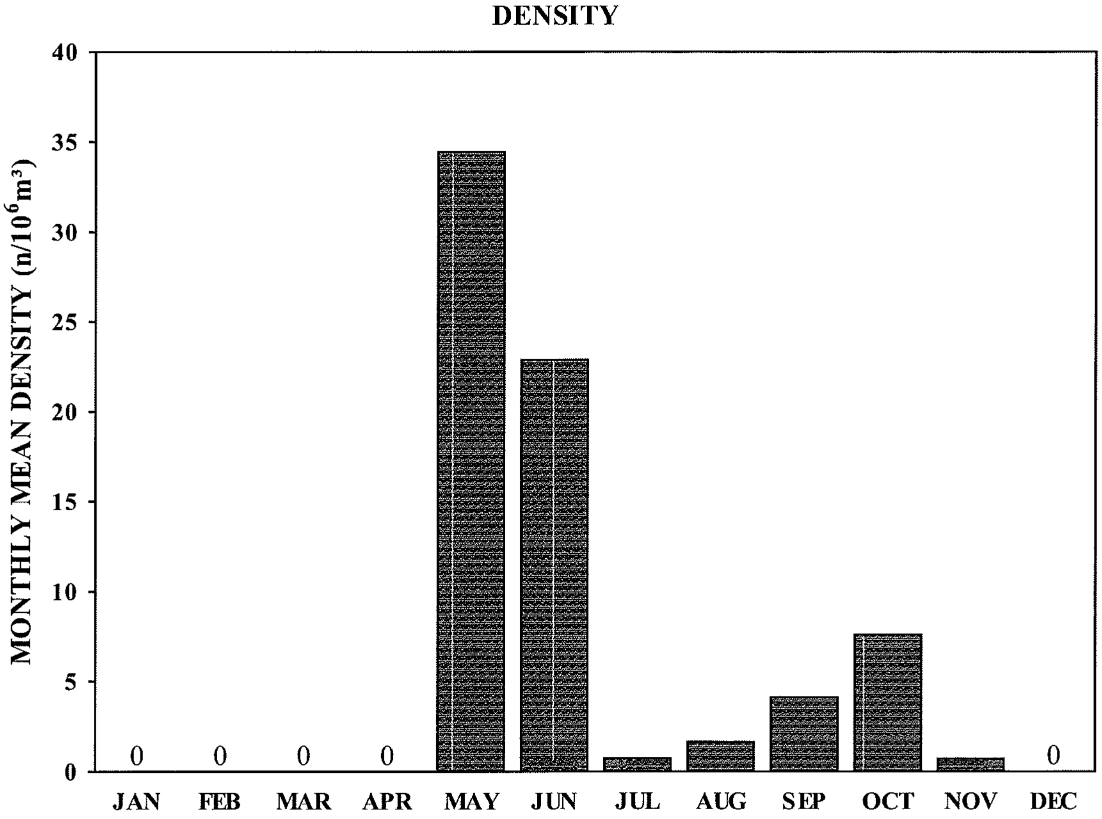


Figure 2-20. Monthly mean density (n/10^6 meters^3) of bluefish taken in impingement sampling at the Salem circulating water intake structure during 2008.

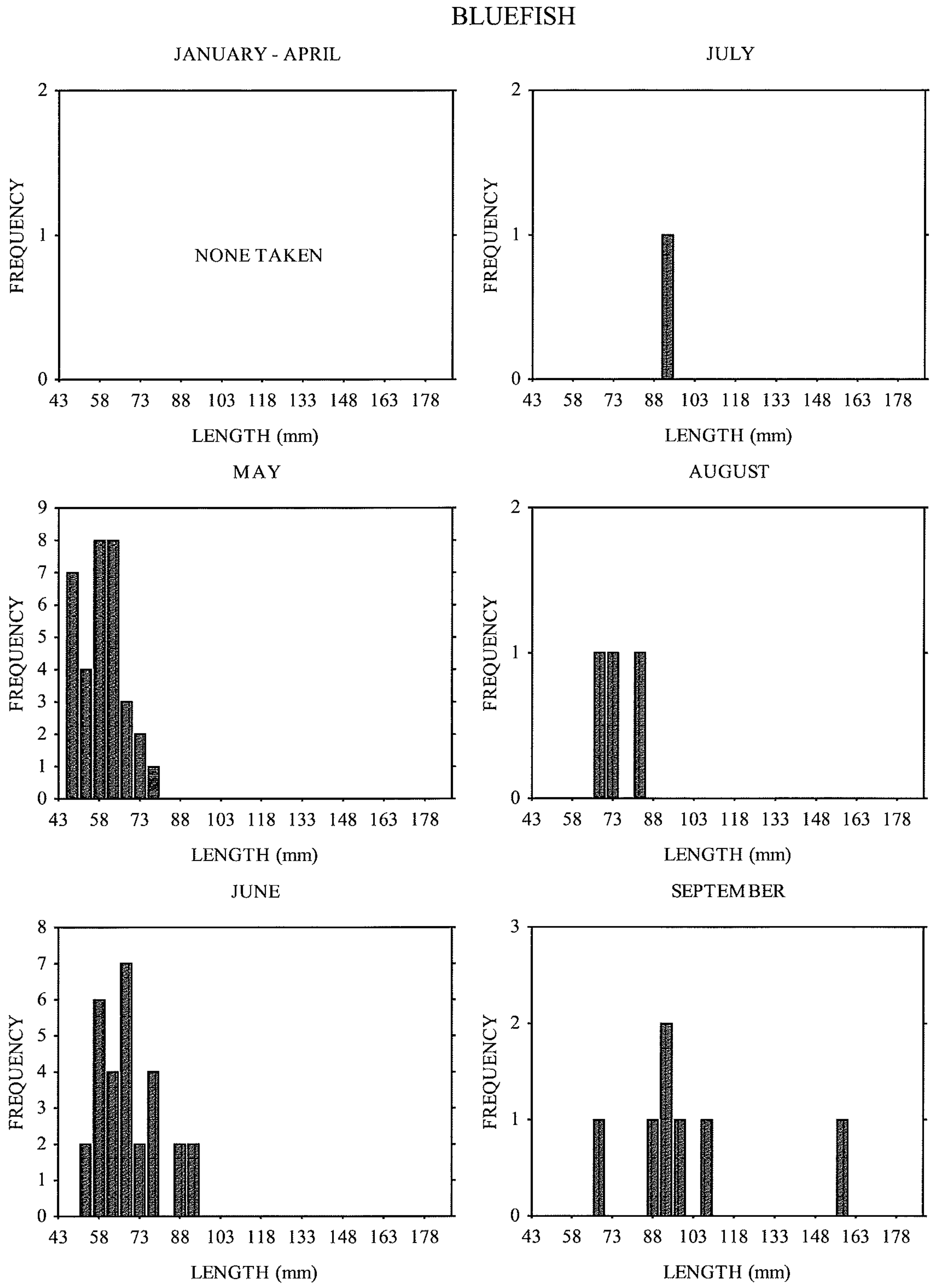


Figure 2-21. Length frequency of bluefish taken in impingement sampling at the Salem circulating water intake structure during 2008.

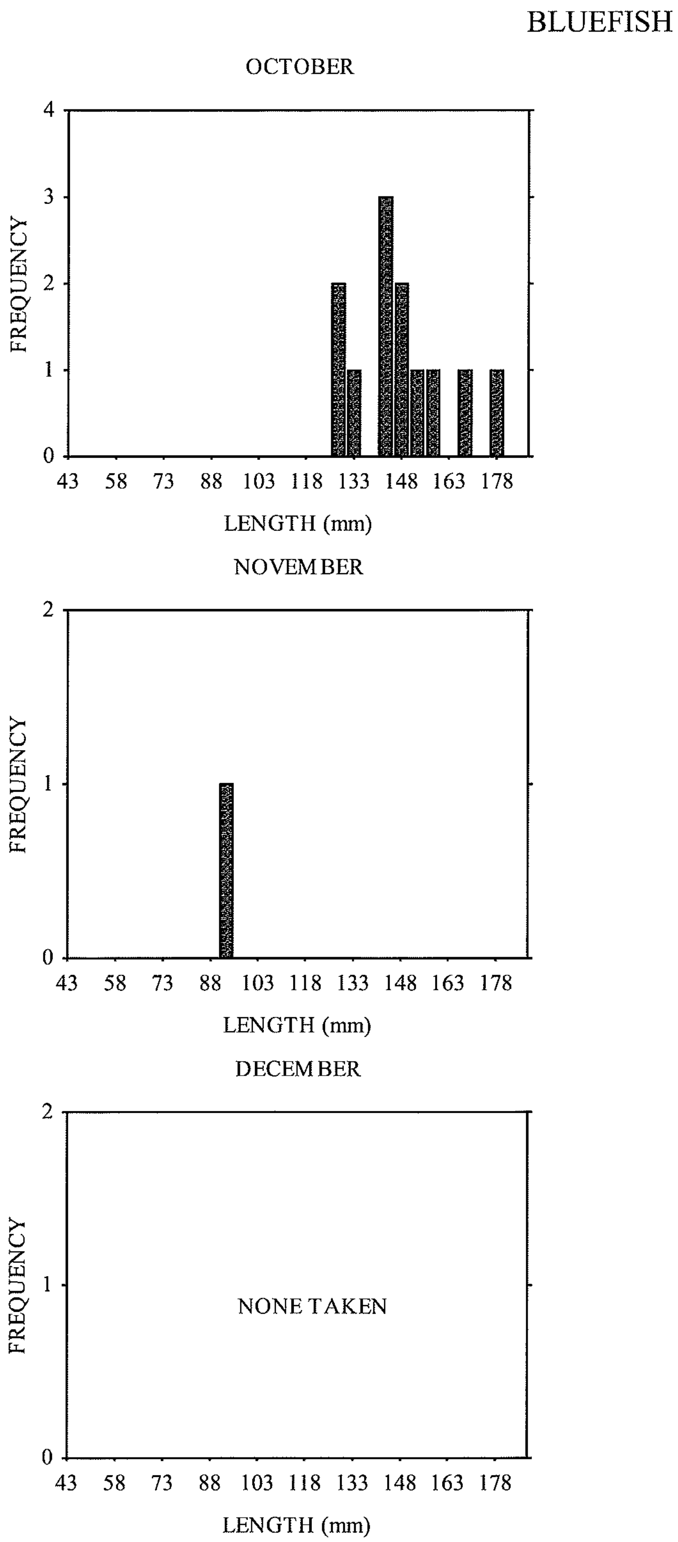


Figure 2-21. Continued.

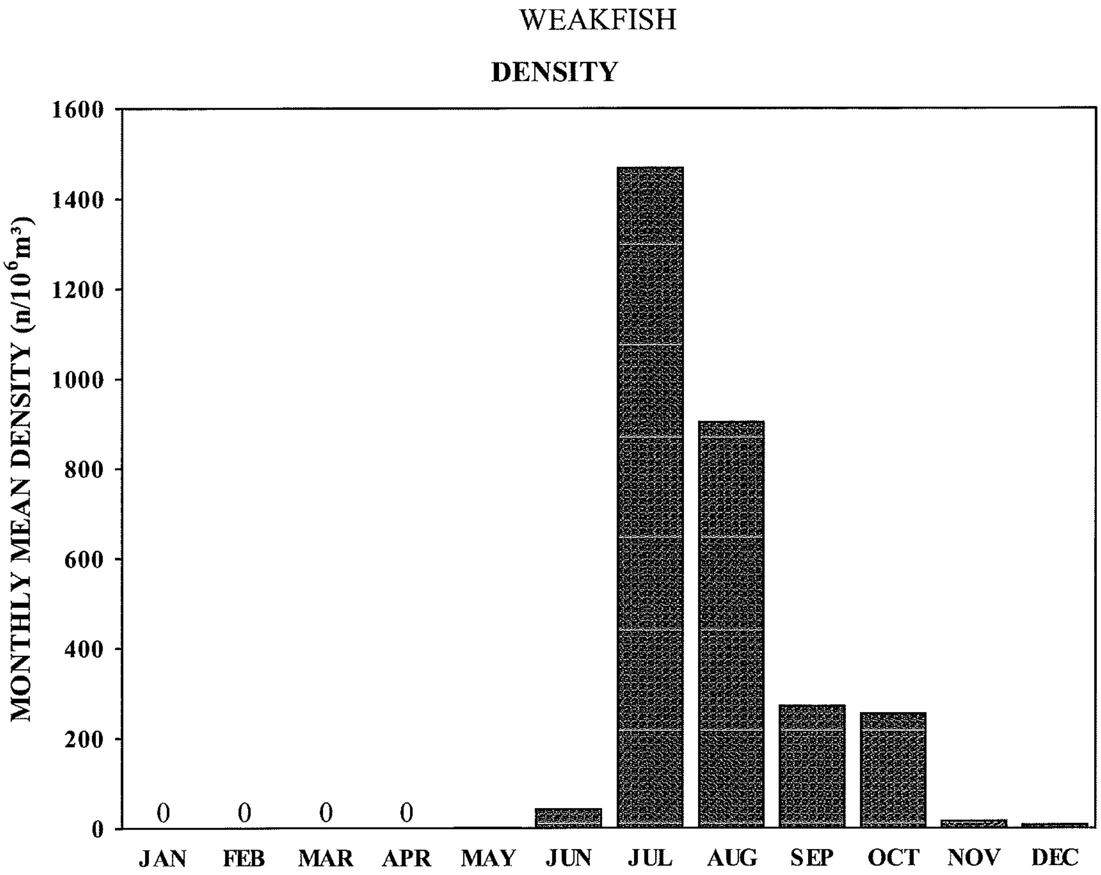


Figure 2-22. Monthly mean density ($n/10^6$ meters^3) of weakfish taken in impingement sampling at the Salem circulating water intake structure during 2008.

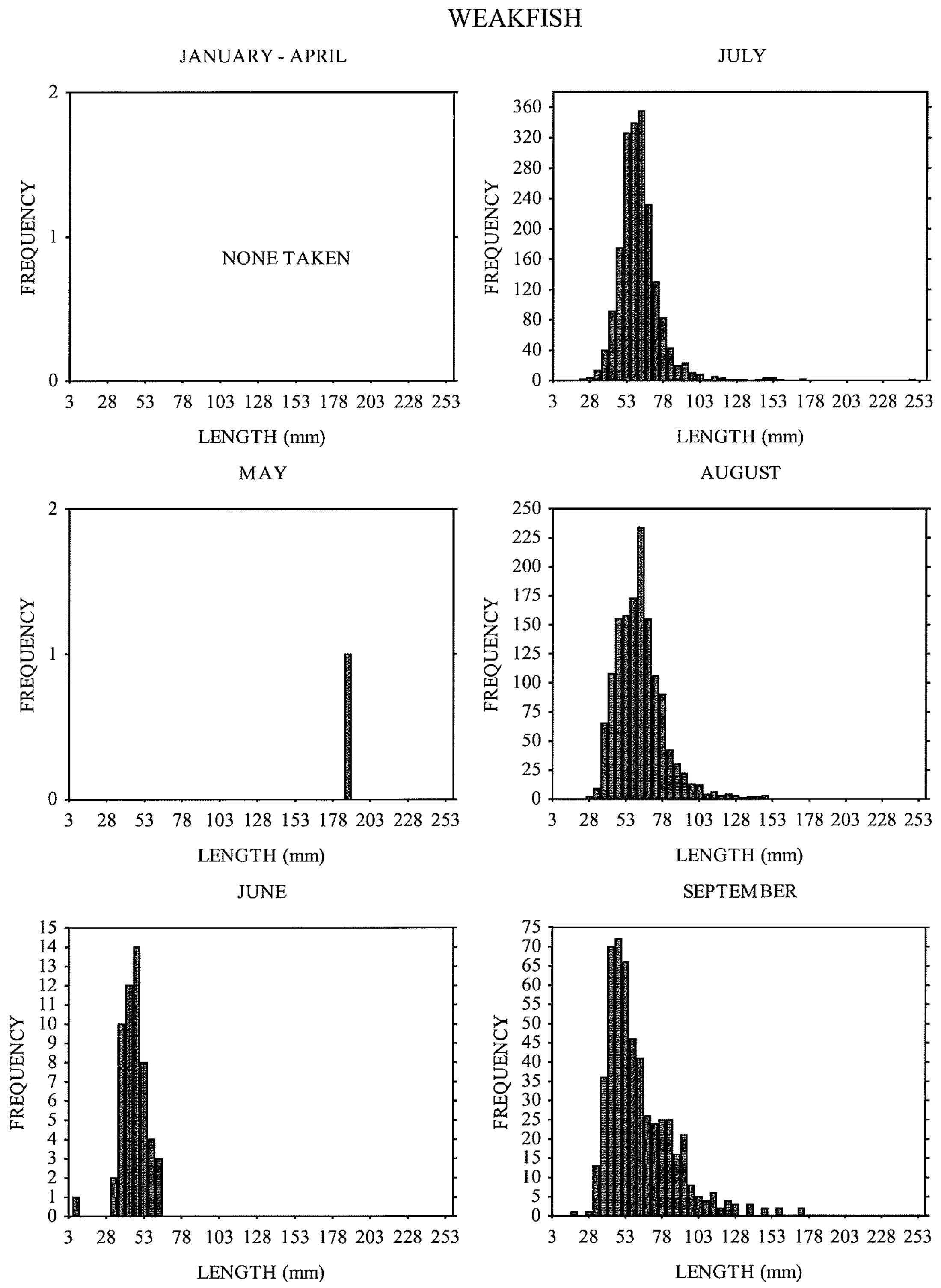


Figure 2-23. Length frequency of weakfish taken in impingement sampling at the Salem circulating water intake structure during 2008.

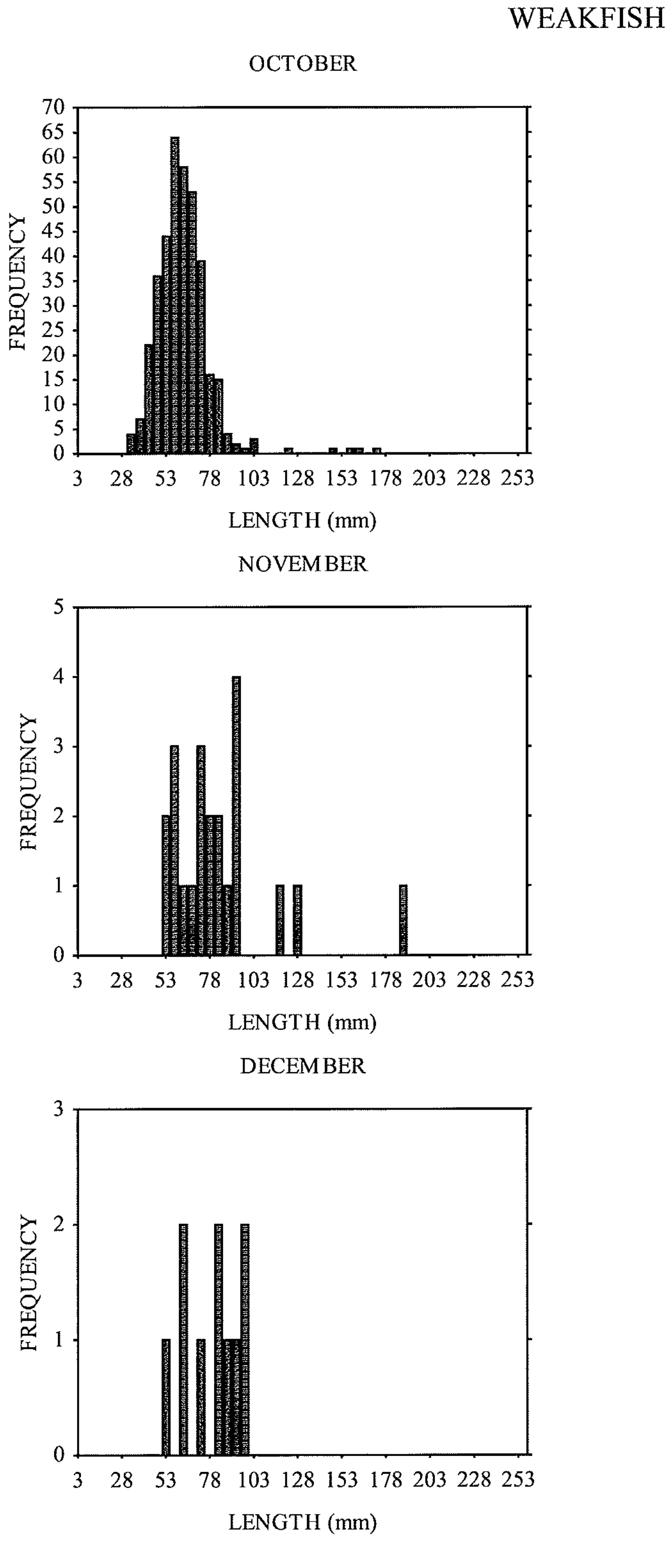


Figure 2-23. Continued.

SPOT

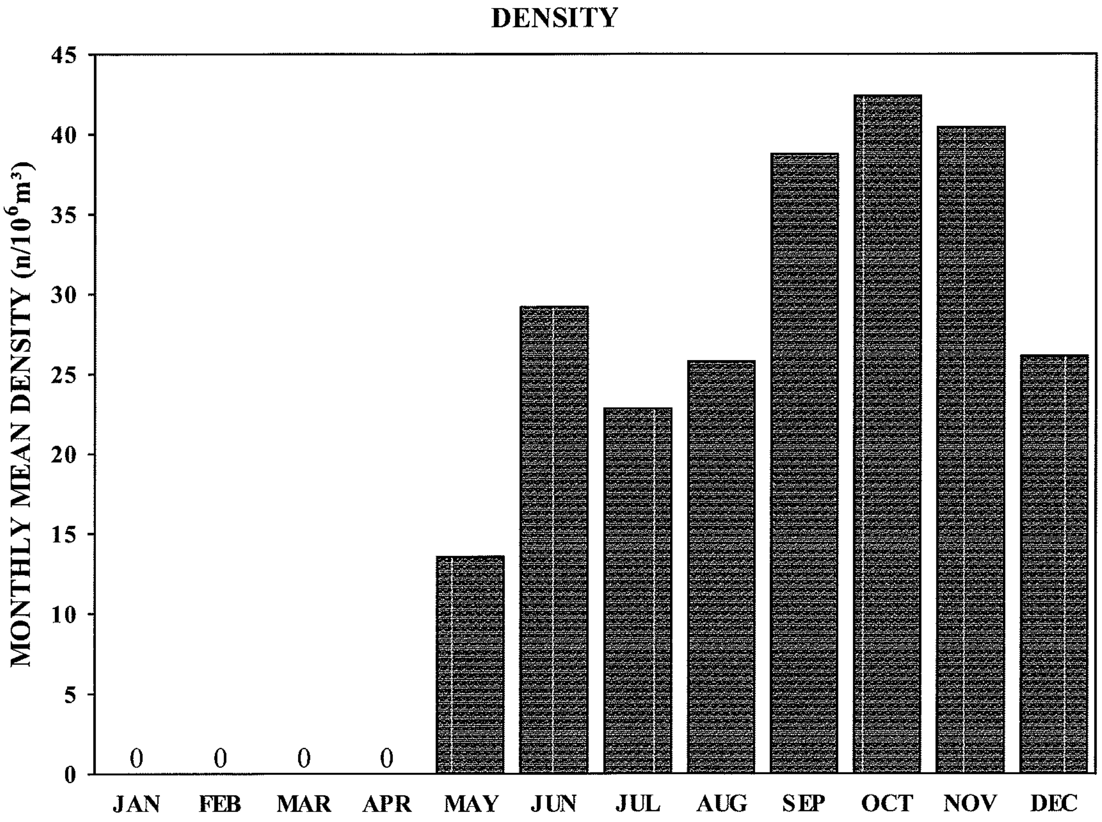


Figure 2-24. Monthly mean density (n/10^6 meters^3) of spot taken in impingement sampling at the Salem circulating water intake structure during 2008.

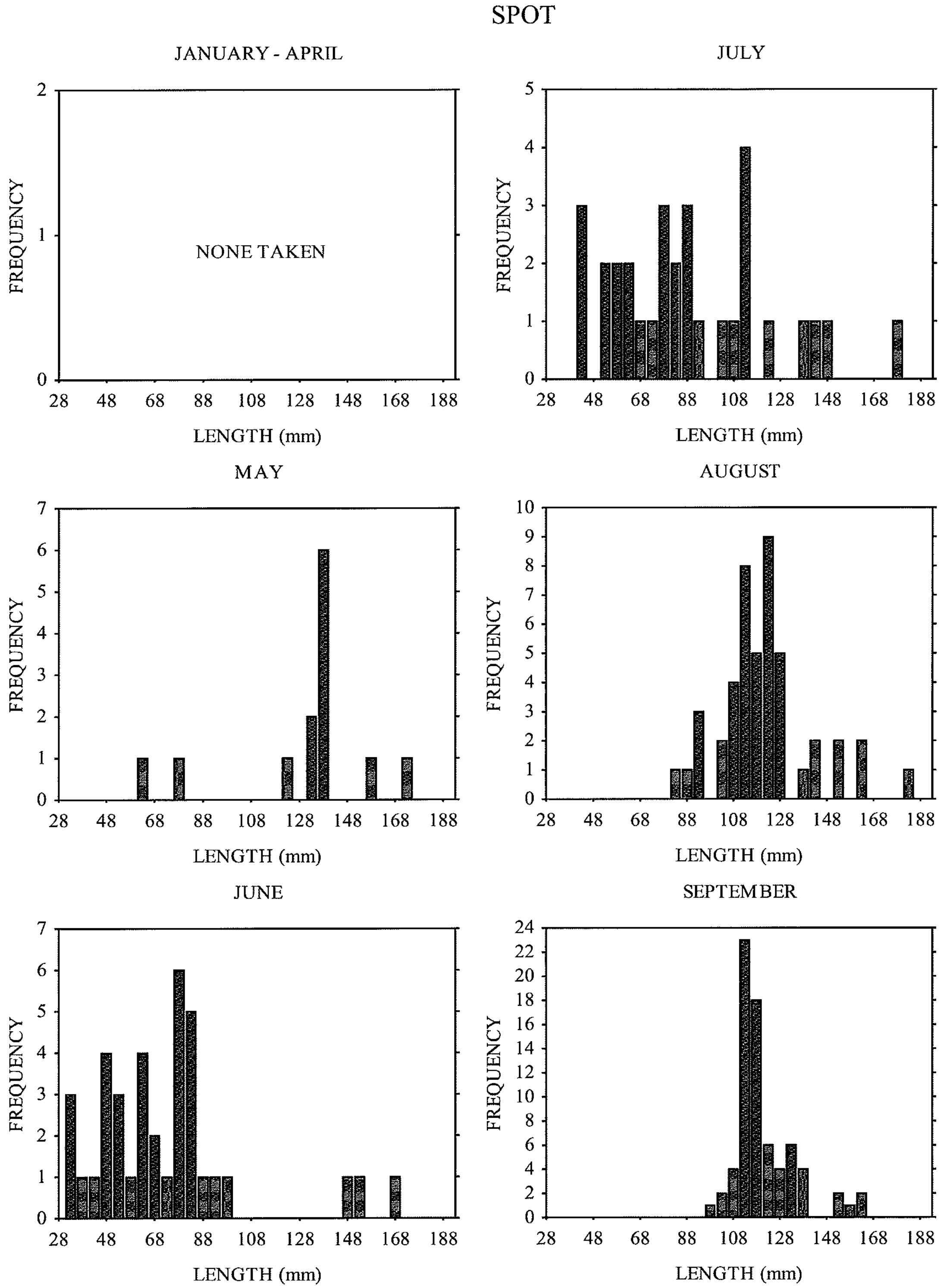


Figure 2-25. Length frequency of spot taken in impingement sampling at the Salem circulating water intake structure during 2008.

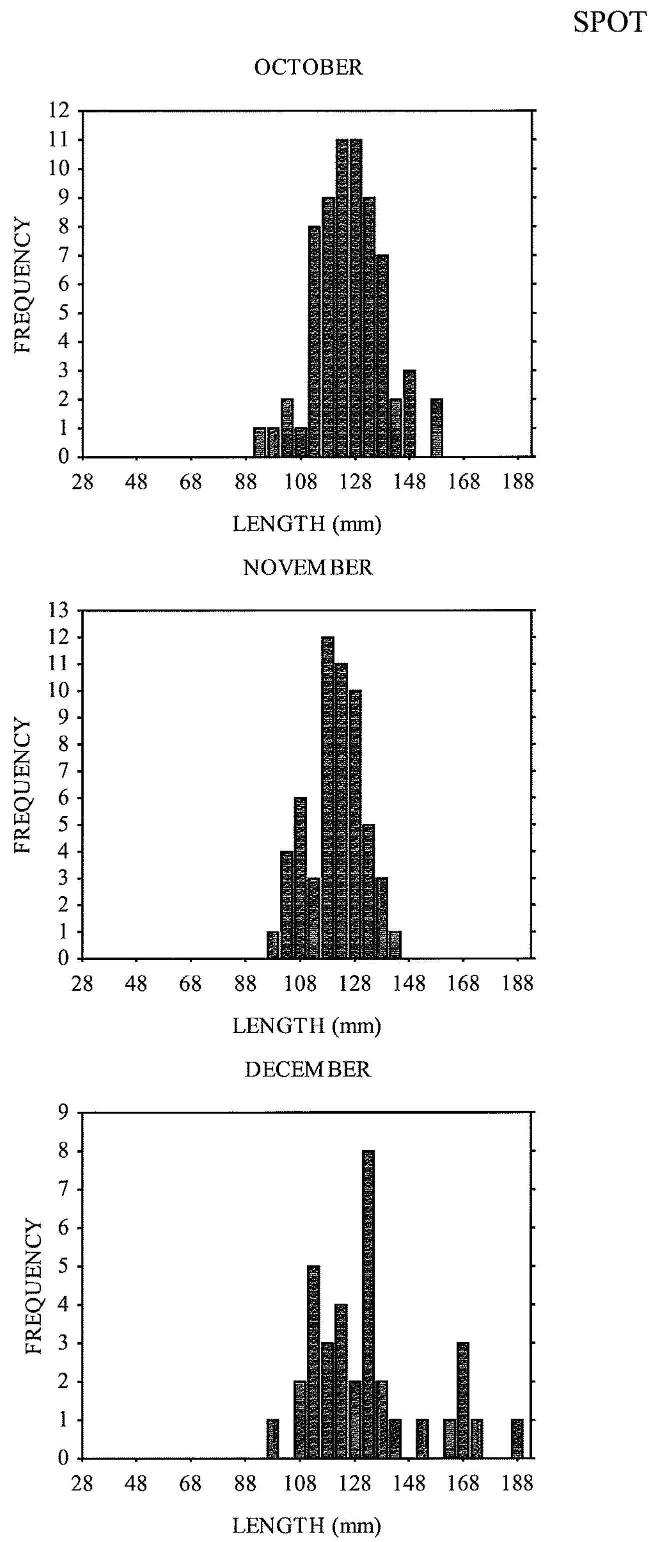


Figure 2-25. Continued.

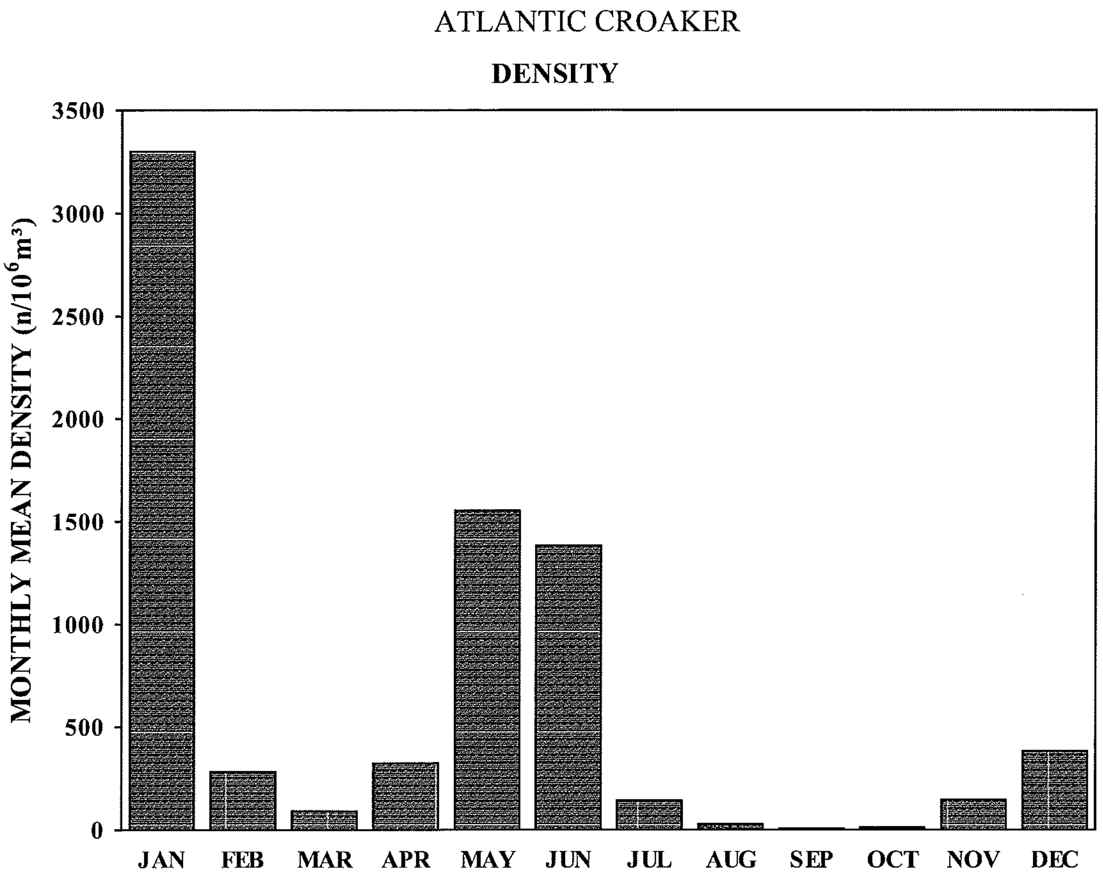


Figure 2-26. Monthly mean density ($n/10^6$ meters^3) of Atlantic croaker taken in impingement sampling at the Salem circulating water intake structure during 2008.

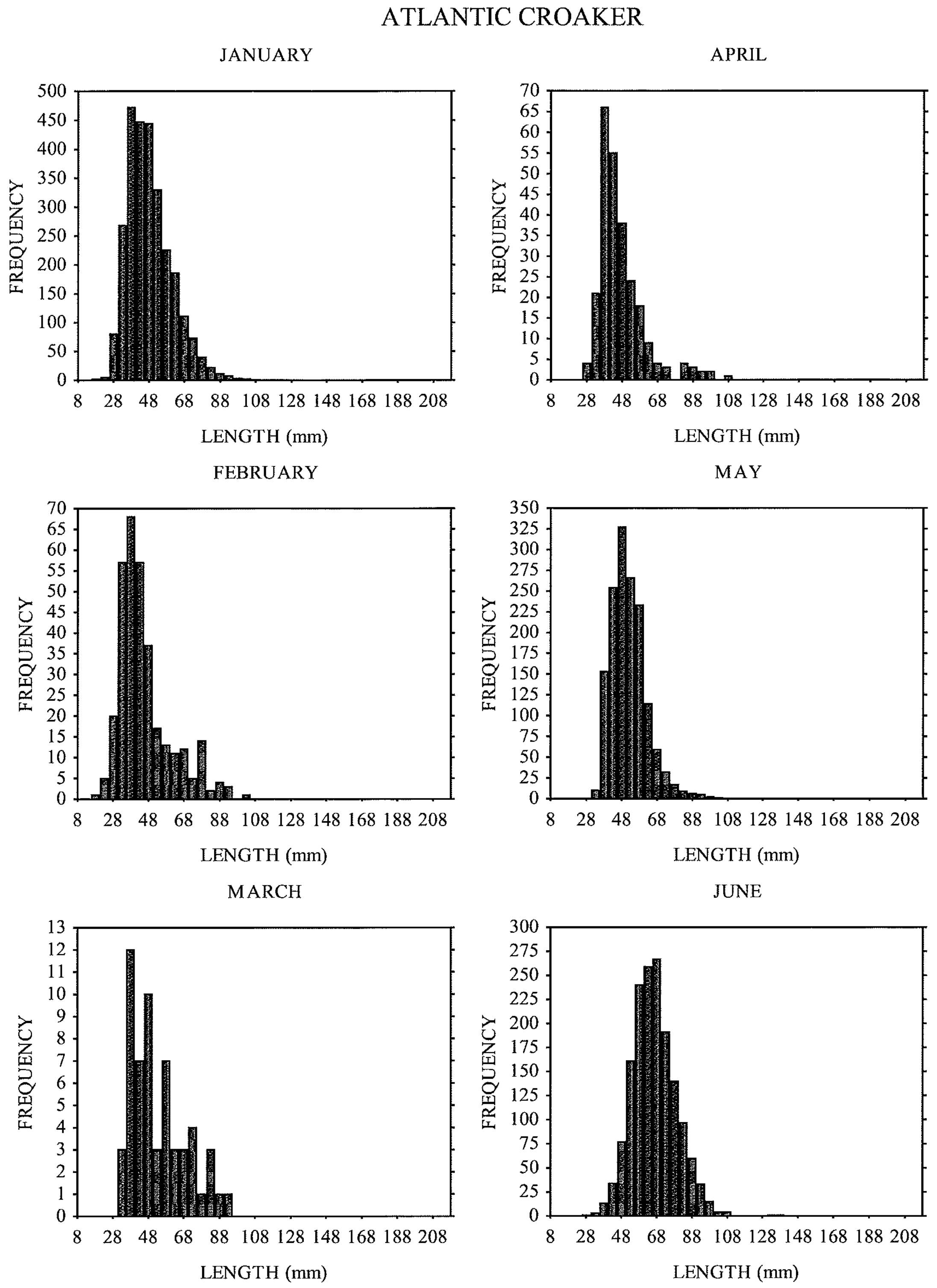


Figure 2-27. Length frequency of Atlantic croaker taken in impingement sampling at the Salem circulating water intake structure during 2008.

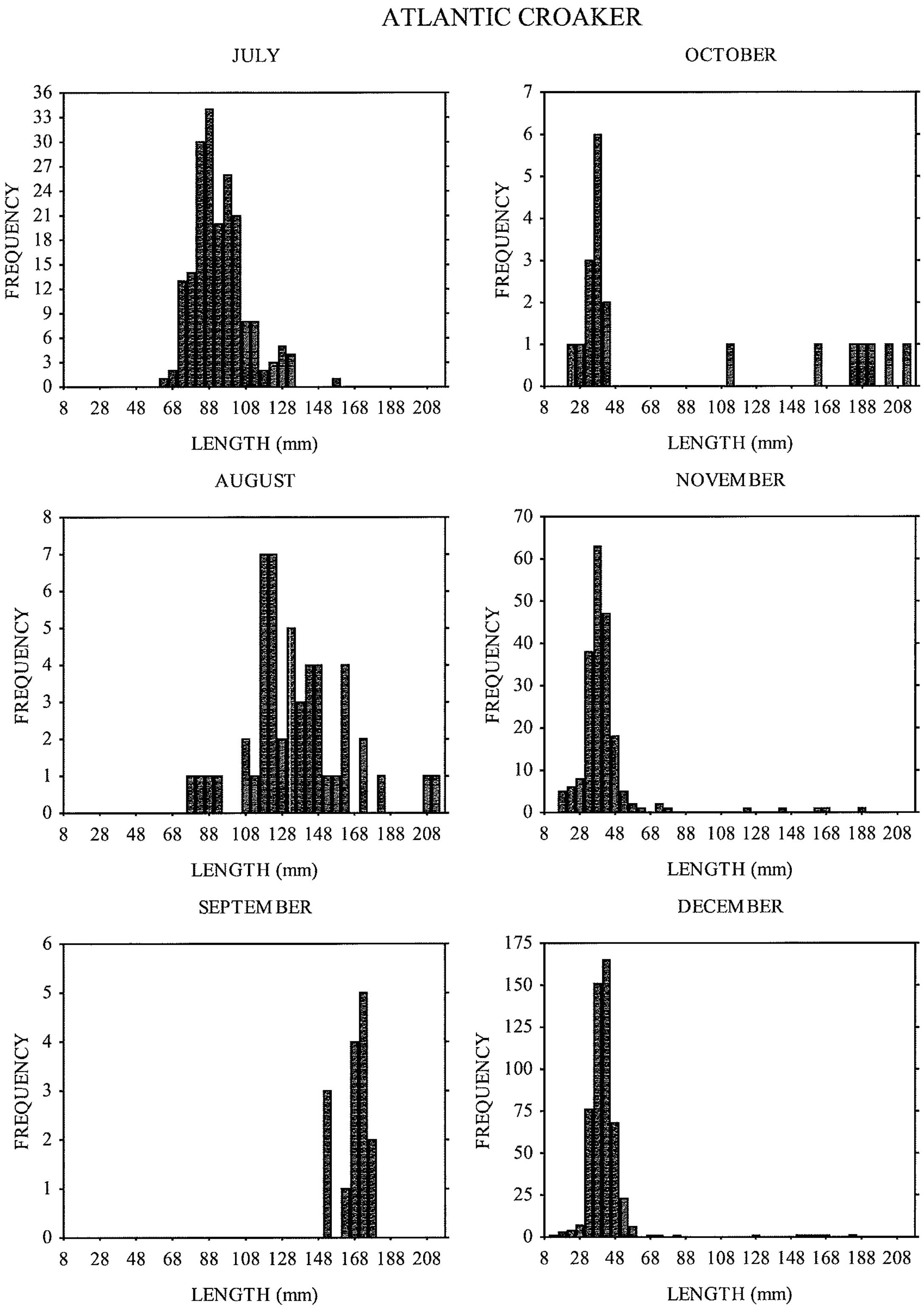


Figure 2-27. Continued.

CHAPTER 3: ENTRAINMENT ABUNDANCE

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ENTRAINMENT ABUNDANCE

INTRODUCTION

Entrainment monitoring is conducted annually as stipulated by the New Jersey Department of Environmental Protection in the New Jersey Pollutant Discharge Elimination System permit for Salem Generating Station, and will continue through the term of the permit. The specified monitoring was performed as described in the Procedures Manual for Biological Monitoring Program for the Delaware Estuary (PSEG 2002). The objective of this monitoring program is to produce accurate density estimates of fish entrained through the Circulating Water Intake System (CWIS) at Salem Units 1 and 2.

This chapter presents the overall results of sampling and specific findings for the year 2008 regarding the occurrence of the Salem finfish target species: blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), Atlantic menhaden (*Brevoortia tyrannus*), bay anchovy (*Anchoa mitchilli*), Atlantic silverside (*Menidia menidia*), white perch (*Morone americana*), striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These species were defined in the Salem 316(b) Demonstration (PSE&G 1999).

MATERIALS AND METHODS

In 2008, entrainment abundance sampling was divided into two periods of frequency and intensity. During the months of January through March and August through December, routine entrainment sampling was scheduled during three 24-hour events per week with seven collections taken at approximately equal intervals during each event. During the months of April through July, intensive entrainment sampling occurred during four events scheduled each week with 14 samples scheduled at equal intervals during each event. Each event monitored a complete diel period encompassing two tidal cycles.

During each 24-hour sampling event, samples were collected at the midpoint of the water column in the intake bay of circulating water pump 12B or 22A, using the Paco (Model 52-6013-21-342000) fish pump and the entrainment abundance chamber (Figures 3-1, 3-2 and 3-3). The fish pump used for sampling was a 6-inch (15.2-cm), single-port impeller, centrifugal pump, and the abundance chamber consisted of a 260-gallon (1-m^3) cylindrical tank containing a 1.0-m diameter, 0.5-mm mesh, conical plankton net within which the sample was concentrated. The abundance chamber was filled with water during sampling, and cushioned the captured fish specimens against mechanical damage. The sample rate was approximately 1.0 m^3/minute. Sample volume and flow rate were determined using a Sparling Envirotech flowmeter (Model 115). Flowmeter calibration was checked and maintained within factory specifications on a monthly basis throughout 2008. Samples were preserved immediately in a 10 percent formalin/rose-bengal solution. During each sample, the following parameters were recorded: water temperature, salinity, tidal elevation and stage, and the number of circulating water pumps and traveling screens in operation. Water temperature was measured with a field thermometer, and salinity was measured using a refractometer.

In the laboratory, all fish specimens were washed in freshwater, removed from the sample detritus, transferred to isopropanol, and identified to the lowest practicable taxonomic level, usually to species. Some specimens could not be identified to species because of the lack of identifying characteristics. Specimens that were in good condition but possessed no distinguishing characteristics were listed as ‘unidentified’ at the family level, while specimens in such poor physical condition that no genus or family level identification could be made were designated as 'unidentifiable fish'.

Each specimen's life stage was determined (i.e. egg, larva, juvenile, or adult) in accordance with the procedures manual (PSEG 2002), and the total number of each was recorded. For each species, the length of up to 50 specimens of each life stage, except eggs, was measured to the nearest 1 mm. Total length (TL) was used for all larvae and those juveniles and adults without forked tails. Fork length (FL) was used for those juveniles and adults with forked tails.

Densities are expressed as number per 100 cubic meters ($n/100m^3$). A volume-weighted mean density was calculated by dividing the total number of specimens in the samples by the total sample volume filtered during a given time period. Entrainment abundance and physical-chemical data were summarized by month and/or year. Sample collection and processing procedures are described in greater detail in the Procedures Manual for Biological Monitoring Program for the Delaware Estuary (PSEG 2002).

Only those fish designated as target species in the Salem 316(b) demonstration (PSE&G 1999) will be discussed in this section. Graphic presentations of abundance and length frequency data were prepared for those target species represented by at least ten total specimens of all life stages collected.

RESULTS AND DISCUSSION

Totals of 19,839 fish eggs, 33,029 larvae, 18,206 juveniles, and 162 adults representing at least 26 species were collected in 1,633 entrainment abundance samples, with 83,299 m^3 of sample water filtered during 2008 (Table 3-1). Specimens of at least eleven of the twelve target species were collected. They were: blueback herring, alewife, Atlantic menhaden, bay anchovy, Atlantic silverside, white perch, striped bass, bluefish, weakfish, spot, and Atlantic croaker. Monthly mean temperatures ranged from 4.8 to 26.7°C, and salinities from 2.0 to 11.0 ppt (Figure 3-4). A summary of collection data is presented below by phylogenic order for each target taxon.

Blueback herring - A total of one juvenile (≥20 mm) blueback herring was taken in entrainment abundance samples at Salem during November of 2008 (Table 3-1). The monthly mean density ($n/100m^3$) was 0.02, when the mean water temperature and salinity were 10.9°C and 10.0 ppt, respectively (Figure 3-4). The length of the one individual collected was 56 mm.

Alewife - A total of one larval (<20 mm) alewife, was taken in entrainment abundance samples at Salem during May of 2008 (Table 3-1). The monthly mean density ($n/100m^3$) was <0.01, and the mean water temperature and salinity were 16.6°C and 5.7 ppt, respectively (Figure 3-4). The length of the one individual collected was 8 mm.

***Alosa* spp.** - A total of one larval (<20mm) *Alosa* spp. (blueback herring or alewife), was taken in entrainment abundance samples at Salem during May of 2008 (Table 3-1). The monthly mean density (n/100m^3) was <0.01, when the mean water temperature and salinity were 16.6°C and 5.7 ppt, respectively (Figure 3-4). The length of the one individual collected was 10 mm.

Atlantic menhaden - A total of 13,500 Atlantic menhaden, including 4,213 larvae and 9,287 juveniles, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these life stages were collected during all months except August and September (Figure 3-5). The abundance of Atlantic menhaden was highest in April, with 6,604 juveniles and 3,117 larvae collected.

Atlantic menhaden larvae (<30 mm) were taken during all months except June, August, and September, when water temperatures and salinities ranged from 4.8 to 26.7°C and 2.0 to 11.0 ppt, respectively (Figures 3-4 and 3-5). The annual mean density (n/100m^3) was 5.06 (Table 3-1). The monthly mean density was highest in March at 26.26, similarly high in April at 26.08, and ≤2.57 during the other months of occurrence (Figure 3-5).

Atlantic menhaden juveniles (≥30 mm) were collected during January through June, and December, when mean water temperatures and salinities ranged from 4.8 to 23.6°C and 2.0 to 5.8 ppt, respectively (Figures 3-4 and 3-5). The annual mean density (n/100m^3) was 11.15 (Table 3-1). The monthly mean density was highest in April at 55.26, intermediately high in March at 39.98, and was ≤8.65 during the other months of occurrence (Figure 3-5).

Based on the specimens measured, the length of Atlantic menhaden collected during the 2008 entrainment abundance studies ranged from 18 to 71 mm (Figure 3-6). During March through May, individuals from 28 to 33 mm comprised 80% of the total specimens measured. During this period, the modal length was 30 mm. During the others months of occurrence, modes of distribution ranged from 20 to 33 mm.

Bay anchovy - A total of 34,878 bay anchovy, including 19,810 eggs, 13,194 larvae, 1,788 juveniles, and 86 adults, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these life stages were collected in all months except March (Figure 3-7). Bay anchovy was most abundant in June, with eggs being the predominant lifestage.

Bay anchovy eggs were collected during the months of May through August when mean water temperatures ranged from 16.6 to 26.7°C, and salinity ranged from 5.7 to 8.9 ppt, respectively (Figures 3-4 and 3-7). The annual mean density (n/100m^3) was 23.78 (Table 3-1). The monthly mean density of eggs was highest in June at 135.89. It was 24.26 in July, and was ≤0.31 in other months in which they were taken (Figure 3-7).

Bay anchovy larvae (<20 mm) were collected during the months of May through October when mean water temperatures and salinities ranged from 16.6 to 26.7°C, and 5.7 to 11.0 ppt, respectively (Figures 3-4 and 3-7). The annual mean density (n/100m^3) was 15.84 (Table 3-1).

Monthly mean density was highest in June at 59.01. It was 43.28 in July and ≤2.50 during the other months of occurrence (Figure 3-7).

Bay anchovy juveniles (≥20 mm) were collected during all months except March and May, when mean water temperatures and salinities ranged from 4.8 to 26.7°C and from 3.1 to 11.0 ppt, respectively (Figures 3-4 and 3-7). Annual mean density (n/100m^3) was 2.15 (Table 3-1). The monthly mean density of juveniles was highest in July at 7.05 and intermediately high in June, August, and September at 2.66, 3.41, and 2.48, respectively. Densities were≤ 1.30 during the other months of occurrence (Figure 3-7).

Bay anchovy adults were taken during the months of April through July with an annual mean density of 0.10 (Table 3-1 and Figure 3-7). Monthly mean densities ranged from 0.01 to 0.48 in all months of occurrence (Figure 3-7). Monthly mean water temperatures and salinities ranged from 12.4 to 26.7°C and from 3.1 to 5.9 ppt, respectively (Figure 3-4).

Based on the subsample of the specimens measured, the bay anchovy collected during the 2008 entrainment abundance studies ranged in length from 3 to 69 mm, and 91% were 4 to 25 mm (Figure 3-8). Modal lengths in June and July, the months of relatively high bay anchovy abundance, were 6 and 10 mm, respectively.

***Menidia* spp.** – A total of 85 Atlantic silversides, including 4 eggs, 48 larvae, 10 juveniles and 23 adults, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Additionally, 11 rough silverside (*Membras martinica*) eggs; and 602 *Menidia* spp. (*Menidia/Membras* spp.), including 593 larvae and 9 juveniles; were identified. These silversides were combined in the following discussion and graphic presentations. This combination was prompted by the distributional overlap, the subtleties of diagnostic and taxonomic features, and the compromised condition of collected specimens. Hence, the summary presented below includes the aggregate total of 698 *Menidia* spp., including 15 eggs, 641 larvae, 19 juveniles, and 23 adults. Specimens representing at least one of the above listed life stages were collected during January, February, May through August, November, and December (Figure 3-9). *Menidia* spp. was most abundant in June, with larvae being the predominant lifestage.

Menidia spp. eggs were collected during May and June when mean water temperatures and salinities ranged from 16.6 to 23.6°C and 5.7 to 5.8 ppt, respectively (Figures 3-4 and 3-9). The annual mean density (n/100m^3) was 0.01 (Table 3-1). The monthly mean density of eggs was highest in June at 0.09 (Figure 3-9).

Menidia spp. larvae (<15 mm) were collected during May through August when mean water temperatures and salinities ranged from 16.6 to 26.7°C and 5.7 to 8.9 ppt, respectively (Figures 3-4 and 3-9). The annual mean density (n/100m^3) was 0.77 (Table 3-1). The monthly mean density of larvae was highest in June at 3.78 and was≤ 1.04 in the other months of occurrence (Figure 3-9).

Menidia spp. juveniles (15 - 20 mm) were taken during June and July when the mean water temperatures and salinities ranged from 23.6 to 26.7°C and 5.8 to 5.9 ppt, respectively (Figures 3-4 and 3-9). The annual mean density (n/100m^3) was 0.02 (Table 3-1). The monthly mean density was highest in June at 0.14 (Figure 3-9).

Menidia spp. adults (>20 mm) were taken during the months of January, February, June, July, November, and December when the mean water temperatures and salinities ranged from 4.8 to 26.7°C and 3.1 to 10.0 ppt, respectively (Figures 3-4 and 3-9). The annual mean density (n/100m^3) was 0.03 (Table 3-1). The monthly mean density was highest in December at 0.16 (Figure 3-9).

Based on the specimens measured, the *Menidia* spp. collected during the 2008 entrainment abundance studies ranged in length from 3 to 73 mm; however 87 % of those measured were from 5 to 12mm (Figure 3-10). During the months of relatively high abundance, i.e., June and July, the modal lengths were 7 and 8 mm, respectively.

White perch - A total of 10 white perch, including 3 larvae and 7 juveniles, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these lifestages were collected during the months of February through June. White perch was most abundant in April, with juveniles being the predominant lifestage (Figure 3-11).

White perch larvae (<20 mm) were taken in May and June when the mean water temperatures and salinities ranged from 16.6 to 23.6°C and 5.7 to 5.8 ppt, respectively. (Figures 3-4 and 3-11). The annual mean density (n/100m^3) was <0.01 (Table 3-1). The monthly mean density of larvae was highest in June at 0.02 (Figure 3-11).

White perch juveniles (≥20 mm) were collected in February through April when mean water temperatures and salinities ranged from 4.8 to 12.4°C and 2.0 to 3.1 ppt, respectively (Figures 3-4 and 3-11). The annual mean density (n/100m^3) was 0.01 (Table 3-1). The monthly mean density of juveniles was highest in April at 0.04 (Figure 3-11).

The white perch collected during the 2008 entrainment abundance studies ranged in length from 3 to 92 mm (Figure 3-12).

Striped bass - A total of 1,433 striped bass, including 6 eggs, 1,317 larvae and 110 juveniles, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these life stages were collected during the months of April through July (Figure 3-13). Striped bass was most abundant in June, with larvae being the predominant lifestage.

Striped bass eggs were collected during April and May when mean water temperatures were 12.4 and 16.6°C and salinities were 3.1 and 5.7 ppt, respectively (Figures 3-4 and 3-13). The annual mean density (n/100m^3) was 0.01 (Table 3-1). The monthly mean densities of eggs in April and May were 0.01 and 0.04, respectively (Figure 3-13).

Striped bass larvae (<20 mm) were taken during May, June and July, when mean water temperature and salinity ranged from 16.6 to 26.7°C and 5.7 to 5.9 ppt, respectively (Figures 3-4 and 3-13). The annual mean density (n/100m^3) was 1.58 (Table 3-1). The monthly mean densities were 3.10, 7.62, and 0.08 in May, June and July, respectively (Figure 3-13).

Striped bass juveniles (≥20 mm) were collected during June and July when mean water temperature ranged from 23.6 to 26.7°C and salinity ranged from 5.8 to 5.9 ppt, respectively (Figures 3-4 and 3-13). The annual mean density (n/100m^3) was 0.13 (Table 3-1). The monthly mean densities in June and July were 0.72, and 0.17, respectively (Figure 3-13).

Based on the subsample of specimens measured, the striped bass collected during the 2008 entrainment abundance studies ranged in length from 5 to 33 mm. Individuals ranging from 5 to 21 mm comprised 96 % of the sample. In May and June, the modal lengths were 6 and 12 mm, respectively (Figure 3-14).

***Morone* spp.** - A total of 20 *Morone* spp. larvae (<20 mm) was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). They were collected during May when mean water temperature and salinity were 16.6ºC and 5.7 ppt, respectively (Figures 3-4 and 3-15). The annual mean density (n/100m^3) was 0.02 (Table 3-1). The monthly mean density in May was 0.16. (Figure 3-15).

Based on the subsample of specimens measured, the *Morone* spp. larvae collected during the 2008 entrainment abundance studies ranged in length from 5 to 7 mm (Figure 3-16). The modal length was 5 mm.

Bluefish - A total of one juvenile (≥14 mm) bluefish was taken in entrainment abundance samples at Salem during May of 2008 (Table 3-1). The monthly mean density (n/100m^3) was <0.01, and the mean water temperature and salinity were 16.6°C and 5.7 ppt, respectively (Figure 3-4). The length of the one individual collected was 56 mm.

Weakfish - A total of 430 weakfish, including 5 eggs, 163 larvae and 262 juveniles, was taken in entrainment abundance samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these life stages were collected during the months of May through October (Figure 3-17). Weakfish was most abundant in June, with juveniles being the predominant lifestage.

Weakfish eggs were collected in May and June when mean water temperature and salinity ranged from 16.6 to 23.6ºC and from 5.7 to 5.8 ppt, respectively (Figures 3-4 and 3-17). The annual mean density (n/100m^3) was 0.01 (Table 3-1). The monthly mean densities in May and June were 0.01 and 0.03, respectively (Figure 3-17).

Weakfish larvae (<10.5 mm) were taken during June through September, when water temperature and salinity ranged from 22.9 to 26.7°C and 5.8 to 9.7 ppt, respectively (Figures 3-4 and 3-17). The annual mean density (n/100m^3) was 0.20 (Table 3-1). The monthly mean densities of larvae were highest in July at 0.74, intermediately high in June at 0.43, and ≤0.23 during the other months of occurrence (Figure 3-17).

Weakfish juveniles (≥10.5 mm) were collected during the months of June through October, when mean water temperature and salinity ranged from 19.3 to 26.7°C and 5.8 to 11.0 ppt, respectively (Figures 3-4 and 3-17). The annual mean density (n/100m^3) was 0.31 (Table 3-1). The highest monthly mean density of 1.10 occurred in June, followed by 0.66 in July, and ≤0.39 during the other months of occurrence (Figure 3-17).

Based on the specimens measured, the weakfish collected during the 2008 entrainment abundance studies ranged in length from 3 to 74 mm (Figure 3-18). During June and July, individuals from 5 to 15 mm comprised over half (54%) of the total specimens measured. The modal lengths for June and July were 8 and 9mm, respectively.

Spot – A total of 114 spot, including one larva and 113 juveniles was collected in entrainment abundance monitoring samples at Salem during 2008 (Table 3-1). Specimens representing at least one of these lifestages were collected during the months of April through June (Figure 3-19). Spot was most abundant in May with juveniles being the predominant lifestage.

A spot larva (<11mm) was collected during June when mean water temperature and salinity were 23.6°C and 5.8 ppt (Figure 3-4 and 3-19). The annual mean density (n/100m^3) was <0.01 (Table 3-1). The monthly mean density was 0.01 in June (Figure 3-19).

Spot juveniles (≥11 mm) were collected during April through June with mean water temperatures and salinities ranging from 12.4 to 23.6°C and 3.1 to 5.8 ppt, respectively (Figures 3-4 and 3-19). The annual mean density (n/100m^3) was 0.14 (Table 3-1). The monthly mean density was highest in May at 0.51, and densities were ≤0.28 during the other months of occurrence (Figure 3-19).

Based on the specimens measured, the spot collected during the 2008 entrainment abundance studies ranged in length from 9 to 35 mm, and 52% of those individuals measured were 20 to 25 mm (Figure 3-20). In May, the month of highest spot abundance, the modal length was 24 mm.

Atlantic croaker - A total of 6,444 Atlantic croaker, including 33 larvae and 6,411 juveniles, was collected in entrainment abundance monitoring samples at Salem during 2008 (Table 3-1). Specimens were collected in all months, except July and August (Figure 3-21). Atlantic croaker was most abundant in October with juveniles being the predominant life stage.

Atlantic croaker larvae (<11 mm) were collected during the months of September through November with mean water temperature and salinity ranging from 10.9 to 22.9°C and 9.7 to 11.0 ppt, respectively (Figures 3-4 and 3-21). The annual mean density (n/100m^3) was 0.04 (Table 3-1). The monthly mean density was highest in October at 1.05. Densities were ≤0.04 during the other months of occurrence (Figure 3-21).

Atlantic croaker juveniles (≥11 mm) were taken during all months except July and August of 2008 with mean water temperature and salinity ranging from 4.8 to 23.6°C and from 2.0 to 11.0 ppt, respectively (Figures 3-4 and 3-21). The annual mean density (n/100m^3) was 7.70 (Table 3-1). Monthly mean density was highest in October at 75.77; and was secondarily high in November at 49.01. During the other months of occurrence, densities were ≤ 14.14 (Figure 3-21).

Based on the subsample of specimens measured, the Atlantic croaker collected in the 2008 entrainment abundance samples ranged in length from 6 to 51 mm, and 91% of those individuals measured were from 11 to 28 mm. In November, the month of highest Atlantic croaker abundance, the modal length was 18mm (Figure 3-22).

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Public Service Enterprise Group (PSEG). 2002. Procedures Manual for Biological Monitoring Program for the Delaware Estuary.

Table 3-1

Annual summary of finfish species, number collected, and mean density, taken in entrainment abundance collections at Salem Generating Station Circulating Water Intake Structure, during January through December, 2008

Number of samples = 1633

Total volume filtered (cubic meters) = 83,299

Life Stage	Common Name	Scientific Name	Total	(n/100m³)
Eggs	Unknown spp.	Unknown spp.	1	<0.01
	Bay Anchovy	*Anchoa mitchilli*	19810	23.78
	Rough Silverside	*Membras martinica*	11	0.01
	Atlantic Silverside	*Menidia menidia*	4	<0.01
	Striped Bass	*Morone saxatilis*	6	0.01
	Weakfish	*Cynoscion regalis*	5	0.01
	Naked Goby	*Gobiosoma bosc*	2	<0.01
Larvae	Alosa spp.	*Alosa* spp.	1	<0.01
	Menidia spp.	*Menidia* spp.	593	0.71
	Morone spp.	*Morone* spp.	20	0.02
	Unidentified Cyprinidae	*Cyprinidae*	1	<0.01
	Unidentified Fundulus spp.	*Fundulus* spp.	13	0.02
	Unknown spp.	Unknown spp.	15	0.02
	American Eel	*Anguilla rostrata*	84	0.10
	Conger Eel	*Conger oceanicus*	2	<0.01
	Alewife	*Alosa pseudoharengus*	1	<0.01
	Atlantic Menhaden	*Brevoortia tyrannus*	4213	5.06
	Bay Anchovy	*Anchoa mitchilli*	13194	15.84
	Atlantic Silverside	*Menidia menidia*	48	0.06
	Northern Pipefish	*Syngnathus fuscus*	1	<0.01
	White Perch	*Morone americana*	3	<0.01
	Striped Bass	*Morone saxatilis*	1317	1.58
	Weakfish	*Cynoscion regalis*	163	0.20
	Spot	*Leiostomus xanthurus*	1	<0.01
	Northern Kingfish	*Menticirrhus saxatilis*	1	<0.01
	Atlantic Croaker	*Micropogonias undulatus*	33	0.04
	Naked Goby	*Gobiosoma bosc*	13298	15.96
	Summer Flounder	*Paralichtys dentatus*	6	0.01
	Hogchoker	*Trinectes maculatus*	21	0.03
Juveniles	Menidia spp.	*Menidia* spp.	9	0.01
	Unknown spp.	Unknown spp.	3	<0.01
	American Eel	*Anguilla rostrata*	8	0.01
	Conger Eel	*Conger oceanicus*	2	<0.01
	Blueback Herring	*Alosa aestivalis*	1	<0.01

Table 3-1				
Lifestage	Common name	Scientific name	Total	Density (n/100m³)
	Atlantic Menhaden	*Brevoortia tyrannus*	9287	11.15
	Atlantic Herring	*Clupea harengus harengus*	1	<0.01
	Bay Anchovy	*Anchoa mitchilli*	1788	2.15
	Oyster Toadfish	*Opsanus tau*	1	<0.01
	Atlantic Silverside	*Menidia menidia*	10	0.01
	Northern Pipefish	*Syngnathus fuscus*	69	0.08
	White Perch	*Morone americana*	7	0.01
	Striped Bass	*Morone saxatilis*	110	0.13
	Bluefish	*Pomatomus saltatrix*	1	<0.01
	Weakfish	*Cynoscion regalis*	262	0.31
	Spot	*Leiostomus xanthurus*	113	0.14
	Atlantic Croaker	*Micropogonias undulatus*	6411	7.70
	Black Drum	*Pogonias cromis*	1	<0.01
	Naked Goby	*Gobiosoma bosc*	80	0.10
	Summer Flounder	*Paralichtys dentatus*	40	0.05
	Hogchoker	*Trinectes maculatus*	2	<0.01
Adults	Bay Anchovy	*Anchoa mitchilli*	86	0.10
	Striped Cusk-eel	*Ophidion marginata*	1	<0.01
	Atlantic Silverside	*Menidia menidia*	23	0.03
	Northern Pipefish	*Syngnathus fuscus*	6	0.01
	Black Sea Bass	*Centropristis striata*	1	<0.01
	Naked Goby	*Gobiosoma bosc*	45	0.05
Summary	Eggs		19839	23.82
	Larvae		33029	39.65
	Juveniles		18206	21.86
	Adults		162	0.19

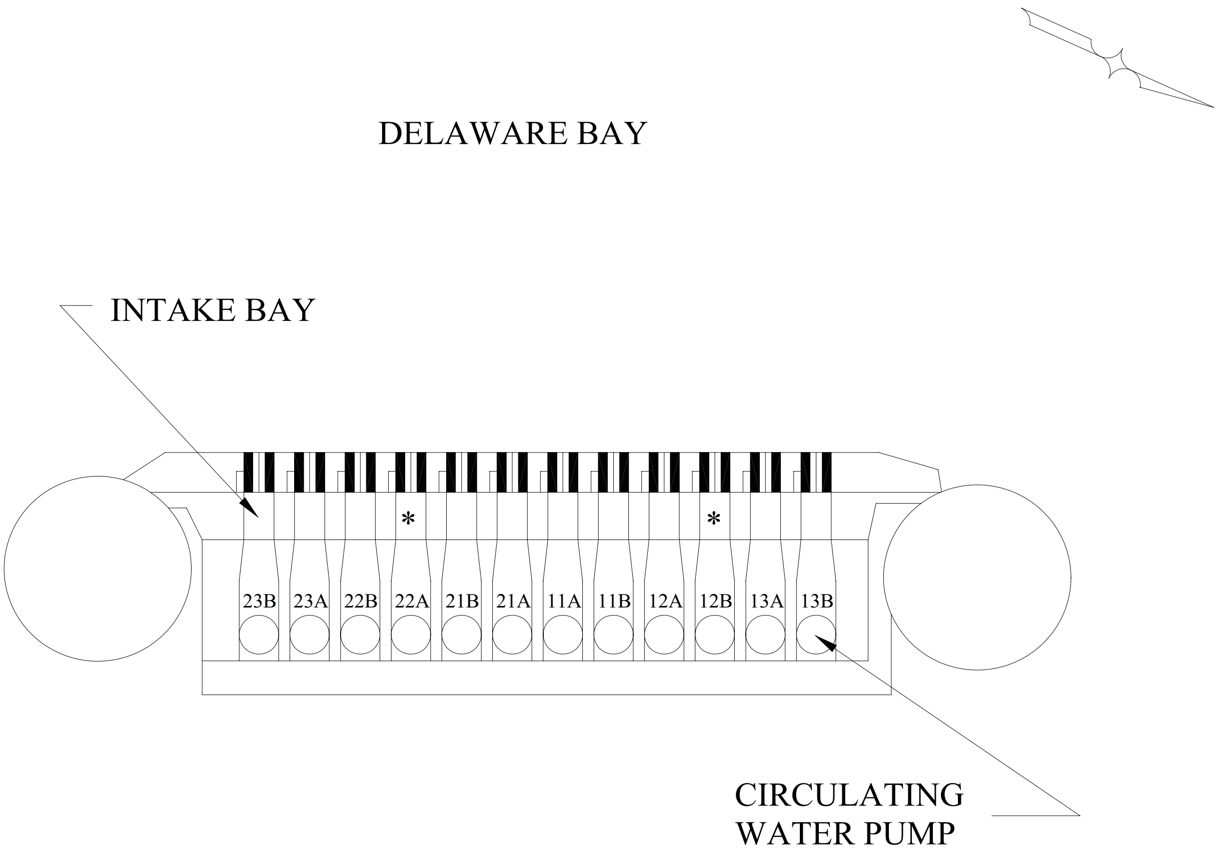


Figure 3-1. Schematic of Salem Generating Station circulating water intake structure with entrainment abundance sampling locations indicated by *.

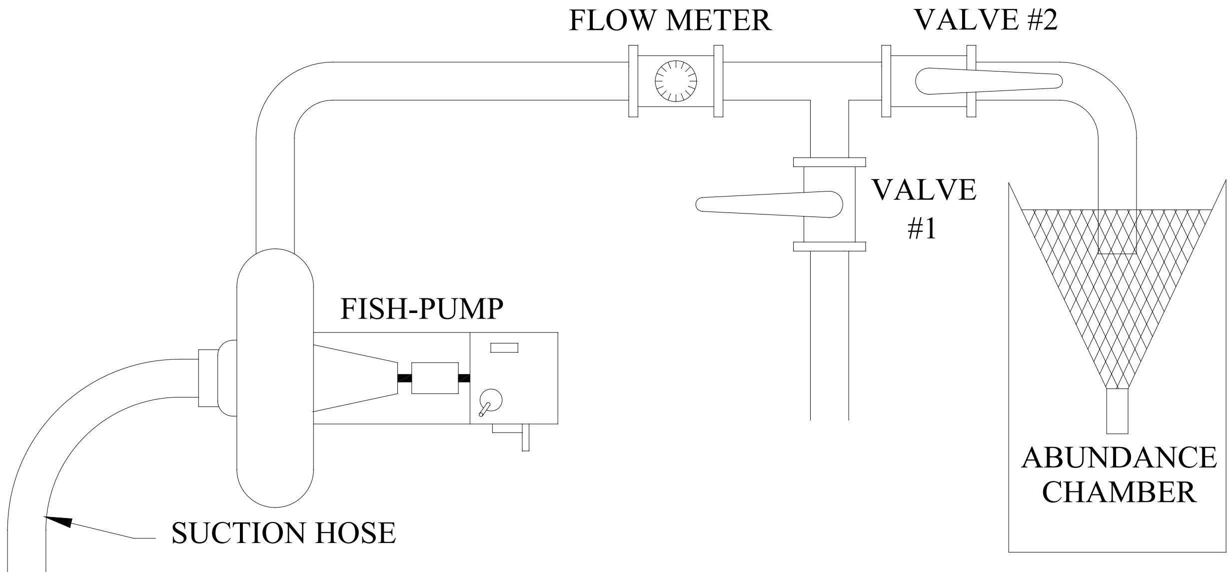


Figure 3-2. Plankton pump and abundance chamber used in entrainment sampling.

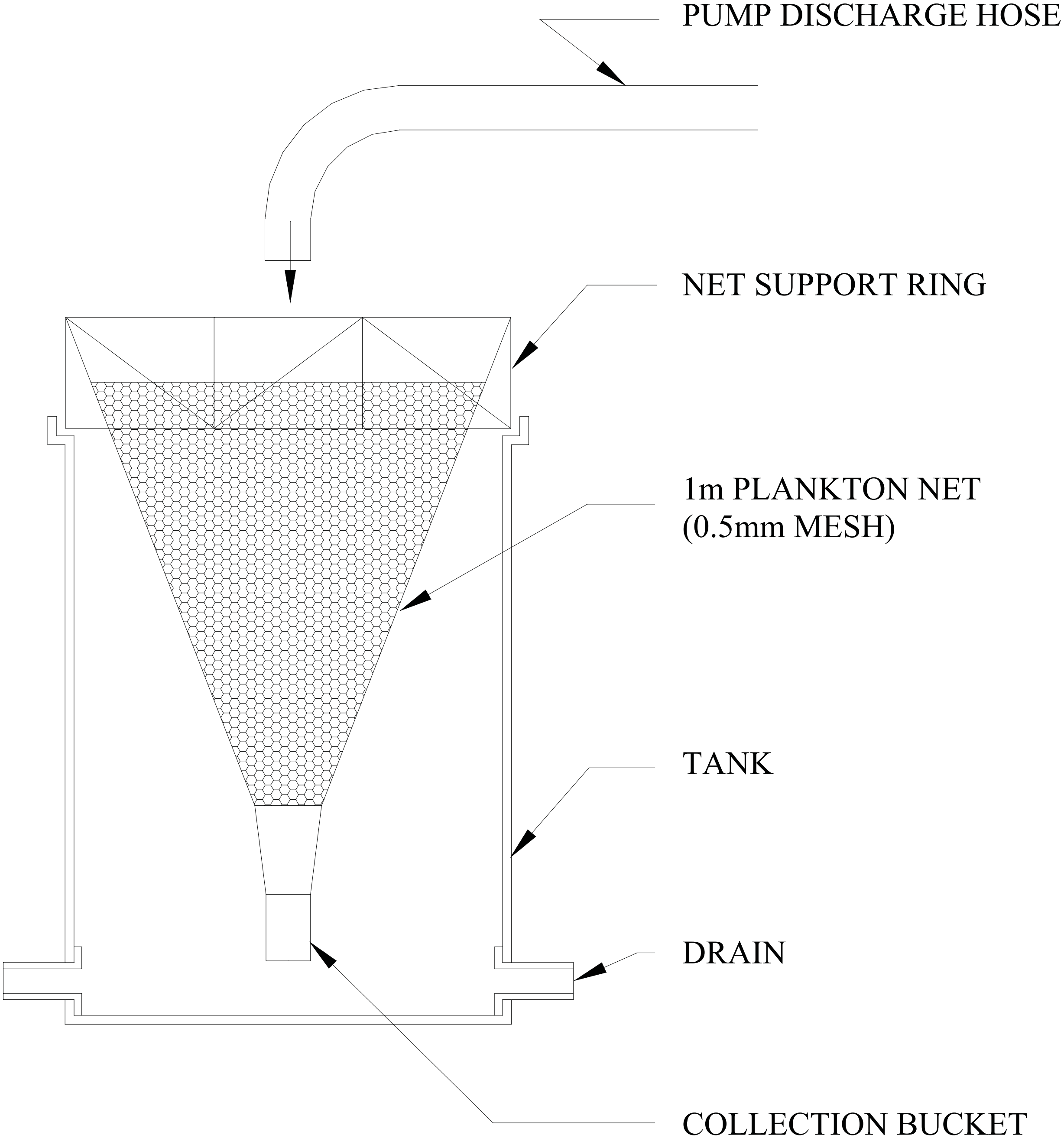


Figure 3-3. Cut away view showing entrainment collection net inside abundance chamber.

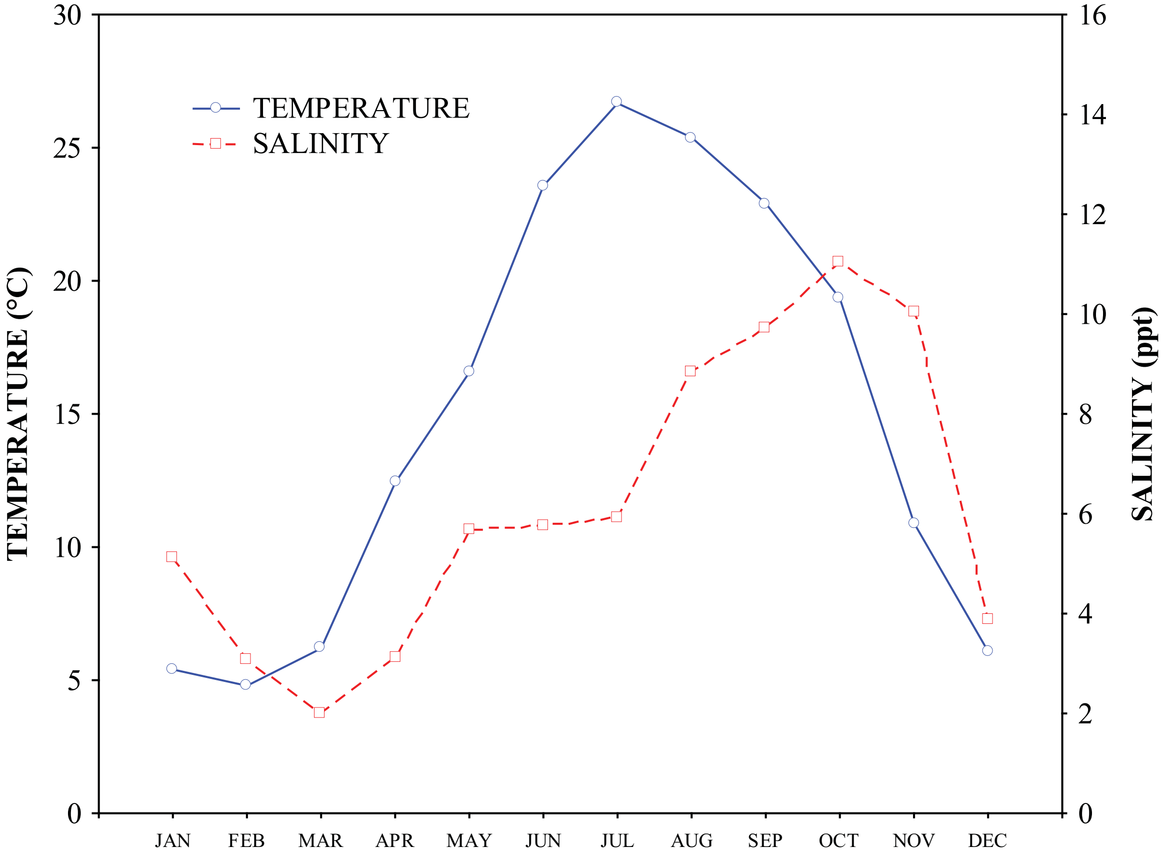


Figure 3-4. Salinity and temperature (mean) by month as observed during 2008 entrainment sampling.

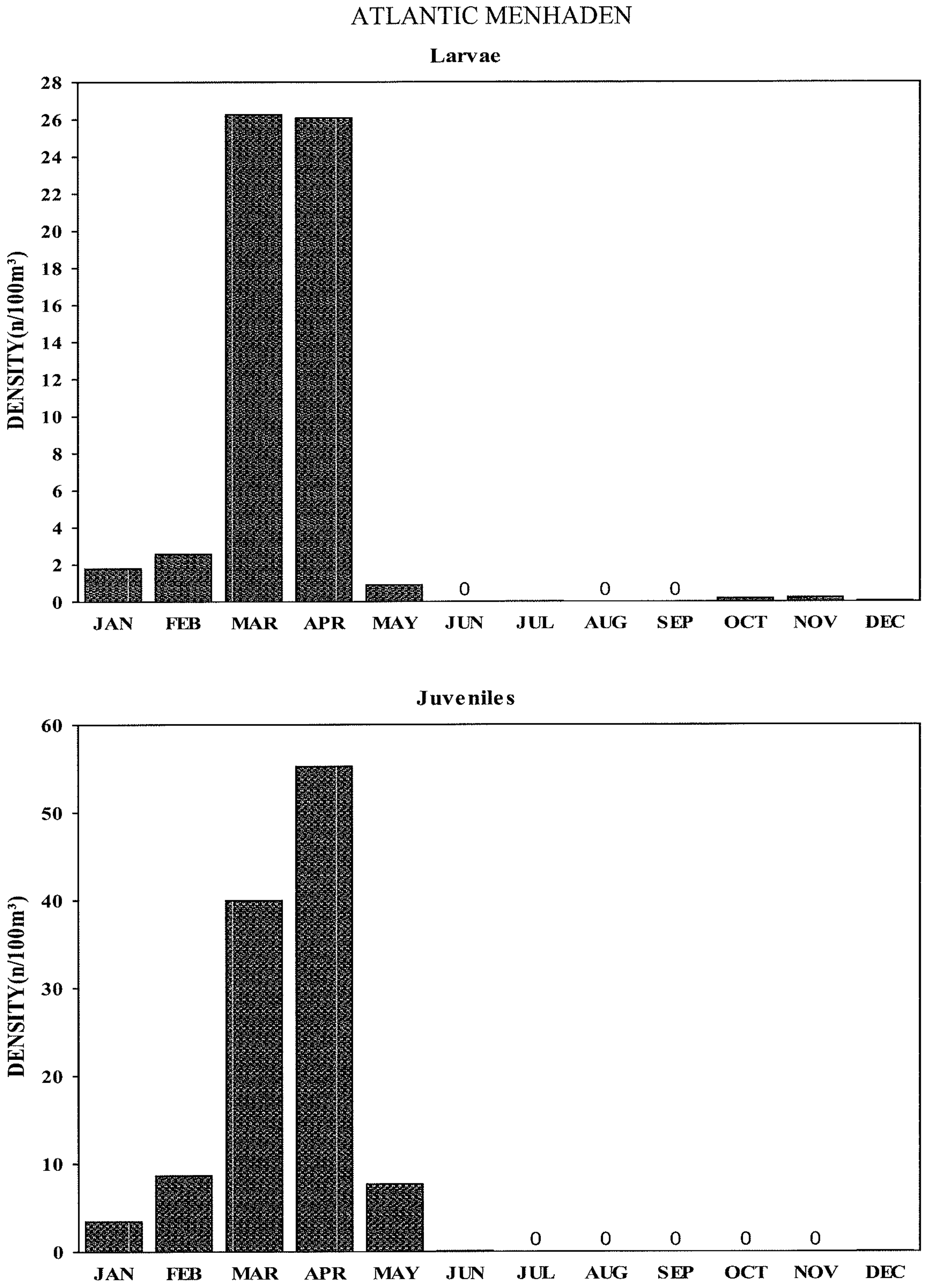


Figure 3-5. Monthly mean density (n/100m^3) of Atlantic menhaden eggs, larvae and juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.

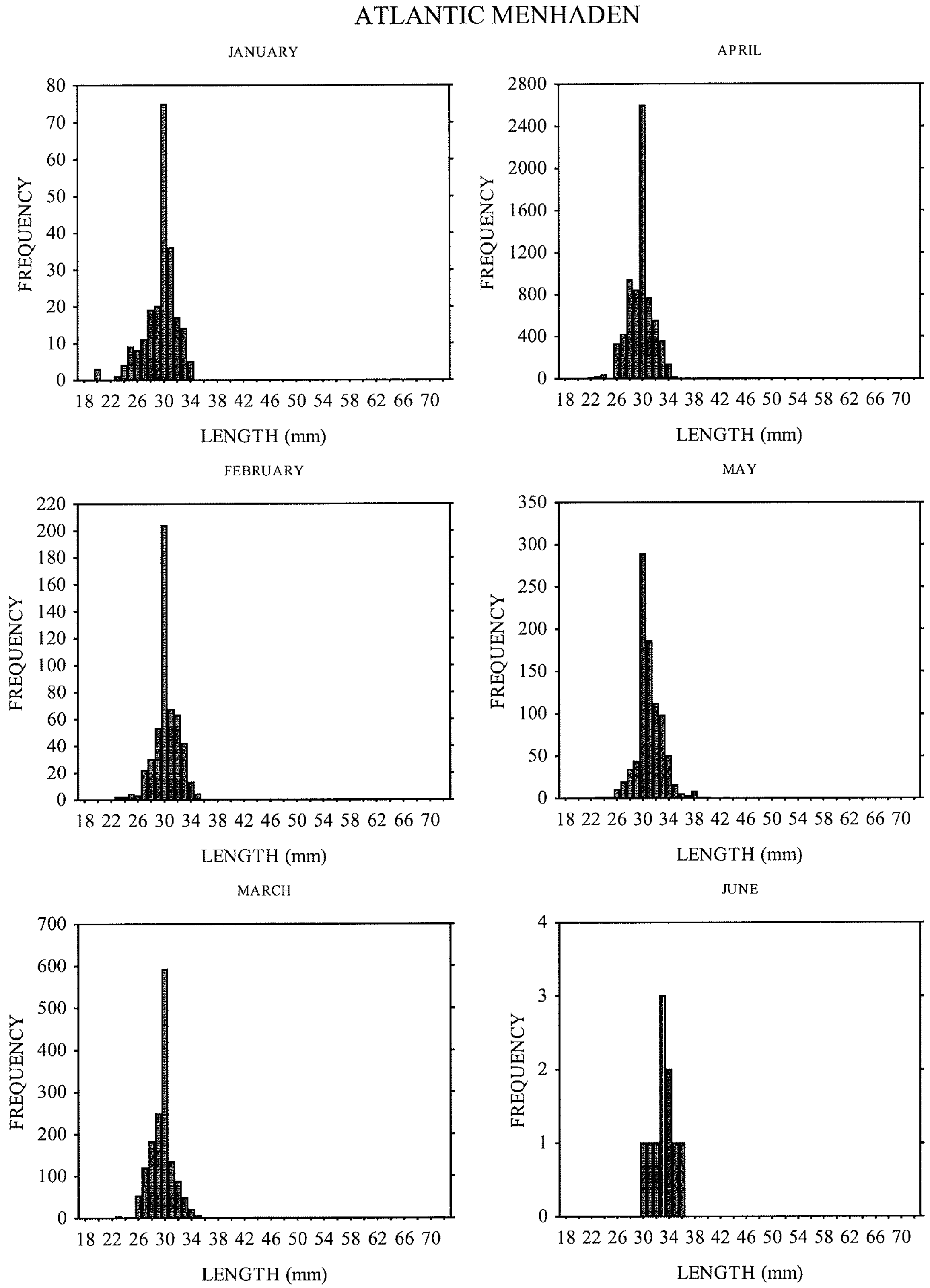


Figure 3-6. Length frequency of Atlantic menhaden taken in entrainment sampling at the Salem circulating water intake structure during 2008.

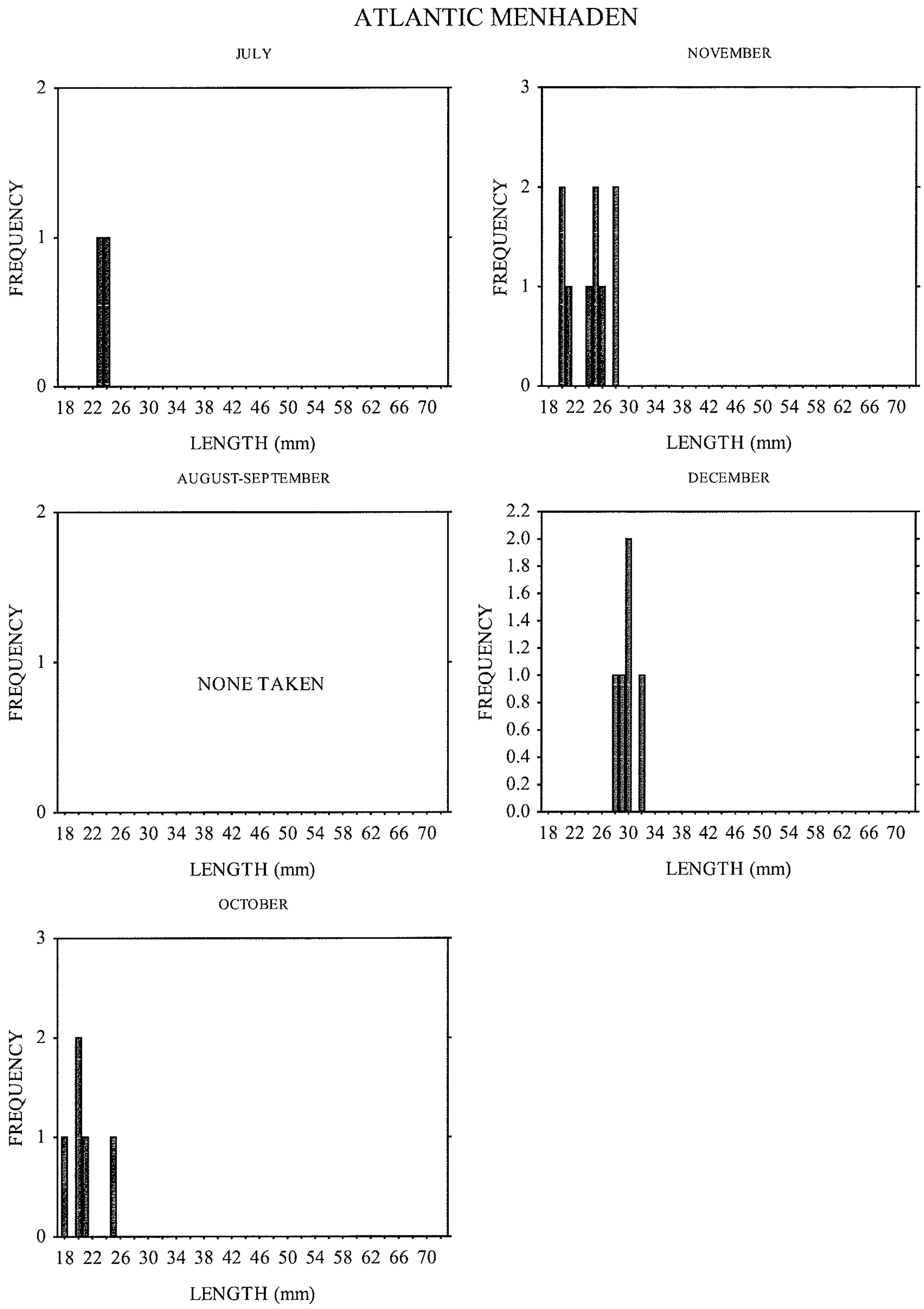
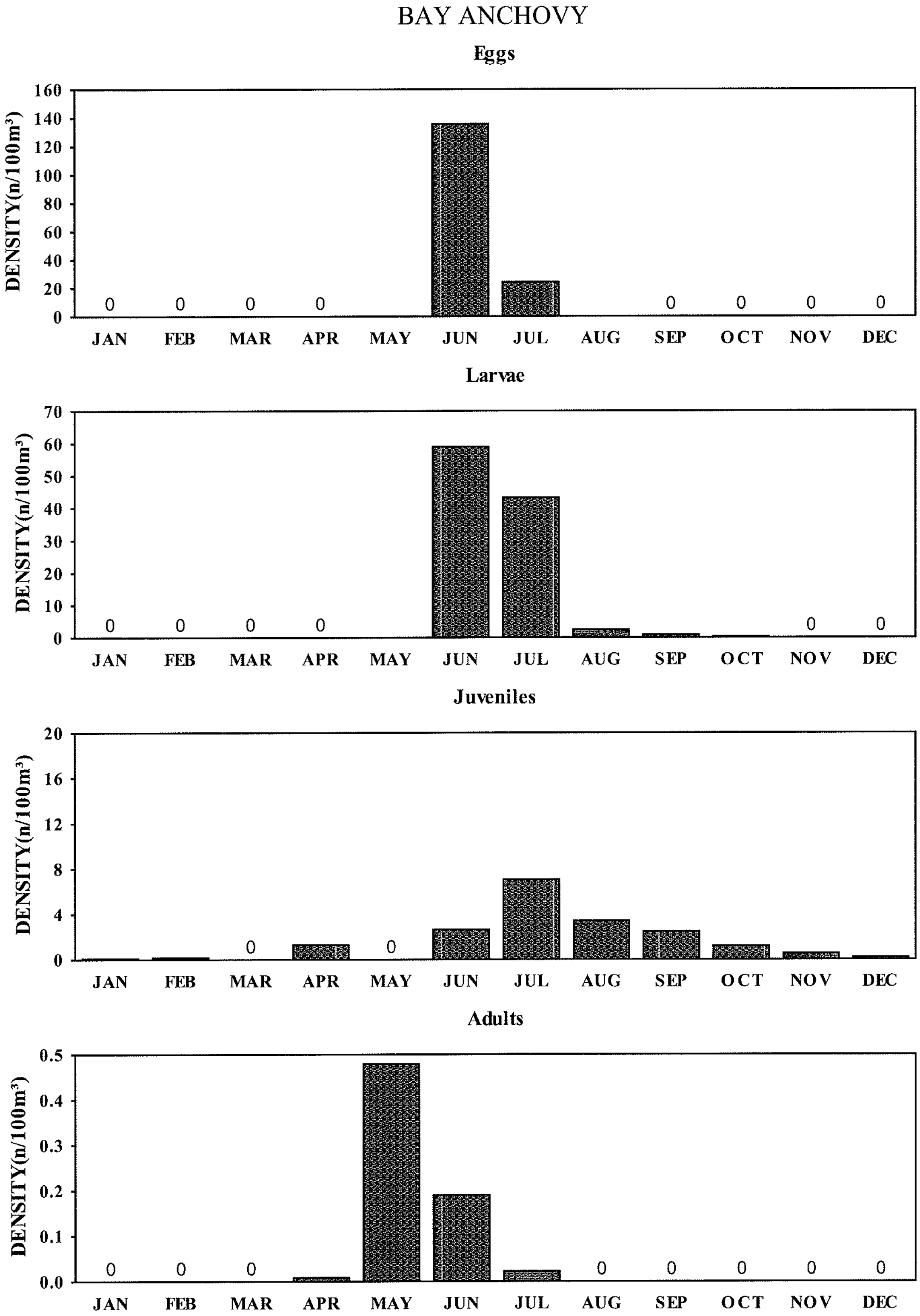


Figure 3-6. Continued.



BAY ANCHOVY

Eggs

Larvae

Juveniles

Adults

Figure 3-7. Monthly mean density (n/100m^3) of bay anchovy eggs, larvae, juveniles and adults taken in entrainment sampling at the Salem circulating water intake structure during 2008.

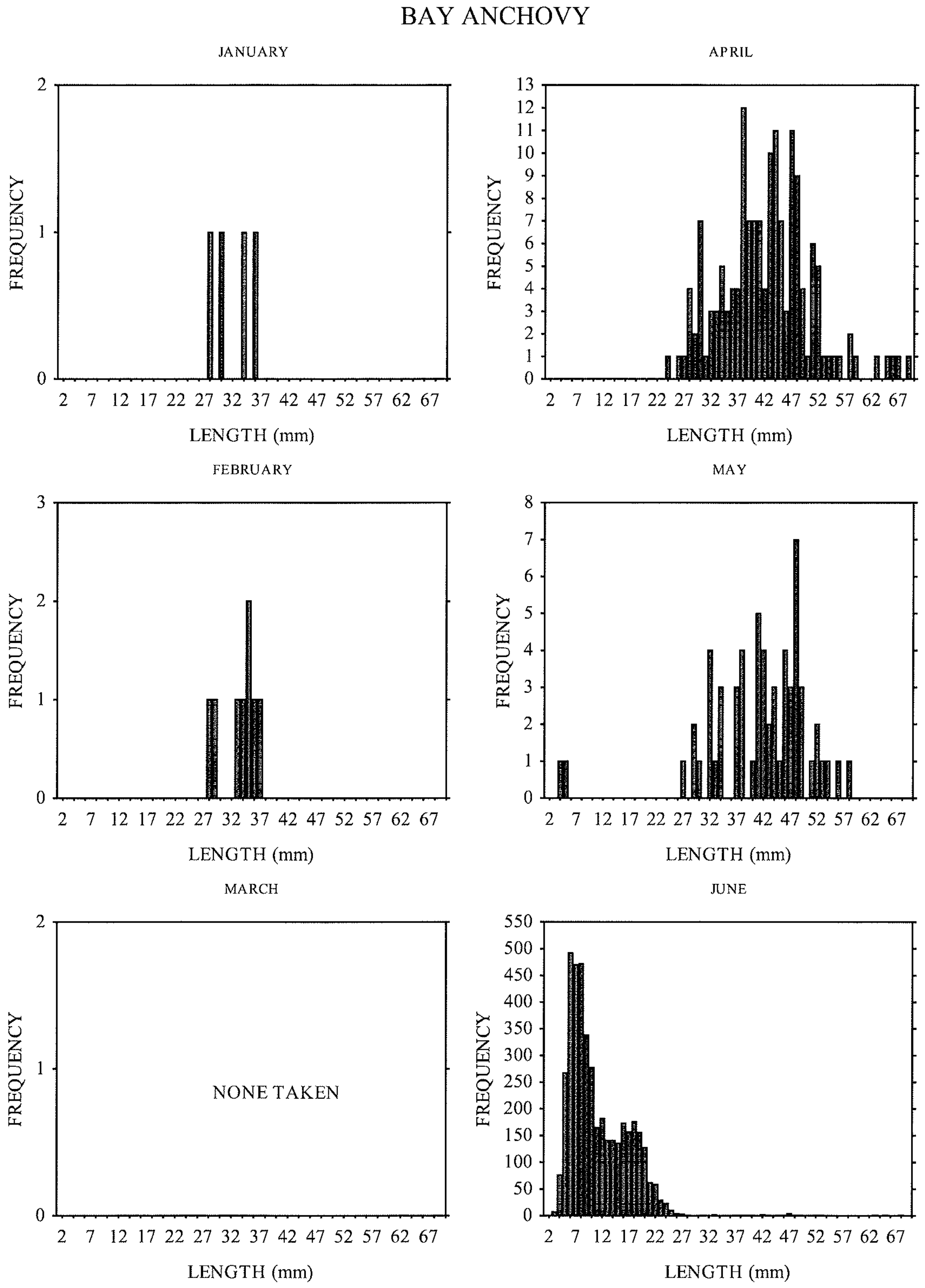


Figure 3-8. Length frequency of bay anchovy taken in entrainment sampling at the Salem circulating water intake structure during 2008.

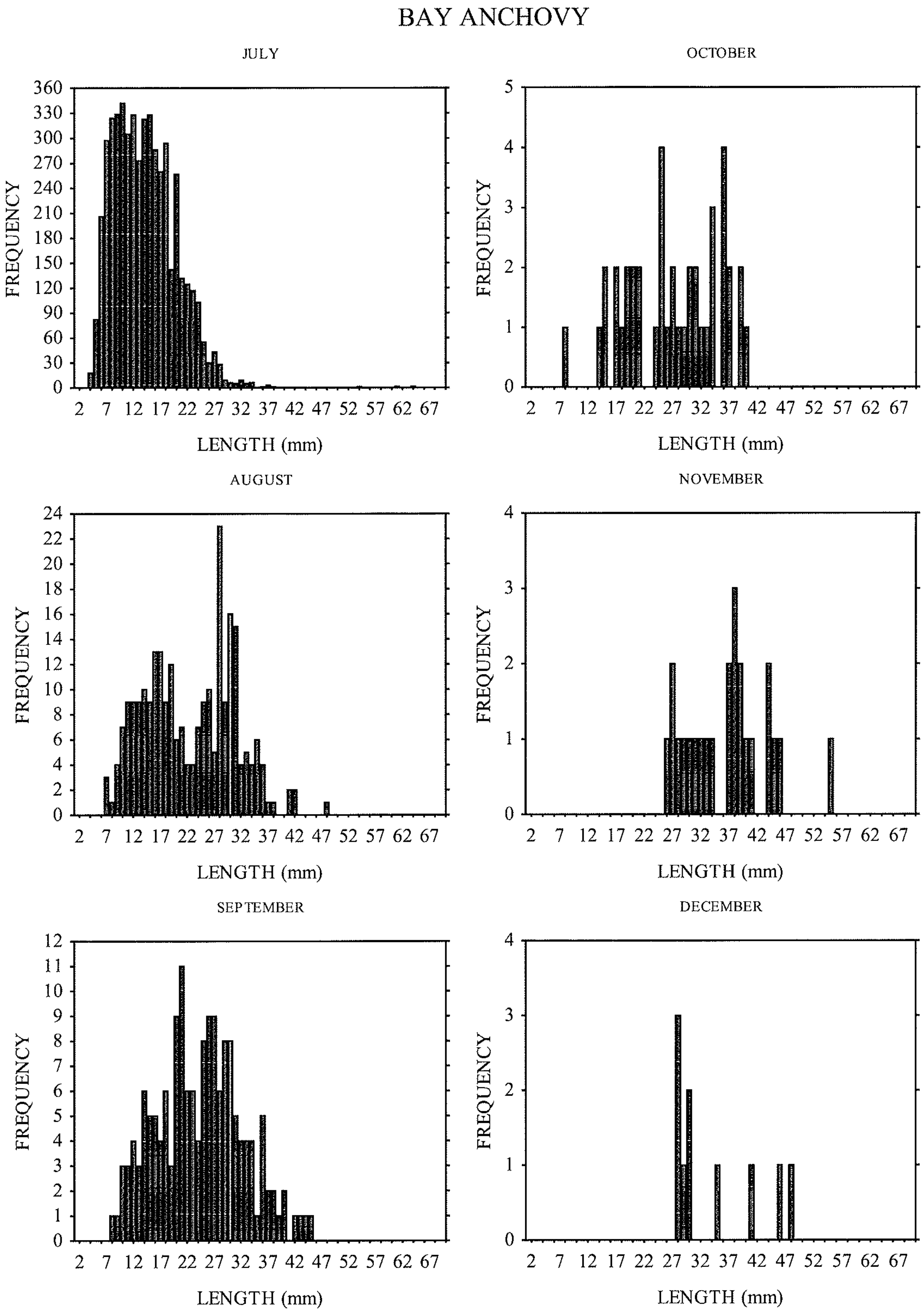


Figure 3-8. Continued.

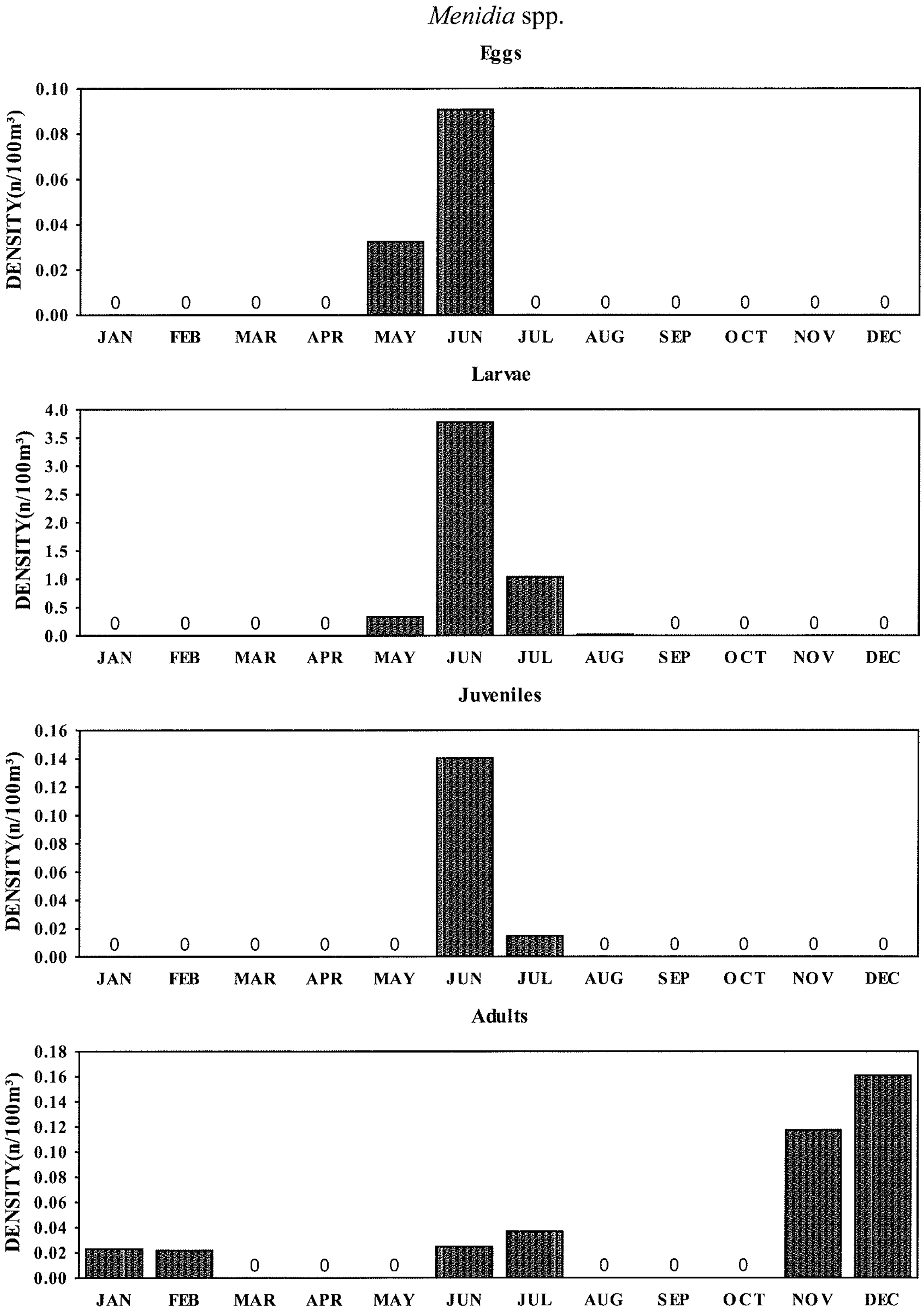


Figure 3-9. Monthly mean density (n/100m^3) of *Menidia* spp. eggs, larvae, juveniles and adults taken in entrainment sampling at the Salem circulating water intake structure during 2008.

Menidia spp.

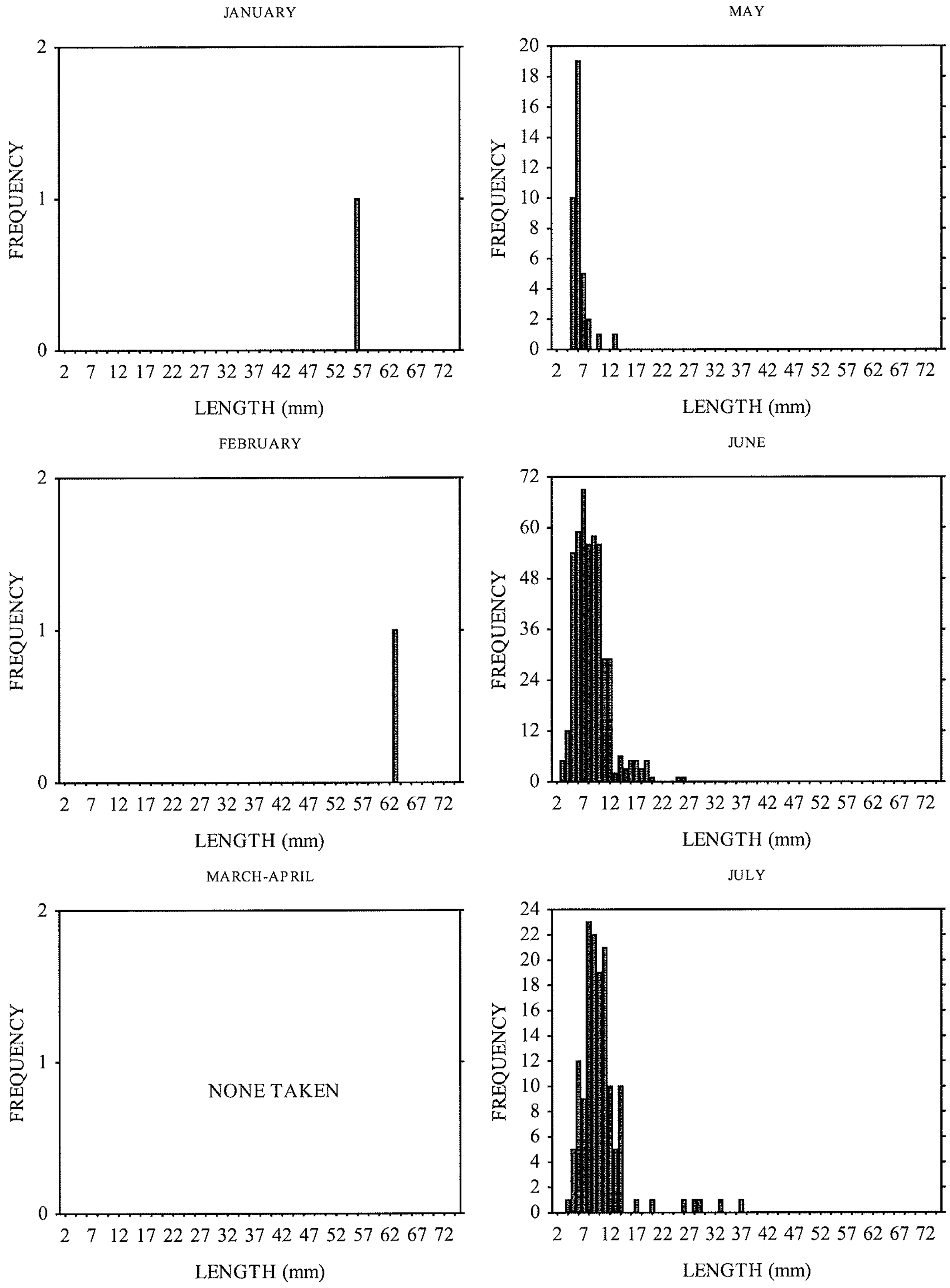
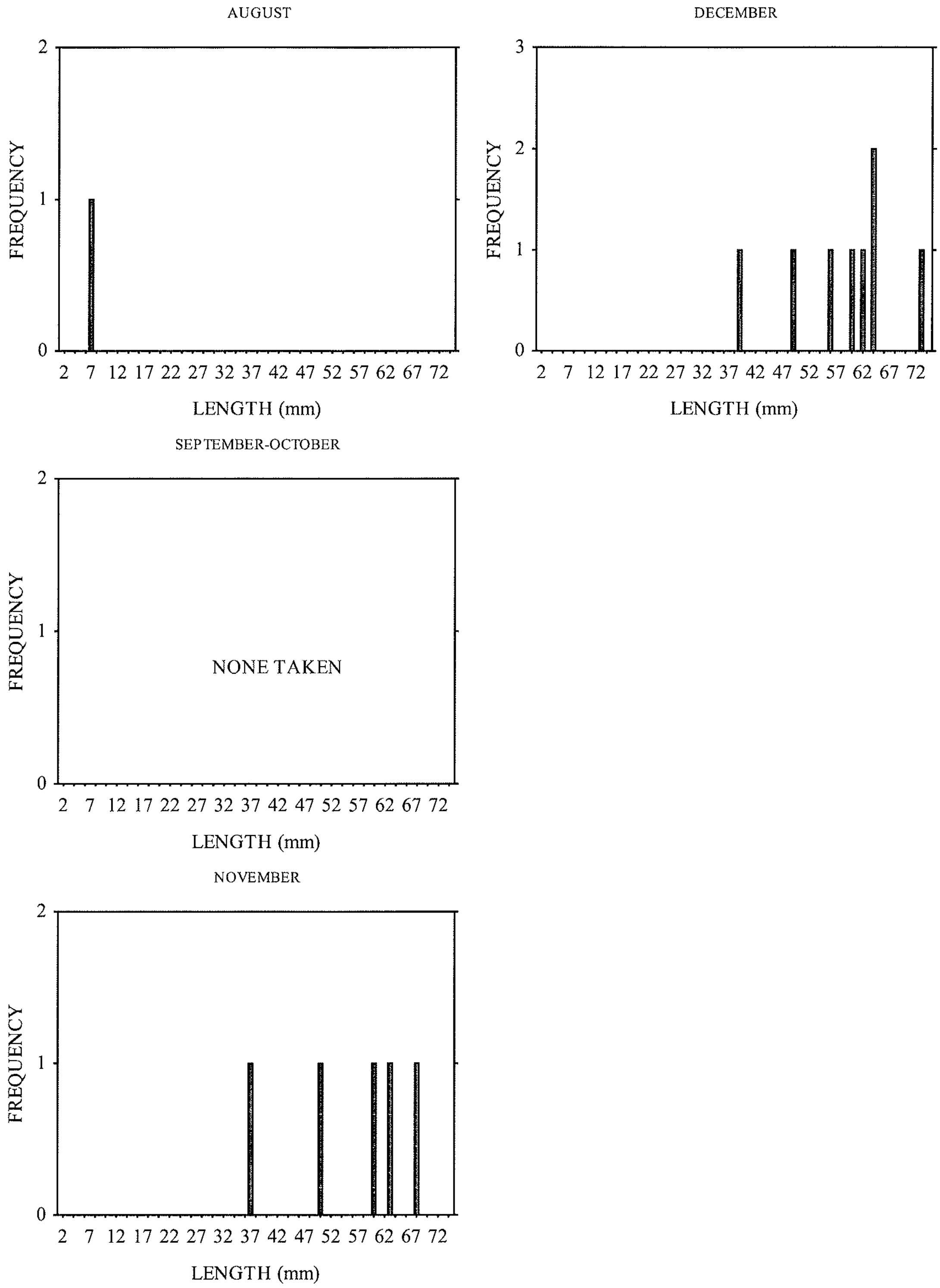


Figure 3-10. Length frequency of *Menidia* spp. taken in entrainment sampling at the Salem circulating water intake structure during 2008.

Menidia spp.



AUGUST

DECEMBER

SEPTEMBER-OCTOBER

NOVEMBER

Figure 3-10. Continued.

WHITE PERCH

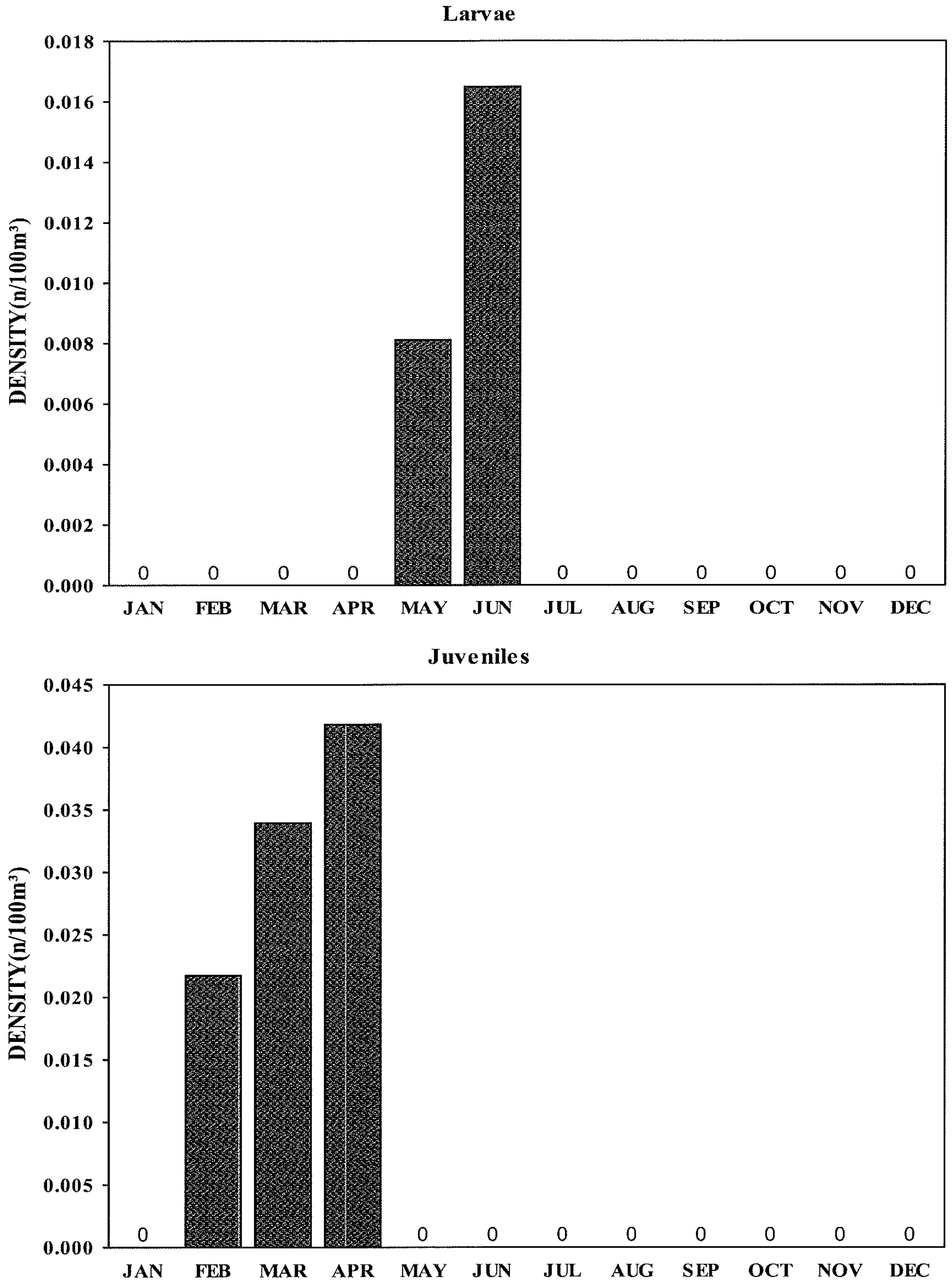


Figure 3-11. Monthly mean density (n/100m^3) of white perch eggs, larvae and juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.

WHITE PERCH

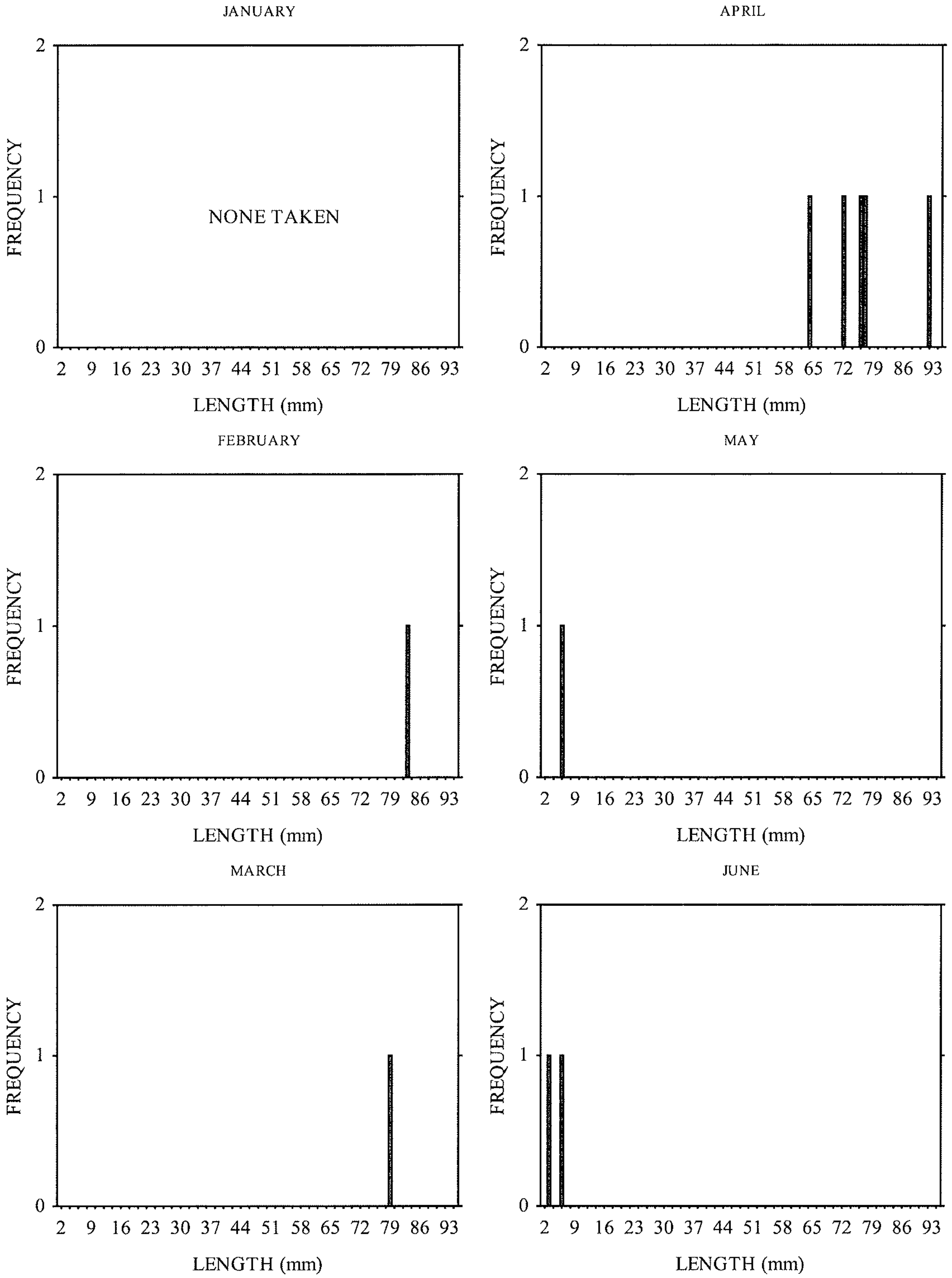


Figure 3-12. Length frequency of white perch taken in entrainment sampling at the Salem circulating water intake structure during 2008.

WHITE PERCH

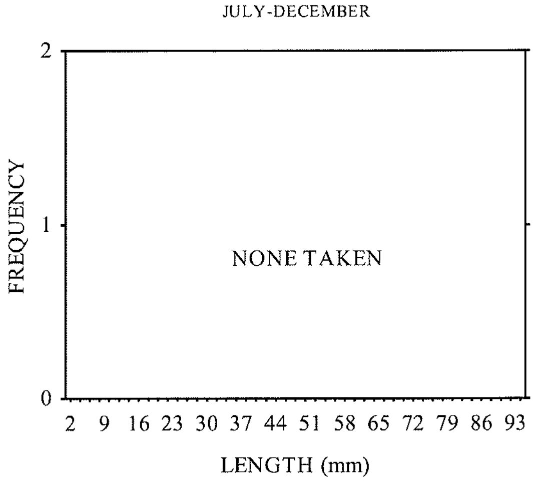


Figure 3-12. Continued.

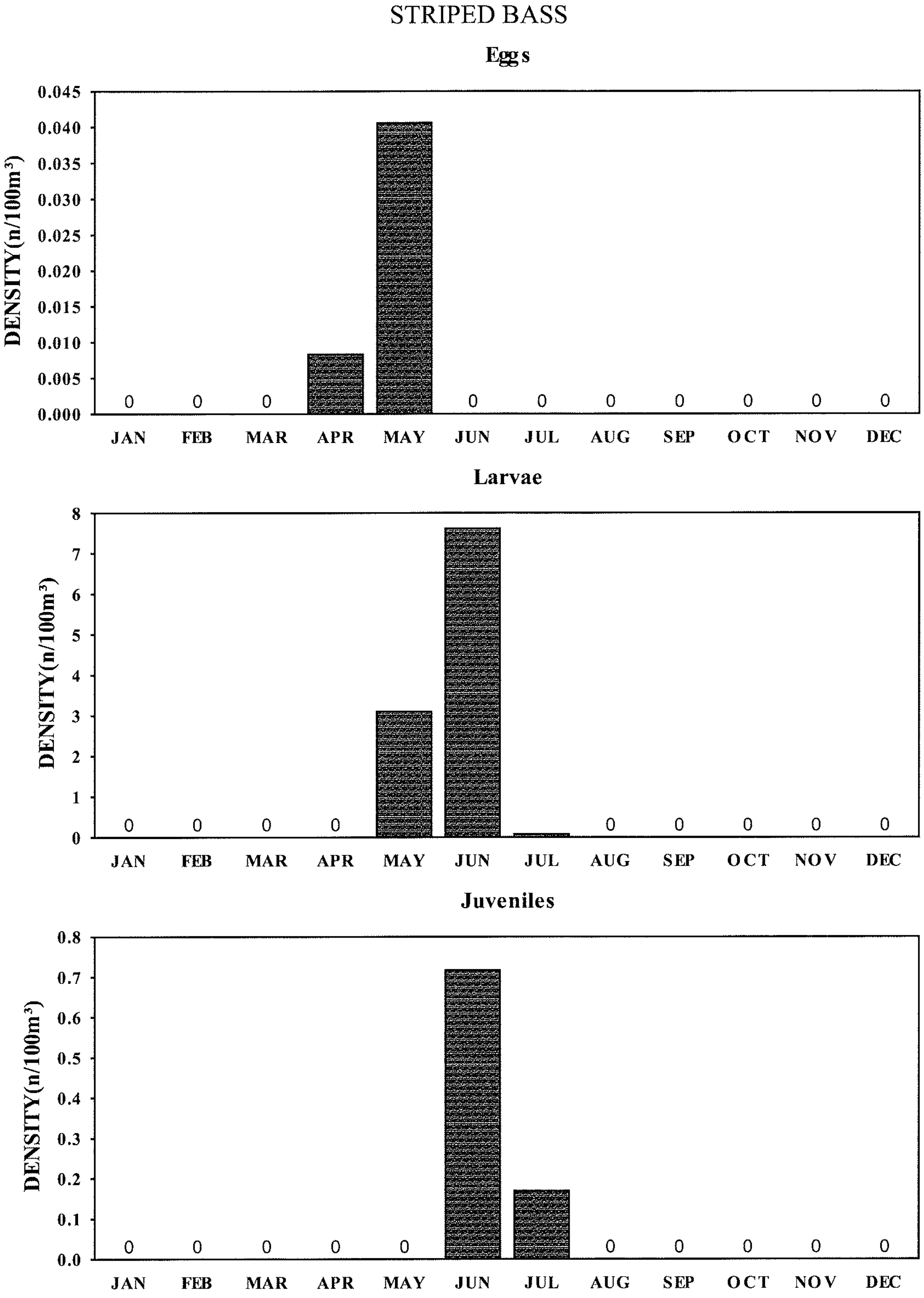
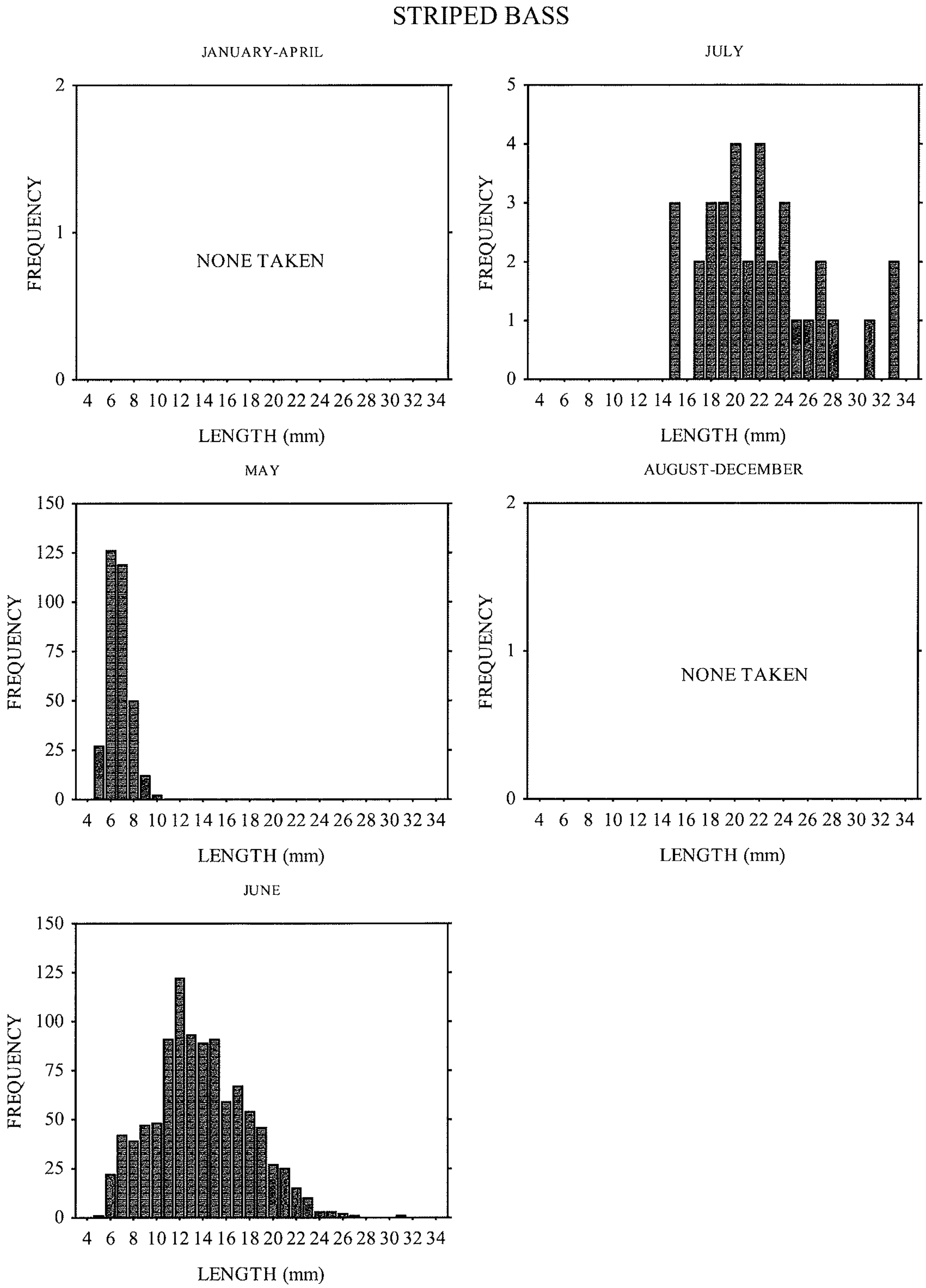


Figure 3-13. Monthly mean density (n/100m^3) of striped bass eggs, larvae and juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.



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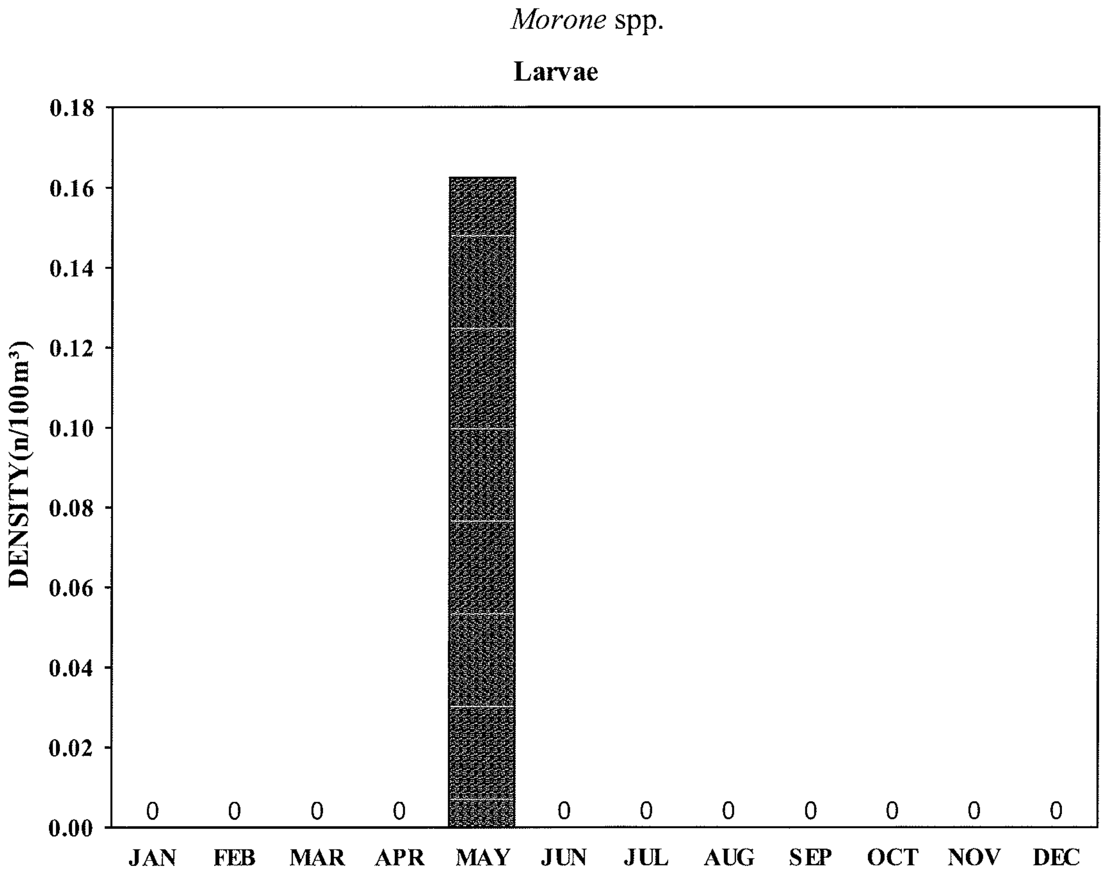


Figure 3-15. Monthly mean density (n/100m^3) of *Morone* spp. larvae taken in entrainment sampling at the Salem circulating water intake structure during 2008.

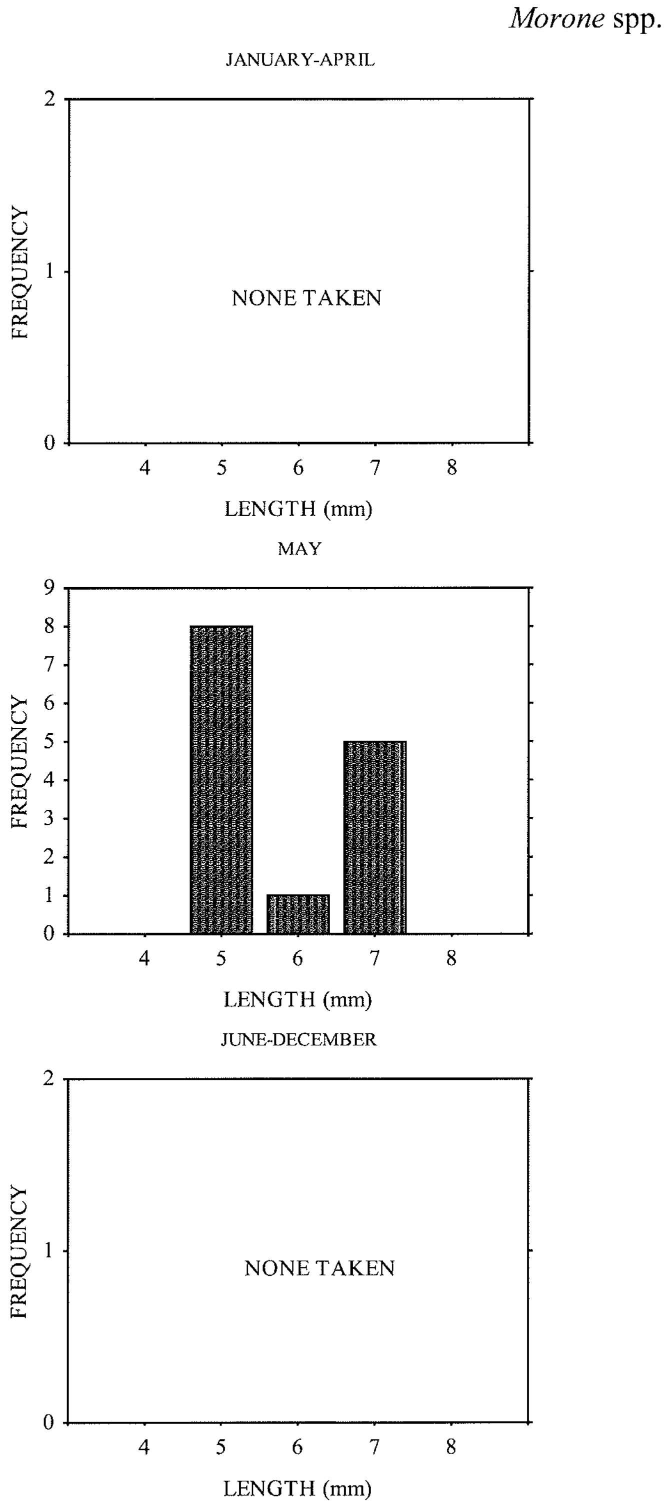


Figure 3-16. Length frequency of *Morone* spp. taken in entrainment sampling at the Salem circulating water intake structure during 2008.

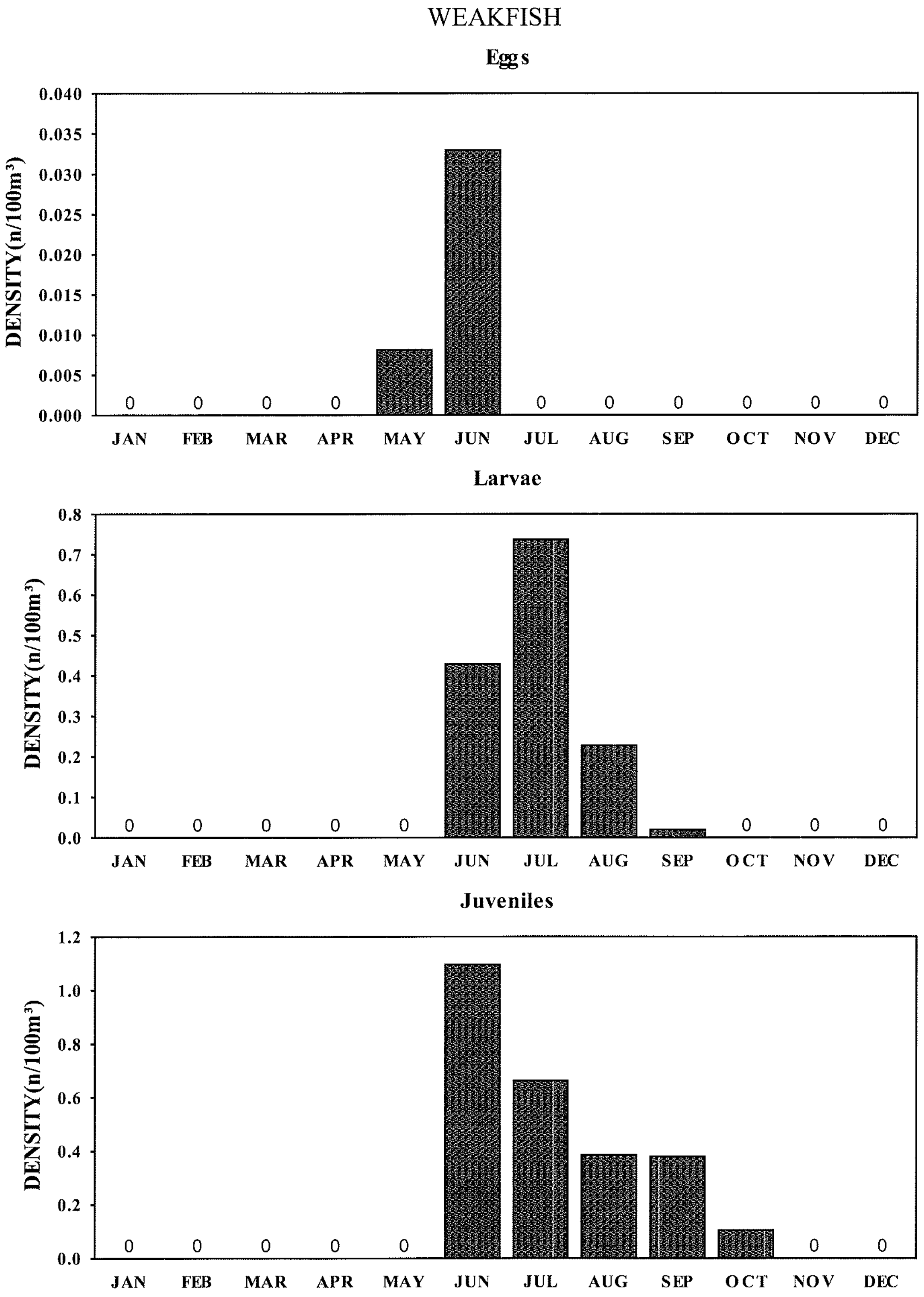


Figure 3-17. Monthly mean density (n/100m^3) of weakfish eggs, larvae and juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.

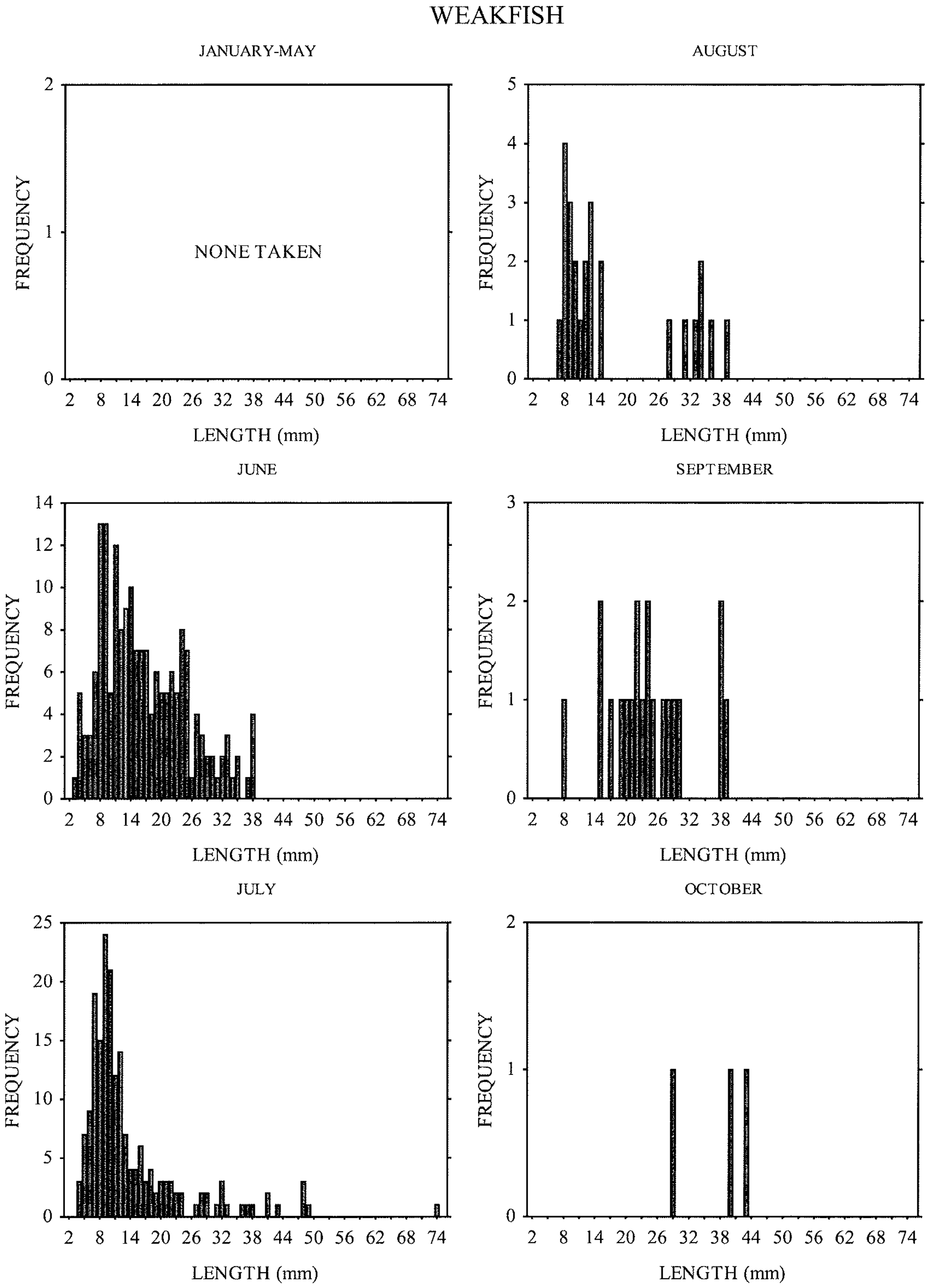
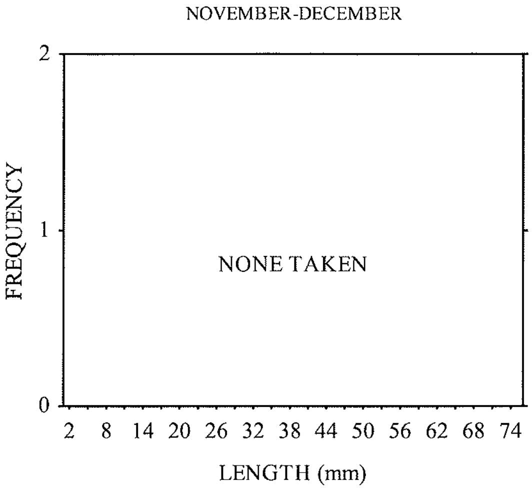


Figure 3-18. Length frequency of weakfish taken in entrainment sampling at the Salem circulating water intake structure during 2008.

WEAKFISH



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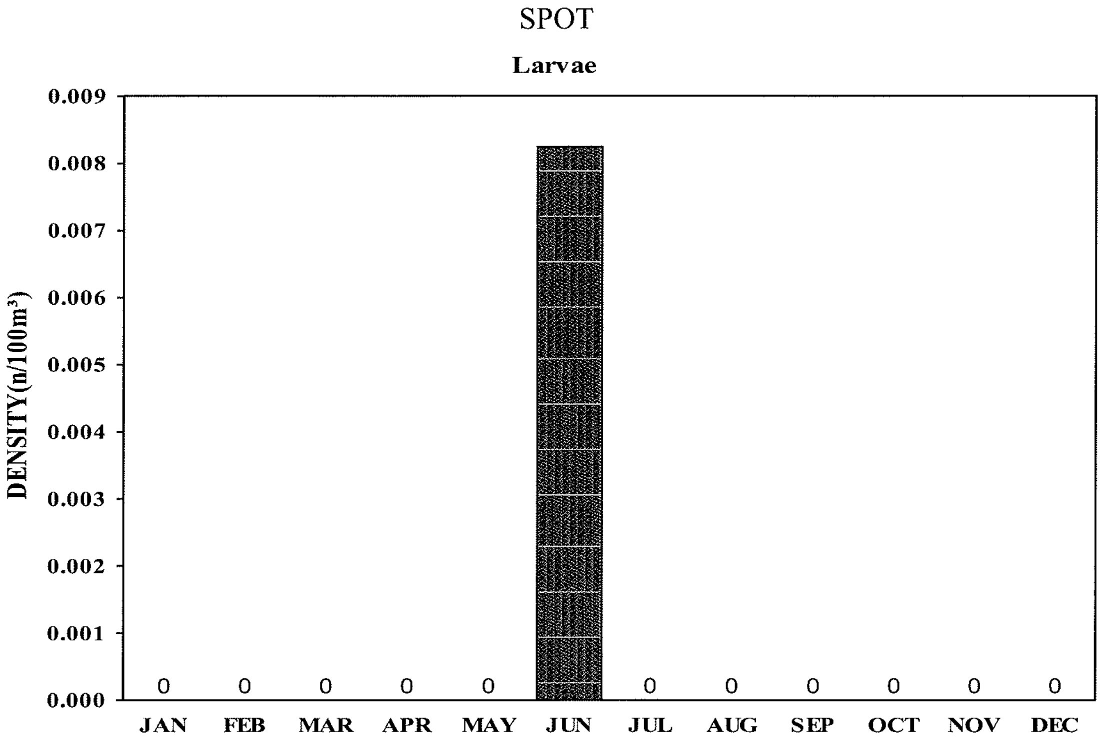


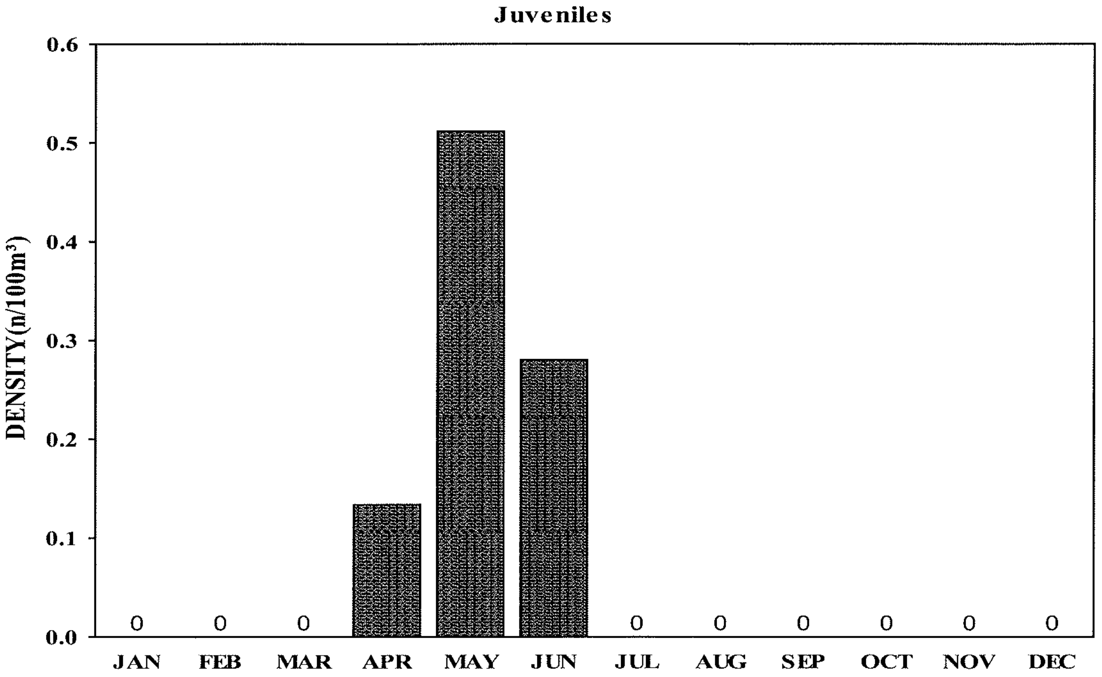


Figure 3-19. Monthly mean density (n/100m^3) of spot juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.

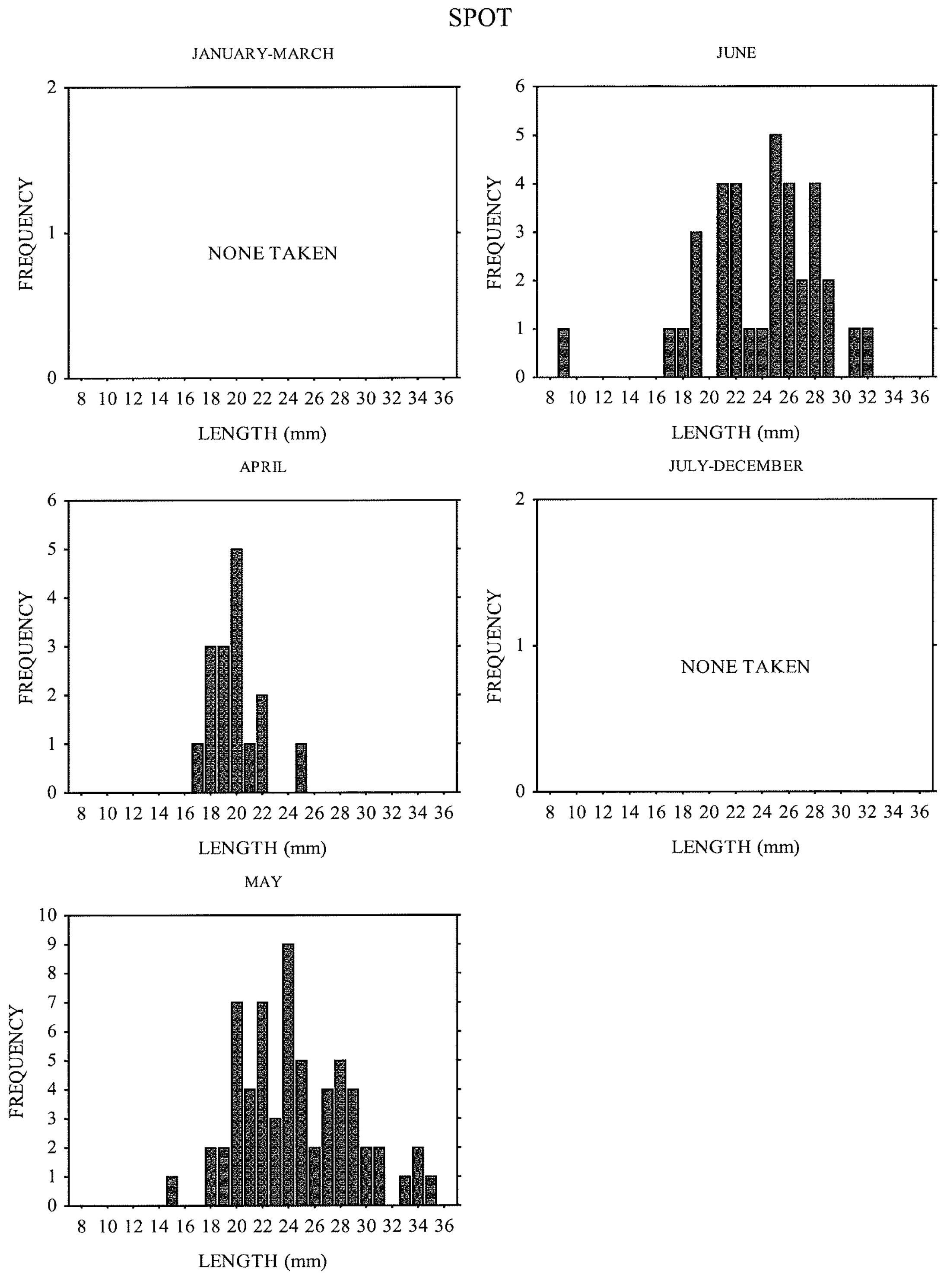
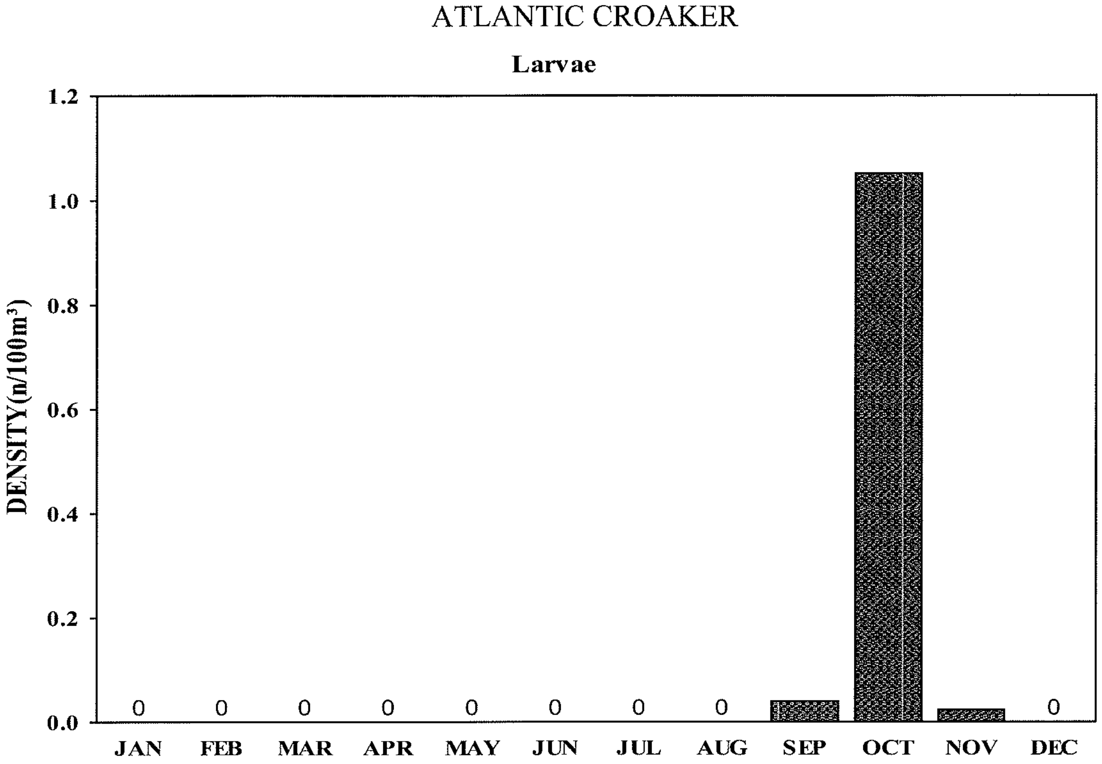


Figure 3-20. Length frequency of spot taken in entrainment sampling at the Salem circulating water intake structure during 2008.



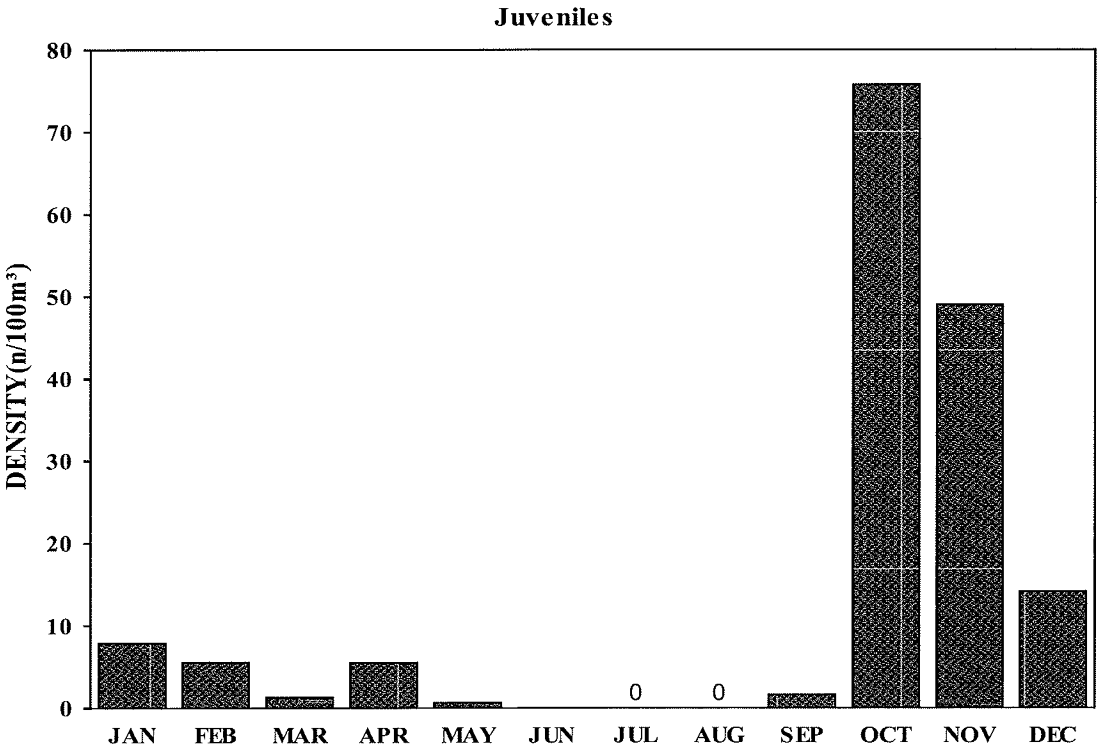


Figure 3-21. Monthly mean density (n/100m^3) of Atlantic croaker larvae and juveniles taken in entrainment sampling at the Salem circulating water intake structure during 2008.

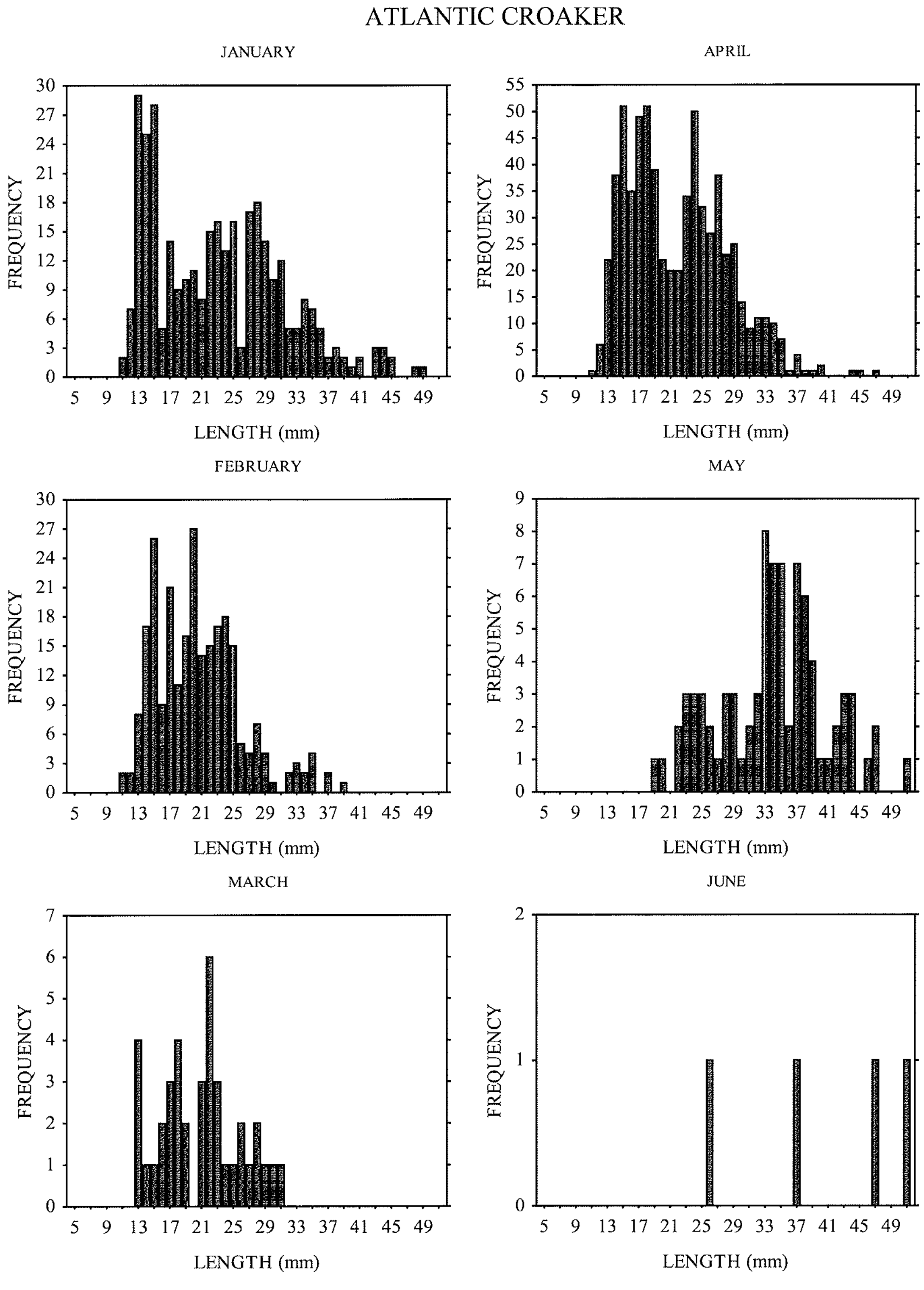


Figure 3-22. Length frequency of Atlantic croaker taken in entrainment sampling at the Salem circulating water intake structure during 2008.

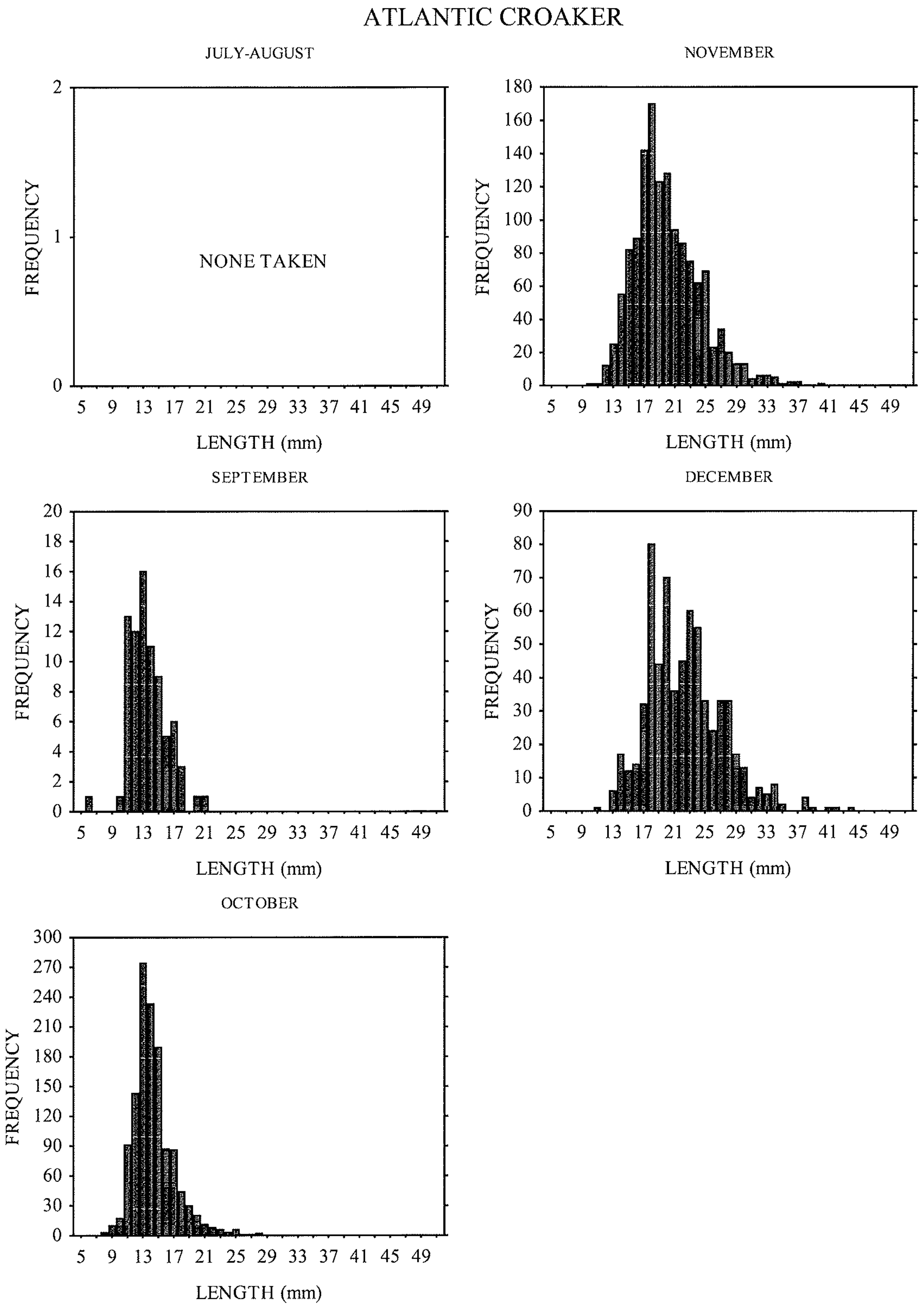


Figure 3-22. Continued.

EXECUTIVE SUMMARY

Bottom Trawl Effort

The 2008 bottom trawl effort was conducted within the Delaware River Estuary from the mouth of the Delaware Bay to just north of the Delaware Memorial Bridge (rkm 0-117) at 40 randomly selected stations allocated from sampling Zones 1-8. The number of sampling stations designated within each of the eight sampling zones was allocated using a Neyman allocation procedure based on the proportional area of each zone and historical fisheries data. One daytime bottom trawl event was completed at each station each month from April through November 2008 using a 4.9-m (16-ft) semi-balloon otter trawl. Eight monthly surveys were completed, resulting in the collection of 320 bottom trawls. Target species for this project were alewife, American shad, Atlantic menhaden, blueback herring, bay anchovy, Atlantic silverside, striped bass, white perch, bluefish, Atlantic croaker, spot, weakfish, and blue crab. All finfish and blue crabs were identified to the lowest practicable taxonomic level, enumerated, and recorded on field data sheets. Length measurements for all target species were recorded to the nearest millimeter. Surface, mid-depth and bottom water quality were recorded for each sample as well as pertinent field observations such as water clarity, weather, and tidal stage.

In the 320 bottom trawls that were completed in 2008, 32,729 specimens (31,418 finfish and 1,311 blue crabs) were collected. Total catch per unit effort (CPUE) was 102.3 for all zones. The results for target species were as follows:

- Alewife: Two specimens were collected during the bottom trawl effort accounting for <0.1% of the total finfish catch. They were collected in Zone 4 in April and May. The CPUE for alewife was <0.1.

- American shad: Eight specimens were caught in bottom trawls, comprising <0.1% of the total finfish catch. They were taken in the April, May, October and November catches in Zones 2, 3 and 5. The CPUE for American shad was <0.1.

- Atlantic croaker: A total of 7,027 specimens were captured in bottom trawls, accounting for 22.4% of the total finfish collected. They were found in all zones and were more evenly distributed than they had been in studies prior to 2006. The largest monthly catch was in July, the second largest in June, the third largest in November and the fourth largest in October. These four months accounted for 80.6% of the Atlantic croaker caught in 2008. The CPUE for Atlantic croaker was 22.0.

- Atlantic menhaden: One hundred fourteen Atlantic menhaden were collected during the 2008 Baywide bottom trawl effort, representing 0.4% of the total finfish catch.

They were found in all zones except Zone 1, and during all months except July. The CPUE for Atlantic menhaden was 0.4.

- Atlantic silverside: Three Atlantic silverside were collected during the bottom trawl effort comprising <0.1% of the total finfish catch. They were caught in Zones 2 and 3 during October and November. The CPUE for Atlantic silverside was <0.1.

- Bay anchovy: A total of 11,759 specimens were captured during the 2008 Baywide bottom trawl effort, comprising 37.4% of the total finfish catch. Bay anchovy were captured in every sampling month, but approximately 32% of them were found in July. They were taken in every zone, but most of them (96%) were taken in Zones 2-5. The CPUE for bay anchovy was 36.7.

- Blueback herring: One specimen was collected during the bottom trawl effort accounting for <0.1% of the total finfish catch. It was collected in Zone 3 during October. The CPUE for blueback herring was <0.1.

- Bluefish: A total of two specimens were caught during the 2008 Baywide bottom trawl effort, representing <0.1% of the total finfish catch. They were found in Zones 3 and 6 in July and August. The CPUE for bluefish was <0.1.

- Spot: A total of 1,453 specimens were captured in bottom trawls, comprising 4.6% of the total finfish collected. Most of them were captured from July through November and, although they were captured in all eight zones, the greatest numbers were found in Zones 2 through 5. The CPUE for spot was 4.5.

- Striped bass: A total of 38 specimens were collected during the bottom trawl effort, accounting for 0.1% of the total finfish collected. Striped bass were taken in Zones 3, 4 and 6-8, and were captured in all sampling months except May and June. CPUE for striped bass was 0.1.

- Weakfish: A total of 2,191 specimens were caught in bottom trawls, representing 7.0% of the total finfish catch. Weakfish were collected in all eight zones and were evenly distributed throughout. They were captured in every month except April. However, most of them were found from July through September. The CPUE for weakfish was 6.8.

- White perch: A total of 406 specimens were captured during the bottom trawl effort, comprising 1.3% of the total finfish catch. White perch were present in all eight zones, except Zone 1, and were most abundant in Zones 5-8. They were taken in all months and the most productive month was April. The CPUE for white perch was 1.3.

- Blue crab: A total of 1,311 specimens were collected in all eight zones and during every month of the program. They were most abundant in Zones 3, 5, 6 and 7, and the heaviest catches were in May, July and October. The CPUE for blue crab was 4.1.

CHAPTER 4: FINFISH MONITORING PROGRAM

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INTRODUCTION

The PSEG Nuclear, LLC bottom trawl effort during 2008 was conducted within the Delaware Bay and River once per month from April through November at 40 stations using a 4.9-m semi-balloon otter trawl. The objective of this trawling effort is to provide representative abundance indices for the target species.

This chapter discusses the overall results of the sampling efforts of the 2008 Bottom Trawl Monitoring Program, and the catch information related to the thirteen target species. The focus of this study was to provide abundance data for the fish species, bay anchovy (*Anchoa mitchilli*), alewife (*Alosa pseudoharengus)*, American shad (*A. sapidissima*), Atlantic menhaden (*Brevoortia tyrannus*), blueback herring (*A. aestivalis*), Atlantic silverside (*Menidia menidia)*, striped bass (*M. saxatilis)*, white perch (*Morone americana*), bluefish (*Pomatomus saltatrix*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and weakfish (*Cynoscion regalis*), and the invertebrate species, blue crab (*Callinectes sapidus*) in the project area. Results of the bottom trawl sampling effort for the Baywide trawl programs conducted from 1995 through 2007 have been summarized in previous reports (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

BOTTOM TRAWL EFFORT

Materials and Methods

The 2008 bottom trawl effort study area extended from the mouth of the Delaware Bay, rkm 0, to just north of the Delaware Memorial Bridge, rkm 117.

The study area was divided into eight zones (Figure 4-1). Zones 1, 2, and 3 (lower bay) are near the mouth of the bay. Zones 4, 5, and 6 are located in the 'middle' bay. Zones 7 and 8 (upper bay) are in the lower Delaware River.

Bottom trawl sampling (daytime only) was conducted once per month from April through November, for a total of eight trawling events. Daylight was defined as the period from one hour after sunrise to one hour before sunset.

Forty trawls were collected monthly during 2008 from randomly selected stations. These stations were distributed among the eight zones for a total of 320 samples. The number of stations within each zone was allocated using a Neyman allocation program that was based on the proportional area of each zone and on historical fishery data. The allocation of trawls per zone was as follows:

River Zone	Number of Trawls Per Zone
1	4
2	6
3	8
4	6
5	4
6	4
7	4
8	4

The primary sampling stations were randomly selected from a list of all available stations in each zone by a computer algorithm program. Alternate stations were also allocated in case a primary station could not be sampled due to navigational hazards, commercial fishing equipment, commercial shipping activity, etc.

Bottom trawls were collected with a 4.9-m (16-ft) semi-balloon otter trawl, manufactured by NETCO in Memphis, Tennessee and described as follows:

> "A 16-ft semi-balloon trawl: 17' headrope; 21' footrope; net made of nylon netting of the following size mesh and thread; 1½" stretch (3/4" square) mesh No. 9 thread body; 1¼" stretch (5/8" square) mesh No. 15 thread codend, fully rigged with four 2" I.D. net rings at top and bottom

> for lazy line and purse rope; inner liner of ½" stretch (¼"square) mesh No. 63 knotless nylon netting inserted and hogtied in codend; head and footropes of 3/8"-diameter poly-Dacron net rope with legs extended 3' and galvanized wire rope thimbles spliced in at each end; six 1½" x 2½" sponge floats spaced evenly on bosom of head rope; net treated in green net dip; trawl doors are 24" in length and 12" in width; doors are made of ¾" marine ply board, 1¼" x 1¼" straps and braces and ½" x 2" bottom shoe runner; 3/16" chain bridle, lap links and 5/16" swivels at the head of each bridle."

Trawl stations were located using an onboard GPS receiver that had been preprogrammed with each station's waypoint (latitude and longitude). The station depths were monitored with an onboard depth sounder.

Trawls were towed for ten minutes at 6 ft/sec. against the direction of the tide. A towline to water depth ratio of 10:1 was used to ensure that the trawl maintained contact with the bottom. Predicted tidal stages were determined using Tides and Currents for Windows™ (version 2.5b) nautical software program and/or *Eldridge Tide and Pilot Book 2008* (Eldridge Tide and Pilot Book 2007). At each station, predicted tidal currents were visually verified by the crew prior to starting each tow. The tow speed was monitored with an electronic flowmeter with on-deck readout and/or engine rpm.

At the completion of each tow, the net was emptied into a collection container to prepare for sample processing. All finfish and blue crabs were transferred to the sorting table for identification to the lowest practicable taxonomic level (i.e., species). All species were identified, enumerated, and recorded on field data sheets. The subsampling procedure described in the procedures manual (PSEG 2002b) was not used because subsampling was not necessary during the 2008 bottom trawl effort. Any unidentifiable specimens were preserved in 10% formalin and returned to the laboratory for species identification.

Length measurements were recorded for all target finfish species and carapace width measurements were recorded for blue crabs. When the count for a target species was less than 100, measurements were recorded for each specimen. When the number of specimens for a target species exceeded 100, a representative subsample of 100 specimens was measured. Total length (TL) to the nearest millimeter was measured for fish with square or rounded caudal fins (tip of the snout to the tip of the longest caudal ray). Fork length (FL) to the nearest millimeter was measured for fish with emarginate or forked caudal fins (tip of the snout to the caudal fork). Carapace width to the nearest millimeter (shell point to point) was measured for blue crabs. Live fish and crabs were returned to the water as quickly as possible.

Water quality measurements for water temperature (°C), dissolved oxygen (DO) in milligrams per liter (mg/L), and salinity in parts per thousands (ppt) were recorded at surface, mid-depth and bottom depths at each trawl station. Surface measurements were recorded at stations where the depth was less than 10 ft. The primary meter used to measure these parameters was the YSI-85 DO/Conductivity/Salinity/Temperature Meter. The YSI-55 DO/Temperature Meter and the YSI-30 Conductivity/Salinity/Temperature Meter were used as backups. Field crews also recorded water clarity (by Secchi disk), weather conditions, station depths, and tidal stage (ebb/flood/slack) at each trawl station.

Results and Discussion

Physical/Chemical Parameters

Trends in physical and chemical parameters recorded in the Delaware Baywide bottom trawl effort zones during 2008 were generally consistent with those results reported in previous study years (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

Surface, mid-depth and bottom water temperatures varied by season, station depth, and river kilometer at all sampling stations in 2008. Mean bottom water temperatures increased throughout the spring and early summer, peaked in August and decreased monthly through November (Figure 4-2). Temperature ranges varied from lows of 10.4 °C in April and 10.0-11.5 °C in October-November to highs of 23.5-27.3 °C in June through September. The lowest mean water temperature was recorded during November (10.0 °C) and the highest mean water temperature was recorded in July (27.3 °C).

The temperature gradient pattern in 2008 was generally consistent with the last three years (2005-2007) when only the current eight lower zones were sampled (PSEG 2006, PSEG 2007). In 2008, bottom water temperatures ranged from 1-8 °C among the eight sampling zones within each sampling period. During 2007, bottom water temperatures ranged from 2-9 °C among the eight sampling zones within each monthly period. In 2006, bottom water temperatures ranged from 1-9 °C among the eight zones within each monthly period. During 2005, bottom water temperatures ranged from 2-9 °C among the eight sampling zones. The greatest temperature gradient in 2008 was recorded in October with 7.9 °C between Zones 3 and 7. The least temperature gradient was recorded in April with 0.8 °C between Zones 4 and 8.

Zone 1 had the coldest water during May, June, July and August. Zone 3 had the coldest water in October. Zones 1 and 3 were tied for the coldest water in September, and Zone 8 had the coldest water in April and November. Zone 4 had the warmest water in April and Zone 1 had the warmest water in November. Zone 6 had the warmest water during June and September. Zone 7 had the warmest water in July and October. Zones 7 and 8 were tied for the warmest water in August, and Zones 3, 4, 6 and 7 were tied for the warmest water in May.

In 2008, the mean bottom salinity distribution was relatively consistent with the data from previous years (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008), as it varied by month and by zone from April through November (Figure 4-3).

Salinity increased from April into May in Zones 1-3 and 5-8, and remained the same in Zone 4. Salinity then increased into June in Zones 1, 2 and 4 and decreased in Zones 3 and 5-8. In July and August, the salinity increased in all eight zones from month to month. The salinity then increased into September in Zones 6 and 8, went down in Zones 1-4 and 7, and remained the same in Zone 5. In October, salinity decreased in Zones 1 and 3, but increased in Zones 2 and 4-8. The salinity then declined in November in Zones 1, 2, 4-6 and 8, and went up in Zone 3 and 7. The seasonal increase from the spring to the fall, which is characteristic of mid-Atlantic estuaries (Moyle and Cech 1988), was evident in 2008 as it was in the years 1995-2003 and 2007. It was not as obvious in the years 2003-2006 (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

Zone 1 exhibited the highest mean bottom salinity (29.9 ppt) in August for any zone in any month. The water in the areas closest to the mouth of the bay (Zones 1, 2 and 3) is nearly marine and its salinity was consistently ≥ 21 ppt for all eight months. The water in Zones 4, 5 and 6 becomes gradually less saline from south to north. Zone 4 was always the fourth highest (17.8-26.3 ppt) in salinity, except during October (third highest). Zone 5 was always the fifth highest (11.1-21.3 ppt), and Zone 6 was always the sixth highest (6.7-15.6 ppt). The water in the river areas (Zones 7 and 8) is nearly fresh and was consistently the least saline of the eight zones throughout the program. The salinity in Zone 7 ranged from 1.1 (April) to 9.6 (November). Zone 8 exhibited salinities between 0.1 (April) and 5.0 ppt (October). Variation among Zones 1 to 8 was relatively consistent from month to month (Figure 4-3). It was lowest in October, with a range of 5.0 to 28.9 ppt, and highest in June with a range of 0.3 to 28.4 ppt.

Monthly zone variations of mean bottom DO readings for the eight zones were lower in 2008 (Figure 4-4) than in 2007 in April and June, and higher during May, July, August, September, October and November. During the eight months of sampling, the gradient among zones ranged from 0.9 mg/L (April) to 2.0 mg/L (June, September and October). Mean bottom DO concentrations throughout all sampling zones ranged from 5.6 to 10.5 mg/L. Overall, the bottom DO concentrations in the eight zones were similar to the historical values recorded during previous study years (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008), and represent a well-mixed, oxygenated estuary (Moyle and Cech 1988).

Catch Composition

During the 2008 Baywide bottom trawl effort, 31,418 finfish from 52 species and 1,311 blue crabs were collected in 320 trawl samples (Table 4-1). Approximately 73.2% (23,004) of the total finfish catch was comprised of target species fish. Bay anchovy (37.4%) and Atlantic croaker (22.4%) dominated the total finfish catch. The remaining ten target finfish species collectively represented 13.4% of the total finfish catch.

A total of 8,414 specimens were collected of 40 non-target finfish species. This represented 26.8% of the total finfish catch. The most abundant non-target finfish species was hogchoker (Table 4-1). The only other relatively abundant (>150 fish caught) non-target species was spotted hake.

Total abundance for target species and others by zone across all months shows dominance of bay anchovy in Zones 2, 3 and 4 (Figure 4-5). Atlantic croaker was the most abundant species in Zones 1 and 5. Hogchoker was the most abundant species in Zones 6, 7 and 8. Bay anchovy was the second most abundant species in Zones 1 and 5. Atlantic croaker was the second most abundant species in Zones 3 and 6-8.

Mean species composition (MSC) and catch per unit effort (CPUE) were calculated by zone and by month for the 2008 sampling season (Figure 4-6). Mean species composition by month is the number of species caught in a month over all zones divided by the number of zones. MSC by zone is the number of species caught in a zone over all months divided by the number of months. Mean CPUE by month is the average CPUE in a month over all zones divided by the number of zones. Mean CPUE by zone is the average CPUE in a zone over all months divided by the number of months.

MSC by month (Figure 4-6) was lowest in June, and highest in September. MSC by zone (Figure 4-6) was the lowest in Zone 7, and the highest in Zone 3.

Mean monthly CPUE (Figure 4-6) was lowest in August after increasing by approximately 33% from April to a small peak in May, and decreasing by about 22% from May to June. From June into July, the CPUE increased by 1.4 times to the highest peak of the year. It then decreased approximately 72% into August and increased 21% in September. The CPUE increased about 68% from September to a medium peak in October and then decreased approximately 13% into November. The highest peak CPUE of 2008 in July was due to high abundance of Atlantic croaker in Zones 2 and 3, the high bay anchovy numbers in all Zones 1-3, and the high hogchoker numbers in Zones 7 and 8 (Tables 4-2 through 4-9).

Mean CPUE was lowest in Zone 1 and highest in Zone 8 (Figure 4-6). Target species had the highest species-specific CPUE in Zones 1-5, but hogchoker had the highest species-specific CPUE in Zones 6-8 (Tables 4-2 through 4-9). Bay anchovy had the highest CPUE for Zones 2-4. Atlantic croaker had the highest CPUE in Zones 1 and 5.

The highest CPUE for blue crab was in Zones 5 and 6. One other zone, out of the eight sampled, had moderate blue crab mean CPUE. It was Zone 7. The blue crab catch varied from month to month rising to peaks in May, July and October (Tables 4-2 through 4-9).

Figure 4-7 outlines MSC and CPUE by month for each zone. Species composition in 2008 was highest in Zone 3 and lowest in Zone 7. The variance of the species composition among all eight zones in 2008 was similar to the variance of the species composition among the same eight zones in 2007.

Length-frequency data are provided for all target fish species in Figures 4-8 through 4-19. Descriptions of the thirteen target species (including blue crab) are presented below. Spatial and temporal distributions are discussed where appropriate. Table 4-1 provides abundance catch by zone for each species while Tables 4-2 through 4-9 provide a monthly catch for each species by zone. More detailed descriptions of the life histories of the target species, except for Atlantic menhaden and bluefish, are described in Appendix C, Attachments C-1 through C-9, C-12 and C-14 of the Salem 316 (b) Demonstration (PSE&G 1999).

Alewife

Two alewives were collected in the 2008 program, which was similar to the number caught in the same eight zones in 2002 (3) and 2006 (1). However, it was much less than the number caught in the same eight zones in 2000 (15), 2001 (42), 2003 (70), 2004 (32), 2005 (25), and 2007 (35) (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The alewives captured in 2008 were found in Zone 4 during April and May. Apparently, the one in April was a yearling and the one in May was a yearling or older fish (Figure 4-8).

American shad

Eight American shad were collected in the 2008 Baywide bottom trawl effort. This is consistent with earlier years of this study. For example, thirteen fish were taken from the same eight zones in 1999, none in 2000, eight in 2001, five in 2002, eight in 2003, ten in 2004, three in 2005 and 2006, and fifteen in 2007 (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The American shad caught in 2008 were caught in April, May, October and November. They were located in Zones 2, 3 and 5. The ones caught in April and May were probably yearlings and the ones in October and November were probably young-of-the-year (YOY) (Figure 4-9).

Atlantic croaker

Atlantic croaker was the second most abundant fish species collected in 2008 representing 22.4% of the total finfish catch with 7,027 specimens captured. They were taken in all zones and were more evenly distributed than they had been in studies prior to 2006 (PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). Approximately 31.8% of the total 2008 Atlantic croaker catch was found in Zone 3, 24.1% in Zone 8, 11.0% in Zone 2, 10.9% in Zone 7, 8.7% in Zone 6, 6.8% in Zone 5, 3.5% in Zone 4 and 3.1% in Zone 1. The largest monthly catch was taken during July (2,286), the second largest was taken in June (1,233), the third largest was taken in November (1,129) and the fourth largest was taken in October (1,016). These four months accounted for 80.6% of the total Atlantic croaker catch for the year. This seasonal pattern is inconsistent with the 1996-2001, 2003-2005 and 2007 data when most of the Atlantic croaker were taken in the later months of the studies. However, it is consistent with the data in 2002 and 2006 when a larger portion of the yearly catch was also taken in the earlier months (PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). It should also be noted that the 2008 Atlantic croaker catch was similar to the 2007 (11,389), 2005 (11,062), 2004 (10,026) and 2003 (9,501) catches from the same eight zones, but only amounted to about 34.5% of the 2002 catch and 52% of the 2007 catch from the same area. Only a small number of adult fish were taken as is shown in the length-frequency distribution graphs presented in Figure 4-10. This is consistent with the data from past years (PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

Atlantic menhaden

In 2008, 114 Atlantic menhaden were collected. This much more than the number of fish caught in the same eight zones in 2000 (15), 2001 (10) and 2003(1), 2004 (29), 2005 (4), 2006 (20) and 2007 (6). However, only approximately 40% of the 286 taken in the same eight zones in 2002 (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The Atlantic menhaden captured in 2008 were found in all zones, except Zone 1. There were 88 caught during June and none in July. The rest were evenly distributed in low numbers (less than or equal to seven) throughout the other six months of the program. There was a mixture of YOY and older fish (Figure 4-11).

Atlantic silverside

Three Atlantic silverside were collected during the 2008 Baywide bottom trawl effort. In the same eight zones, six were caught in 2005, 27 were collected in 2003, 11 were captured in 2002, and only two were taken in 2001. None were captured in 2000, 2004, 2006 and 2007 (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The Atlantic silverside were caught in Zones 2 and 3 during October and November. The length distribution of Atlantic silverside is presented in Figure 4-12.

Bay anchovy

Bay anchovy occur throughout Delaware Bay and are seasonally abundant from the lower Delaware River up to Wilmington, DE (rkm 120), and Philadelphia, PA (rkm 150). O'Herron et al. (1994) reported that bay anchovy was the fourth most abundant species, representing 10.1% of the overall catch, in an extensive survey of the Delaware River Estuary, ranging from the C & D Canal to Trenton, NJ.

Historically, bay anchovy is one of the most abundant species of the mid-Atlantic region estuaries and, in previous years, they represented the largest or second largest number of fish caught in the Baywide bottom trawl effort (PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). In 2008, bay anchovy accounted for the largest number of fish caught (11,759; 37.4% of the total finfish). This was about the same as the 2006 catch (11,857), approximately 66% of the 2005 catch (17,776), 24% of the 2004 catch (48,286) and 58% of the 2002 catch (20,396) from the same eight zones. The 2008 catch was about 14% more than the 2003 catch (10,314), as well as 14% more than the 2001 (10,351) catch, and 89% more than the 2000 catch (6,233) from the same area. The bay anchovy captured in 2008 were found in every sampling month, but approximately 32% of them were found in July (3,731). They were taken in every zone, but most of them (96%) were taken in Zones 2-5.

Yearlings and adults dominated the length-frequency distribution of bay anchovy from April through June, 2007 (Figure 4-13). In July, the YOY fish appeared in the catches in great numbers. The YOY and yearling/adults demonstrated separate frequency cycles (peaks) from July through September, and finally overlapped in October and November. Although separate peaks are represented in the last two months of the program, it is difficult to determine where the YOY frequency cycle ends and the adult frequency cycle begins. This pattern is somewhat consistent with data from previous years' programs, which exhibited similar seasonal length-frequency distributions (PSE&G 1996, PSE&G 1997, PSE&G 1998, PSE&G 1999, PSE&G 2000, PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

Blueback herring

One blueback herring was collected in 2008. This is consistent with the numbers found in previous surveys in 2006 (1), 2004 (8), 2003 (5), 2002 (9), 2001 (3) and 2000 (3), but much less than those found in 2007 (31) and 2005 (19) from the same eight zones (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The blueback herring caught in 2008 was found in Zone 3 during October. It was probably a YOY (Figure 4-14).

Bluefish

Two bluefish were taken in the 2008 Baywide bottom trawl effort, which was a low catch but still fairly similar in number to the 15 collected in 2007, five in 2006, four in 2005, five in 2004, 10 in 2003, 13 in 2002, 19 in 2001 and 17 in 2000 from the same eight zones (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). The bluefish caught in 2008 were found in Zones 3 and 6 in July and August. They were probably both YOY (Figure 4-15).

Spot

The spawning season of spot along the Atlantic coast varies, extending possibly from mid-October through mid-March (Warlen and Chester 1985, Flores-Coto and Warlen 1993). In 2008, 1,453 spot were collected, which is much more than the 2007 (312), 2006 (102), 2005 (1,002), 2004 (42), 2003 (11), 2002 (52), 2001 (12) and 2000 (424) catches from the same area (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). Spot were found in all eight zones in 2008 with the greatest numbers in Zone 2 (802), Zone 5 (201), Zone 3 (136) and Zone 4 (124). Most of them were captured from July through November with none caught in April, fourteen in May and four in June. Figure 4-16 demonstrates the presence of YOY in all seven months in which spot were caught and the possible presence of a few yearlings during May through September.

Striped bass

In 2008, 38 striped bass were collected. This catch is similar to the number caught in 2007 (23) and 2006 (20), which were the lowest numbers caught in previous years (2005, 201 caught; 2004, 79 caught; 2003, 269 caught; 2002, 88 caught; 2001, 318 caught; 2000, 45 caught) from the same eight zones (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG

2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). Weisberg and Burton (1993) deduced that striped bass larvae spawned in the upper Delaware River in the late 1980s and early 1990s were possibly from a recovering native population. However, the species still represented 0.1% of the total finfish catch in the 2008 Baywide bottom trawl effort, which was the same as the 0.1% of the total finfish catch that striped bass accounted for in 2007 and 2006, and about the same as the 0.5% in 2005, 0.2% in 2004, 0.7% in 2003, the 0.2% in 2002, the 1.1% in 2001 and the 0.3% in 2000 (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008).

Striped bass were taken in Zones 3, 4 and 6-8. There were two fish caught in Zone 3, one in Zone 4, 12 in Zone 6, 16 in Zone 7, and seven in Zone 8. They were captured in all sampling months, except May and June. YOY fish were found from July through September. Yearlings and/or older specimens were present in April and July through November (Figure 4-17).

Weakfish

The total catch for weakfish in the 2008 survey was 2,191, accounting for 7.0% of the total finfish catch and representing the fourth largest number of fish caught. This number is comparable to the annual weakfish catches from the same eight zones in 2007 (3,193), 2006 (2,185), 2004 (2,964), 2003 (1,672), 2002 (2,035) and 2000 (1,623), but significantly less than the catches in 2005 (7,644) and 2001 (5,261). Weakfish were found in all eight zones and, as they were in 2007 and 2006, were much more evenly distributed than they had been in 2000-2005 (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). Weakfish were collected in every month except April. However, most of them were taken from July through September (88.6%).

The spawning season for weakfish extends from mid May through early August in the lower Delaware Bay and Indian River Bay (Wang and Kernehan 1979). Connaughton and Taylor (1996) reported spawning in Delaware Bay between mid May and early July or August. The appearance of YOY fish was responsible for the great increase in the weakfish catch totals from July through September (Figure 4-18). These smaller fish were a substantial part of the weakfish collections in these three months.

White perch

Wang and Kernehan (1979) note that white perch is one of the most abundant resident species of the Delaware River Estuary. O'Herron et al. (1994) reported that white perch was the second most abundant species representing 20.6% of the overall catch. Adult white perch are typically semi-anadromous, making their upriver spawning migration in the spring and returning to the lower reaches of the estuary in the fall where they overwinter (Mansueti 1961).

Four hundred six white perch were collected in 2008 accounting for approximately 1.3% of the total finfish catch. This was less than any of the previous catches from 2000 through 2007 (800 in 2000, 478 in 2001, 574 in 2002, 3,037 in 2003, 1,447 in 2004, 904 in 2005, 598 in 2006 and 1,015 in 2007) from the same eight zones (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). White perch were found in all eight zones, except Zone 1. Approximately 92.1% of the white perch collected were located in Zones 5-8 with the most observed in Zone 8.

White perch were collected in every month. The most productive month was April. More moderate numbers were found in May, June, and October. The least productive months were July, August and September. In 2008, YOY were not recruited to the gear until one in August, possibly a few in September and October, and several in November (Figure 4-19).

Blue crab

The blue crab catch for 2008 (1,311) was about 56% of the catch in 2007 (2,354), 35% of the catch in 2006 (3,771) 72% of the catch in 2001 (1,810) and 72% of the catch in 2000 (1,831). However it was about 1.3 times the catch in 2005 (1,044), 1.9 times the catch in 2004 (698) and twice the catch in 2003 (658) from the same area (PSEG 2001, PSEG 2002a, PSEG 2003, PSEG 2004, PSEG 2005, PSEG 2006, PSEG 2007, PSEG 2008). In 2008, blue crabs were caught in all eight zones. However, most of them (89.8%) were captured in Zones 3, 5, 6 and 7. Blue crabs were collected in all months. About 57% them were found May (221), July (213) and October (313) with the rest of them relatively evenly distributed throughout the rest of the sampling months.

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Bottom Trawl Effort Tables

Table 4-1
PSEG Estuary Enhancement Program
Total catch collected by zone using a bottom trawl,
April through November 2008

Family	Common Name	Scientific Name	BZ-1	BZ-2	BZ-3	BZ-4	BZ-5	BZ-6	BZ-7	BZ-8	Total
PORTUNIDAE											
	BLUE CRAB (BLUECLAW)	CALLINECTES SAPIDUS	3	22	208	82	315	480	174	27	1311
SQUALIDAE											
	SPINY DOGFISH	SQUALUS ACANTHIAS	4	4							8
CARCHARHINIDAE											
	SMOOTH DOGFISH	MUSTELUS CANIS	26	14	15	1	3				59
RAJIDAE											
	CLEARNOSE SKATE	RAJA EGLANTERIA	8		2						10
MYLIOBATIDAE											
	BULLNOSE RAY	MYLIOBATIS FREMINVILLEI	1	2							3
ACIPENSERIDAE											
	SHORTNOSE STURGEON	ACIPENSER BREVIROSTRUM								2	2
ANGUILLIDAE											
	AMERICAN EEL	ANGUILLA ROSTRATA				1	1	13	43	80	138
CONGRIDAE											
	CONGER EEL	CONGER OCEANICUS		1							1
ENGRAULIDAE											
	STRIPED ANCHOVY	ANCHOA HEPSETUS	1	1	4					1	7
	BAY ANCHOVY	ANCHOA MITCHILLI	106	4697	4446	1678	449	177	84	122	11759
CLUPEIDAE											
	ATLANTIC MENHADEN	BREVOORTIA TYRANNUS		6	91	1	4	3	3	6	114
	BLUEBACK HERRING	ALOSA AESTIVALIS			1						1
	ALEWIFE	ALOSA PSEUDOHARENGUS				2					2
	AMERICAN SHAD	ALOSA SAPIDISSIMA		2	5		1				8
	ATLANTIC HERRING	CLUPEA HARENGUS		1	3						4
ICTALURIDAE											
	CHANNEL CATFISH	ICTALURUS PUNCTATUS					1		7	60	68
	WHITE CATFISH	AMEIURUS CATUS						1			1
ATHERINOPSIDAE											
	ATLANTIC SILVERSIDE	MENIDIA MENIDIA		1	2						3
GADIDAE											
	SPOTTED HAKE	UROPHYCIS REGIA	68	146	117	63	155	62	7		618
	SILVER HAKE	MERLUCCIUS BILINEARIS	1								1
	RED HAKE	UROPHYCIS CHUSS			3		2				5

Table 4-1 (continued)
PSEG Estuary Enhancement Program
Total catch collected by zone using a bottom trawl,
April through November 2008

Family	Common Name	Scientific Name	BZ-1	BZ-2	BZ-3	BZ-4	BZ-5	BZ-6	BZ-7	BZ-8	Total
BATRACHOIDIDAE											
	OYSTER TOADFISH	OPSANUS TAU	4	1	1		19	50	2		77
OPHIDIIDAE											
	STRIPED CUSK-EEL	OPHIDION MARGINATA	3	6	8	3	57	62	2		141
POMATOMIDAE											
	BLUEFISH	POMATOMUS SALTATRIX			1			1			2
SPARIDAE											
	PINFISH	LAGODON RHOMBOIDES	3		1						4
	SCUP	STENOTOMUS CHRYSOPS	37	25	7	34	21				124
SCIAENIDAE											
	WEAKFISH	CYNOSCION REGALIS	51	484	222	139	441	522	187	145	2191
	SILVER PERCH	BAIRDIELLA CHRYSOURA	2	10	1	3	9	4	3	7	39
	SPOT	LEIOSTOMUS XANTHURUS	37	802	136	124	201	77	10	66	1453
	NORTHERN KINGFISH	MENTICIRRHUS SAXATILIS	2	10		1			2		15
	ATLANTIC CROAKER	MICROPOGONIAS UNDULATUS	220	774	2236	247	481	609	766	1694	7027
	BLACK DRUM	POGONIAS CROMIS			1		3	3			7
URANOSCOPIDAE											
	NORTHERN STARGAZER	ASTROSCOPUS GUTTATUS						1			1
GOBIIDAE											
	NAKED GOBY	GOBIOSOMA BOSC								5	5
STROMATEIDAE											
	BUTTERFISH	PEPRILUS TRIACANTHUS	22	17	19	15	3	1			77
BOTHIDAE											
	SUMMER FLOUNDER	PARALICHTHYS DENTATUS	1	2	3	2	6	2	3		19
	WINDOWPANE	SCOPHTHALMUS AQUOSUS	4	4	15	2	6	2			33
	SMALLMOUTH FLOUNDER	ETROPUS MICROSTOMUS	7	4	1	1	1				14
SOLEIDAE											
	HOGCHOKER	TRINECTES MACULATUS	18	170	83	118	164	809	2512	2885	6759
	BLACKCHEEK TONGUEFISH	SYMPHURUS PLAGIUSA					1	1			2
TETRAODONTIDAE											
	NORTHERN PUFFER	SPHOEROIDES MACULATUS		1							1
CARANGIDAE											
	BLUE RUNNER	CARANX CRYSOS	1			5					6
	ATLANTIC MOONFISH	SELENE SETAPINNIS	1	3	4	6					14
	LOOKDOWN	SELENE VOMER		1		1					2

Table 4-1 (continued)
PSEG Estuary Enhancement Program
Total catch collected by zone using a bottom trawl, April through November 2008

Family	Common Name	Scientific Name	BZ-1	BZ-2	BZ-3	BZ-4	BZ-5	BZ-6	BZ-7	BZ-8	Total
TRICHIURIDAE											
	ATLANTIC CUTLASSFISH	TRICHIURUS LEPTURUS		1							1
SYNGNATHIDAE											
	LINED SEAHORSE	HIPPOCAMPUS ERECTUS			4						4
	NORTHERN PIPEFISH	SYNGNATHUS FUSCUS		5	9	4	2	2			22
TRIGLIDAE											
	NORTHERN SEAROBIN	PRIONOTUS CAROLINUS	17		14	13	58	2			104
	STRIPED SEAROBIN	PRIONOTUS EVOLANS	1	3			1				5
PERCICHTHYIDAE											
	WHITE PERCH	MORONE AMERICANA		2	16	14	26	57	125	166	406
	STRIPED BASS	MORONE SAXATILIS			2	1		12	16	7	38
SERRANIDAE											
	BLACK SEA BASS	CENTROPRISTIS STRIATA	2	2		1	4	3			12
CYPRINIDAE											
	EASTERN SILVERY MINNOW	HYBOGNATHUS REGIS								1	1
		TOTAL CATCH	651	7224	7681	2562	2435	2956	3946	5274	32729

Table 4-2
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 1 using a bottom trawl
April - November 2008

Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	CPUE
ATLANTIC CROAKER					5	7	157	51	**220**	**6.88**
ATLANTIC MOONFISH				1					**1**	**0.03**
BAY ANCHOVY	6			61	4		26	9	**106**	**3.31**
BLACK SEA BASS			1			1			**2**	**0.06**
BLUE CRAB (BLUECLAW)	2							1	**3**	**0.09**
BLUE RUNNER							1		**1**	**0.03**
BULLNOSE RAY					1				**1**	**0.03**
BUTTERFISH		1		3	6	10	2		**22**	**0.69**
CLEARNOSE SKATE		2		1	1	4			**8**	**0.25**
HOGCHOKER						10	1	7	**18**	**0.56**
NORTHERN KINGFISH						2			**2**	**0.06**
NORTHERN SEAROBIN	1	4	1		11				**17**	**0.53**
OYSTER TOADFISH	1						3		**4**	**0.13**
PINFISH		3							**3**	**0.09**
SCUP			1	13	18	5			**37**	**1.16**
SILVER HAKE	1								**1**	**0.03**
SILVER PERCH								2	**2**	**0.06**
SMALLMOUTH FLOUNDER			1			4	1	1	**7**	**0.22**
SMOOTH DOGFISH		1	4		2	19			**26**	**0.81**
SPINY DOGFISH	3							1	**4**	**0.13**
SPOT		8			1	3	19	6	**37**	**1.16**
SPOTTED HAKE	2	38	6	3			8	11	**68**	**2.13**
STRIPED ANCHOVY				1					**1**	**0.03**
STRIPED CUSK-EEL								3	**3**	**0.09**
STRIPED SEAROBIN								1	**1**	**0.03**
SUMMER FLOUNDER		1							**1**	**0.03**
WEAKFISH		8			18	8	9	8	**51**	**1.59**
WINDOWPANE	1	1				1		1	**4**	**0.13**
Total Finfish Collected	17	67	14	83	67	74	227	102	**651**	
Trawls per Month	4	4	4	4	4	4	4	4	**32**	
Total CPUE	4.3	16.8	3.5	20.8	16.8	18.5	56.8	25.5	**20.3**	

Table 4-3
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 2 using a bottom trawl
April - November 2008

Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	CPUE
AMERICAN SHAD	1	1							**2**	**0.04**
ATLANTIC CROAKER				6	211	62	76	419	**774**	**16.13**
ATLANTIC CUTLASSFISH				1					**1**	**0.02**
ATLANTIC MENHADEN		1				3		2	**6**	**0.13**
ATLANTIC MOONFISH				2			1		**3**	**0.06**
ATLANTIC HERRING	1								**1**	**0.02**
ATLANTIC SILVERSIDE								1	**1**	**0.02**
BAY ANCHOVY	604	890	195	2503	15	7	160	323	**4697**	**97.85**
BLACK SEA BASS	1	1							**2**	**0.04**
BLUE CRAB (BLUECLAW)	2		1	3	3	6	1	6	**22**	**0.46**
BULLNOSE RAY				2					**2**	**0.04**
BUTTERFISH				8	4	3	2		**17**	**0.35**
CONGER EEL							1		**1**	**0.02**
HOGCHOKER	4	82	8	1	16	43	3	13	**170**	**3.54**
LOOKDOWN								1	**1**	**0.02**
NORTHERN KINGFISH		2				8			**10**	**0.21**
NORTHERN PIPEFISH	1				1	1	1	1	**5**	**0.10**
NORTHERN PUFFER					1				**1**	**0.02**
OYSTER TOADFISH							1		**1**	**0.02**
SCUP			5		20				**25**	**0.52**
SILVER PERCH					4	2	4		**10**	**0.21**
SMALLMOUTH FLOUNDER	2				1	1			**4**	**0.08**
SMOOTH DOGFISH			3	4	2	4	1		**14**	**0.29**
SPINY DOGFISH	1							3	**4**	**0.08**
SPOT		4		417	124	178	16	63	**802**	**16.71**
SPOTTED HAKE	15	106	12	1			1	11	**146**	**3.04**
STRIPED ANCHOVY			1						**1**	**0.02**
STRIPED CUSK-EEL				1		5			**6**	**0.13**
STRIPED SEAROBIN								3	**3**	**0.06**
SUMMER FLOUNDER					2				**2**	**0.04**
WEAKFISH		13	58	196	146	42	16	13	**484**	**10.08**
WHITE PERCH								2	**2**	**0.04**
WINDOWPANE	3					1			**4**	**0.08**
Total Finfish Collected	635	1100	283	3145	550	366	284	861	**7224**	
Trawls per Month	6	6	6	6	6	6	6	6	**48**	
Total CPUE	105.8	183.3	47.2	524.2	91.7	61.0	47.3	143.5	**150.5**	

Table 4-4
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 3 using a bottom trawl
April - November 2008

Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	CPUE
AMERICAN SHAD	1	1					1	2	**5**	**0.08**
ATLANTIC CROAKER		2	6	1294	1	204	287	442	**2236**	**34.94**
ATLANTIC HERRING	2	1							**3**	**0.05**
ATLANTIC MENHADEN	2		87		1			1	**91**	**1.42**
ATLANTIC MOONFISH					4				**4**	**0.06**
ATLANTIC SILVERSIDE							2		**2**	**0.03**
BAY ANCHOVY	398	461	269	805	34	211	544	1724	**4446**	**69.47**
BLACK DRUM		1							**1**	**0.02**
BLUEBACK HERRING							1		**1**	**0.02**
BLUE CRAB (BLUECLAW)	8	7	6	4	2	3	168	10	**208**	**3.25**
BLUEFISH				1					**1**	**0.02**
BUTTERFISH		1		8	1	9			**19**	**0.30**
CLEARNOSE SKATE		2							**2**	**0.03**
HOGCHOKER		44		17	1	19	2		**83**	**1.30**
LINED SEAHORSE		3	1						**4**	**0.06**
NORTHERN PIPEFISH	1	1		4		3			**9**	**0.14**
NORTHERN SEAROBIN	1	9		3		1			**14**	**0.22**
OYSTER TOADFISH							1		**1**	**0.02**
PINFISH		1							**1**	**0.02**
RED HAKE								3	**3**	**0.05**
SCUP			2	4	1				**7**	**0.11**
SILVER PERCH								1	**1**	**0.02**
SMALLMOUTH FLOUNDER								1	**1**	**0.02**
SMOOTH DOGFISH		15							**15**	**0.23**
SPOT		1	3	7		107	12	6	**136**	**2.13**
SPOTTED HAKE	4	101				2	7	3	**117**	**1.83**
STRIPED ANCHOVY			1	1	2				**4**	**0.06**
STRIPED BASS							1	1	**2**	**0.03**
STRIPED CUSK-EEL				2		2	2	2	**8**	**0.13**
SUMMER FLOUNDER		1	1					1	**3**	**0.05**
WEAKFISH		6	7	132	6	71			**222**	**3.47**
WHITE PERCH							7	9	**16**	**0.25**
WINDOWPANE		14				1			**15**	**0.23**
Total Finfish Collected	417	672	383	2282	53	633	1035	2206	**7681**	
Trawls per Month	8	8	8	8	8	8	8	8	**64**	
Total CPUE	52.1	84.0	47.9	285.3	6.6	79.1	129.4	275.8	**120.0**	

Table 4-5
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 4 using a bottom trawl
April - November 2008

Common Name	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**	**CPUE**
ALEWIFE	1	1							**2**	**0.04**
AMERICAN EEL			1						**1**	**0.02**
ATLANTIC CROAKER		29		5	11	102	82	18	**247**	**5.15**
ATLANTIC MENHADEN			1						**1**	**0.02**
ATLANTIC MOONFISH					6				**6**	**0.13**
BAY ANCHOVY	386	91	203	282	76	412	143	85	**1678**	**34.96**
BLACK SEA BASS				1					**1**	**0.02**
BLUE CRAB (BLUECLAW)	4	63	5	2	2		2	4	**82**	**1.71**
BLUE RUNNER					4	1			**5**	**0.10**
BUTTERFISH	3	1			4	7			**15**	**0.31**
HOGCHOKER		91		3	1	3	6	14	**118**	**2.46**
LOOKDOWN						1			**1**	**0.02**
NORTHERN KINGFISH						1			**1**	**0.02**
NORTHERN PIPEFISH		2			1		1		**4**	**0.08**
NORTHERN SEAROBIN	1	11			1				**13**	**0.27**
SCUP			7	8	17	2			**34**	**0.71**
SILVER PERCH							3		**3**	**0.06**
SMALLMOUTH FLOUNDER		1							**1**	**0.02**
SMOOTH DOGFISH				1					**1**	**0.02**
SPOT			1	8	6	24	54	31	**124**	**2.58**
SPOTTED HAKE	17	45					1		**63**	**1.31**
STRIPED BASS								1	**1**	**0.02**
STRIPED CUSK-EEL		3							**3**	**0.06**
SUMMER FLOUNDER	1		1						**2**	**0.04**
WEAKFISH		1	19	41	42	32	3	1	**139**	**2.90**
WHITE PERCH	1	3						10	**14**	**0.29**
WINDOWPANE		1					1		**2**	**0.04**
Total Finfish Collected	414	343	238	351	171	585	296	164	**2562**	
Trawls per Month	6	6	6	6	6	6	6	6	**48**	
Total CPUE	69.0	57.2	39.7	58.5	28.5	97.5	49.3	27.3	**53.4**	

Table 4-5
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 4 using a bottom trawl
April - November 2008

Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	CPUE
ALEWIFE	1	1							**2**	**0.04**
AMERICAN EEL			1						**1**	**0.02**
ATLANTIC CROAKER		29		5	11	102	82	18	**247**	**5.15**
ATLANTIC MENHADEN			1						**1**	**0.02**
ATLANTIC MOONFISH					6				**6**	**0.13**
BAY ANCHOVY	386	91	203	282	76	412	143	85	**1678**	**34.96**
BLACK SEA BASS				1					**1**	**0.02**
BLUE CRAB (BLUECLAW)	4	63	5	2	2		2	4	**82**	**1.71**
BLUE RUNNER					4	1			**5**	**0.10**
BUTTERFISH	3	1			4	7			**15**	**0.31**
HOGCHOKER		91		3	1	3	6	14	**118**	**2.46**
LOOKDOWN						1			**1**	**0.02**
NORTHERN KINGFISH						1			**1**	**0.02**
NORTHERN PIPEFISH		2			1		1		**4**	**0.08**
NORTHERN SEAROBIN	1	11			1				**13**	**0.27**
SCUP			7	8	17	2			**34**	**0.71**
SILVER PERCH							3		**3**	**0.06**
SMALLMOUTH FLOUNDER		1							**1**	**0.02**
SMOOTH DOGFISH				1					**1**	**0.02**
SPOT			1	8	6	24	54	31	**124**	**2.58**
SPOTTED HAKE	17	45					1		**63**	**1.31**
STRIPED BASS								1	**1**	**0.02**
STRIPED CUSK-EEL		3							**3**	**0.06**
SUMMER FLOUNDER	1		1						**2**	**0.04**
WEAKFISH		1	19	41	42	32	3	1	**139**	**2.90**
WHITE PERCH	1	3						10	**14**	**0.29**
WINDOWPANE		1					1		**2**	**0.04**
Total Finfish Collected	414	343	238	351	171	585	296	164	**2562**	
Trawls per Month	6	6	6	6	6	6	6	6	**48**	
Total CPUE	69.0	57.2	39.7	58.5	28.5	97.5	49.3	27.3	**53.4**	

Table 4-6
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 5 using a bottom trawl
April - November 2008

Common Name	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**	**CPUE**
AMERICAN EEL		1							**1**	**0.03**
AMERICAN SHAD								1	**1**	**0.03**
ATLANTIC CROAKER	1	1	18	217	126	49	66	3	**481**	**15.03**
ATLANTIC MENHADEN	1				1	2			**4**	**0.13**
BAY ANCHOVY	15	88	65	11	219	7	6	38	**449**	**14.03**
BLACKCHEEK TOUNGEFISH	1								**1**	**0.03**
BLACK DRUM								3	**3**	**0.09**
BLACK SEA BASS		2		1				1	**4**	**0.13**
BLUE CRAB (BLUECLAW)	79	30	13	87	15	8	61	22	**315**	**9.84**
BUTTERFISH						3			**3**	**0.09**
CHANNEL CATFISH	1								**1**	**0.03**
HOGCHOKER	2	77		11	3	11	38	22	**164**	**5.13**
NORTHERN PIPEFISH		1	1						**2**	**0.06**
NORTHERN SEAROBIN	3	51	4						**58**	**1.81**
OYSTER TOADFISH	1	3	3			6	4	2	**19**	**0.59**
RED HAKE								2	**2**	**0.06**
SCUP			4	1		7	9		**21**	**0.66**
SILVER PERCH					2	2	5		**9**	**0.28**
SMALLMOUTH FLOUNDER		1							**1**	**0.03**
SMOOTH DOGFISH					1	1	1		**3**	**0.09**
SPOT				43	82	42	18	16	**201**	**6.28**
SPOTTED HAKE	38	117							**155**	**4.84**
STRIPED CUSK-EEL		3		28	8	5	10	3	**57**	**1.78**
STRIPED SEAROBIN								1	**1**	**0.03**
SUMMER FLOUNDER	1	2			1		2		**6**	**0.19**
WEAKFISH		3	2	254	122	38	22		**441**	**13.78**
WHITE PERCH	10	1					2	13	**26**	**0.81**
WINDOWPANE	1	5							**6**	**0.19**
Total Finfish Collected	154	386	110	653	580	181	244	127	**2435**	
Trawls per Month	4	4	4	4	4	4	4	4	**32**	
Total CPUE	38.5	96.5	27.5	163.3	145.0	45.3	61.0	31.8	**76.1**	

Table 4-7
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 6 using a bottom trawl
April - November 2008

Common Name	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**	**CPUE**
AMERICAN EEL	2	5	1		4		1		**13**	**0.41**
ATLANTIC CROAKER	36	4	111	89	92	37	209	31	**609**	**19.03**
ATLANTIC MENHADEN						1	2		**3**	**0.09**
BAY ANCHOVY	3	1	3	62	2	4	98	4	**177**	**5.53**
BLACKCHEEK TOUNGUEFISH							1		**1**	**0.03**
BLACK DRUM						1		2	**3**	**0.09**
BLACK SEA BASS	1					2			**3**	**0.09**
BLUE CRAB (BLUECLAW)	16	67	72	103	62	93	46	21	**480**	**15.00**
BLUEFISH					1				**1**	**0.03**
BUTTERFISH						1			**1**	**0.03**
HOGCHOKER	72	281	32	21	145	80	139	39	**809**	**25.28**
NORTHERN PIPEFISH				1			1		**2**	**0.06**
NORTHERN SEAROBIN	1	1							**2**	**0.06**
NORTHERN STARGAZER				1					**1**	**0.03**
OYSTER TOADFISH	9	4	1		13	19	4		**50**	**1.56**
SILVER PERCH							4		**4**	**0.13**
SPOT				6	27	26	15	3	**77**	**2.41**
SPOTTED HAKE	26	34						2	**62**	**1.94**
STRIPED BASS	4			2		2	4		**12**	**0.38**
STRIPED CUSK-EEL	1		14	3	21	14	9		**62**	**1.94**
SUMMER FLOUNDER				1	1				**2**	**0.06**
WEAKFISH			1	359	100	42	20		**522**	**16.31**
WHITE CATFISH		1							**1**	**0.03**
WHITE PERCH	25	8				1	7	16	**57**	**1.78**
WINDOWPANE	1	1							**2**	**0.06**
Total Finfish Collected	197	407	235	648	468	323	560	118	**2956**	
Trawls per Month	4	4	4	4	4	4	4	4	**32**	
Total CPUE	49.3	101.8	58.8	162.0	117.0	80.8	140.0	29.5	**92.4**	

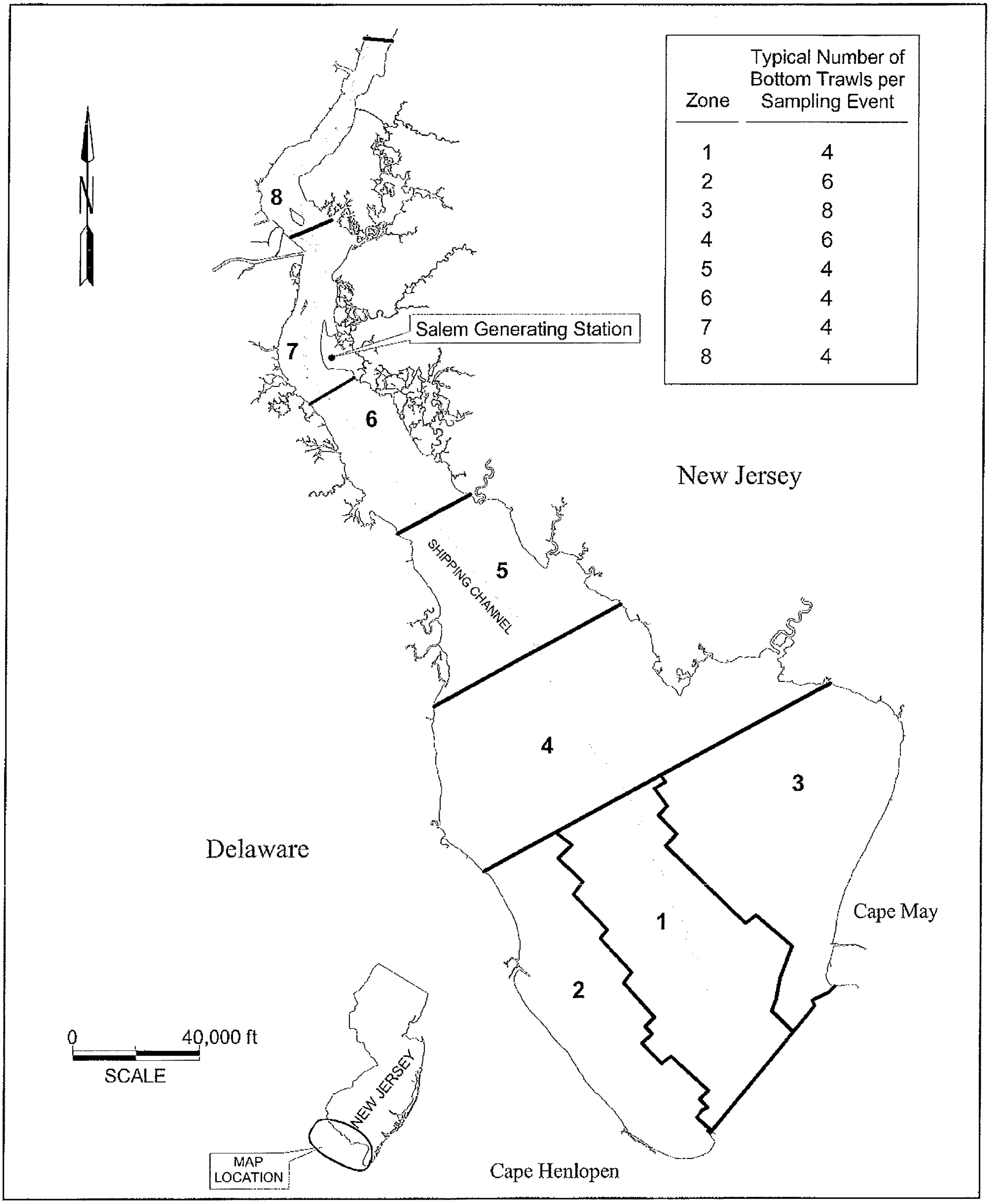
Table 4-8
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 7 using a bottom trawl
April - November 2008

Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	CPUE
AMERICAN EEL	4	7	1	6	1	6	14	4	**43**	**1.34**
ATLANTIC CROAKER	30	13	320	288	12	7	42	54	**766**	**23.94**
ATLANTIC MENHADEN	3								**3**	**0.09**
BAY ANCHOVY	2	4		4	22	20	31	1	**84**	**2.63**
BLUE CRAB (BLUECLAW)		53	24	12	9	23	31	22	**174**	**5.44**
CHANNEL CATFISH	3			1				3	**7**	**0.22**
HOGCHOKER	981	183	69	172	33	64	592	418	**2512**	**78.50**
NORTHERN KINGFISH								2	**2**	**0.06**
OYSTER TOADFISH				1			1		**2**	**0.06**
SILVER PERCH							3		**3**	**0.09**
SPOT					3	2	4	1	**10**	**0.31**
SPOTTED HAKE		7							**7**	**0.22**
STRIPED BASS	5			2		8		1	**16**	**0.50**
STRIPED CUSK-EEL							2		**2**	**0.06**
SUMMER FLOUNDER		1	1			1			**3**	**0.09**
WEAKFISH				94	20	44	29		**187**	**5.84**
WHITE PERCH	45	7	8	7	1	6	21	30	**125**	**3.91**
Total Finfish Collected	1073	275	423	587	101	181	770	536	**3946**	
Trawls per Month	4	4	4	4	4	4	4	4	**32**	
Total CPUE	268.3	68.8	105.8	146.8	25.3	45.3	192.5	134.0	**123.3**	

Table 4-9
PSEG Estuary Enhancement Program
Total catch and catch per unit effort (CPUE) by month in Zone 8 using a bottom trawl
April - November 2008

Common Name	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**	**CPUE**
AMERICAN EEL		4	5	4	1	35	19	12	**80**	**2.50**
ATLANTIC CROAKER		300	778	387	11	10	97	111	**1694**	**52.94**
ATLANTIC MENHADEN		2				1	3		**6**	**0.19**
BAY ANCHOVY		5		3	6	13	95		**122**	**3.81**
BLUE CRAB (BLUECLAW)		1	4	2	2	4	4	10	**27**	**0.84**
CHANNEL CATFISH	6	19	3	3	2	5	9	13	**60**	**1.88**
EASTERN SILVERY MINNOW		1							**1**	**0.03**
HOGCHOKER	144	576	470	396	20	329	624	326	**2885**	**90.16**
NAKED GOBY		1						4	**5**	**0.16**
SHORTNOSE STURGEON		1	1						**2**	**0.06**
SILVER PERCH						1	6		**7**	**0.22**
SPOT		1				10	55		**66**	**2.06**
STRIPED ANCHOVY						1			**1**	**0.03**
STRIPED BASS				3	2	1	1		**7**	**0.22**
WEAKFISH				64	22	48	11		**145**	**4.53**
WHITE PERCH	19	16	49	2	3	11	24	42	**166**	**5.19**
Total Finfish Collected	169	927	1310	864	69	469	948	518	**5274**	
Trawls per Month	4	4	4	4	4	4	4	4	**32**	
Total CPUE	42.3	231.8	327.5	216.0	17.3	117.3	237.0	129.5	**164.8**	

Bottom Trawl Effort Figures



Zone	Typical Number of Bottom Trawls per Sampling Event
1	4
2	6
3	8
4	6
5	4
6	4
7	4
8	4

Public Service Enterprise Group

Figure 4-1 Delaware Bay Sampling Zones

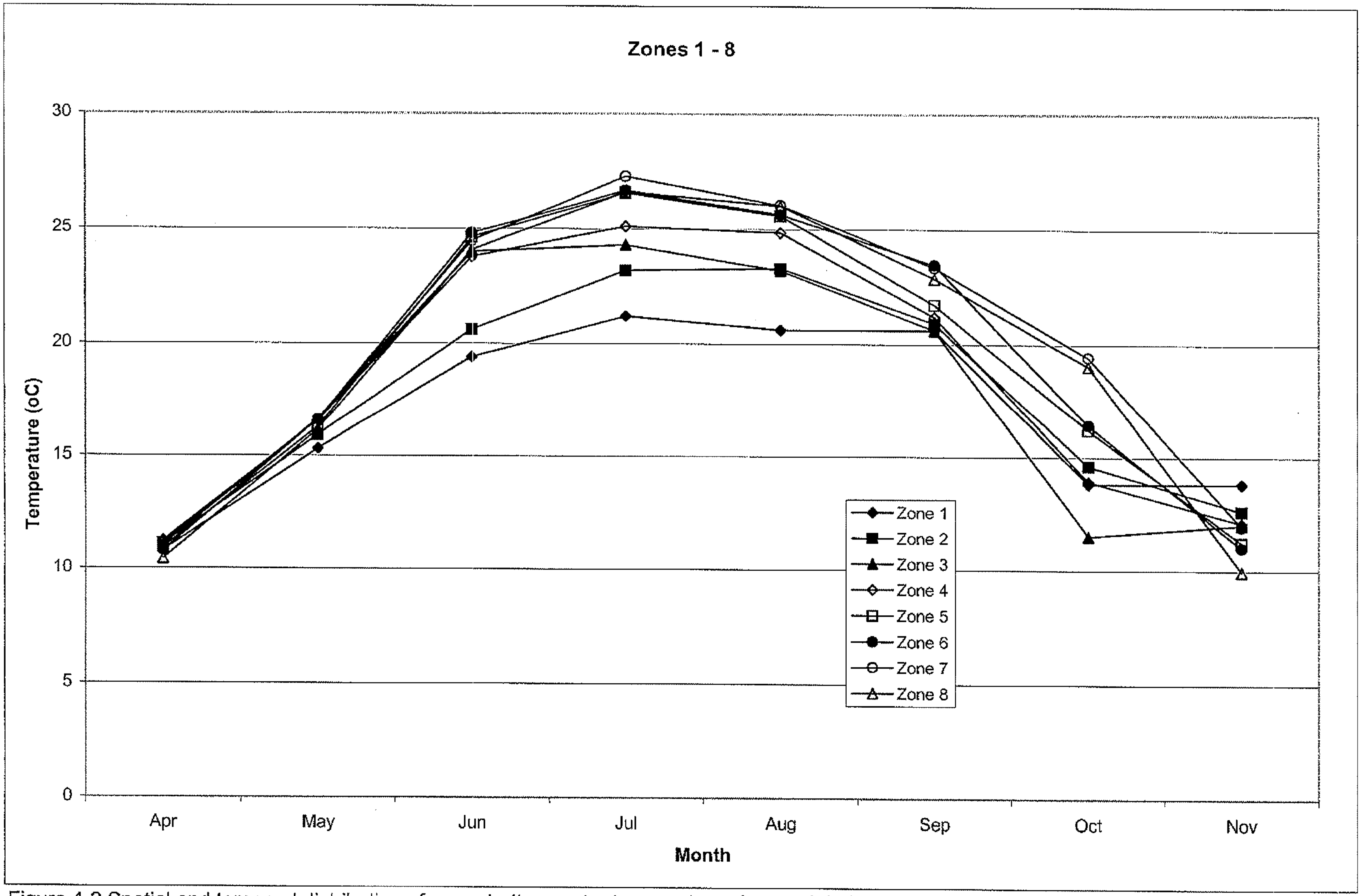


Figure 4-2 Spatial and temporal distribution of mean bottom water temperature observed during the Bottom Trawl Effort, April - November 2008

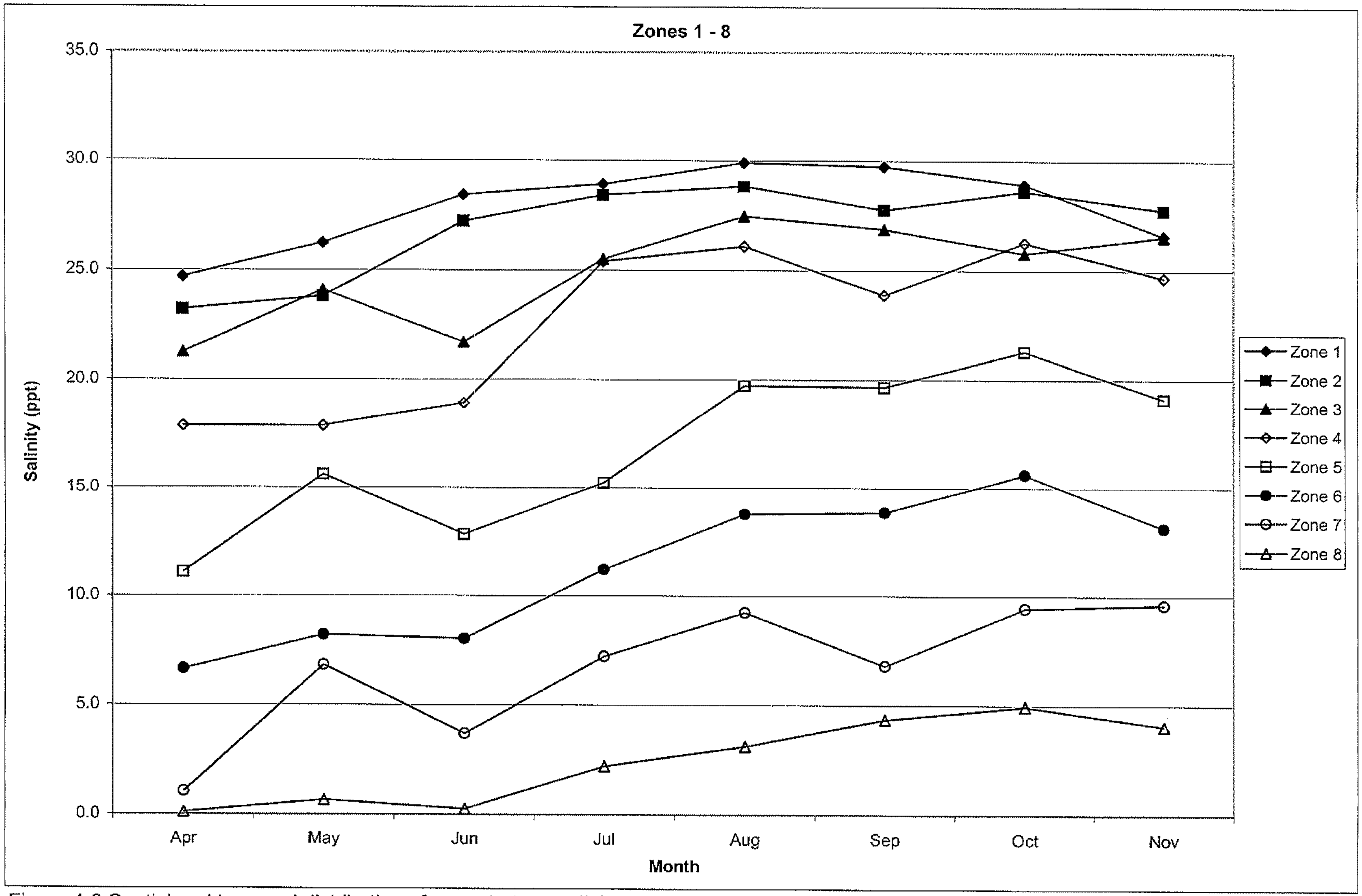


Figure 4-3 Spatial and temporal distribution of mean bottom salinity observed during the Bottom Trawl Effort, April - November 2008

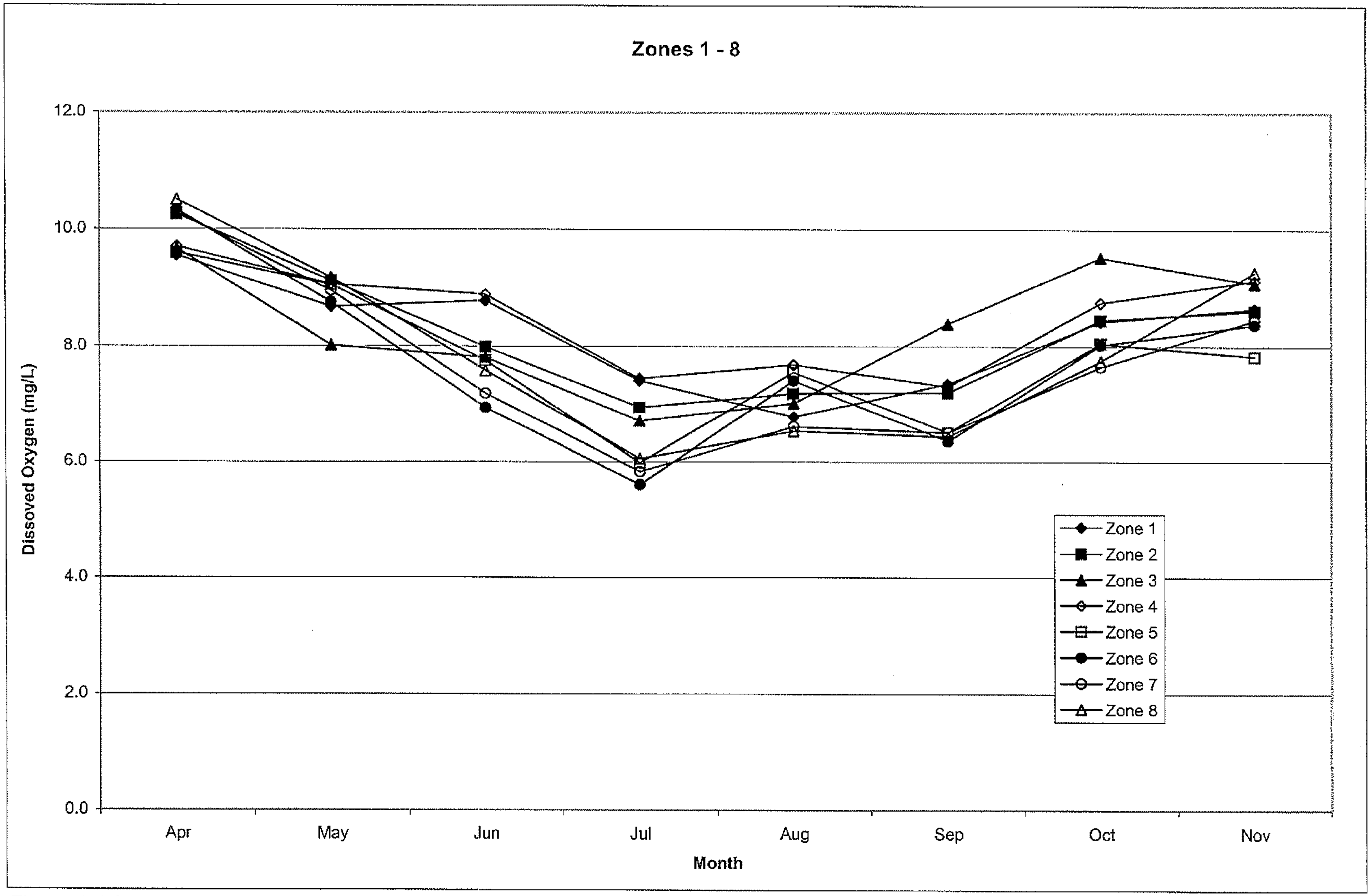


Figure 4-4 Spatial and temporal distribution of mean bottom dissolved oxygen observed during the Bottom Trawl Effort, April - November 2008

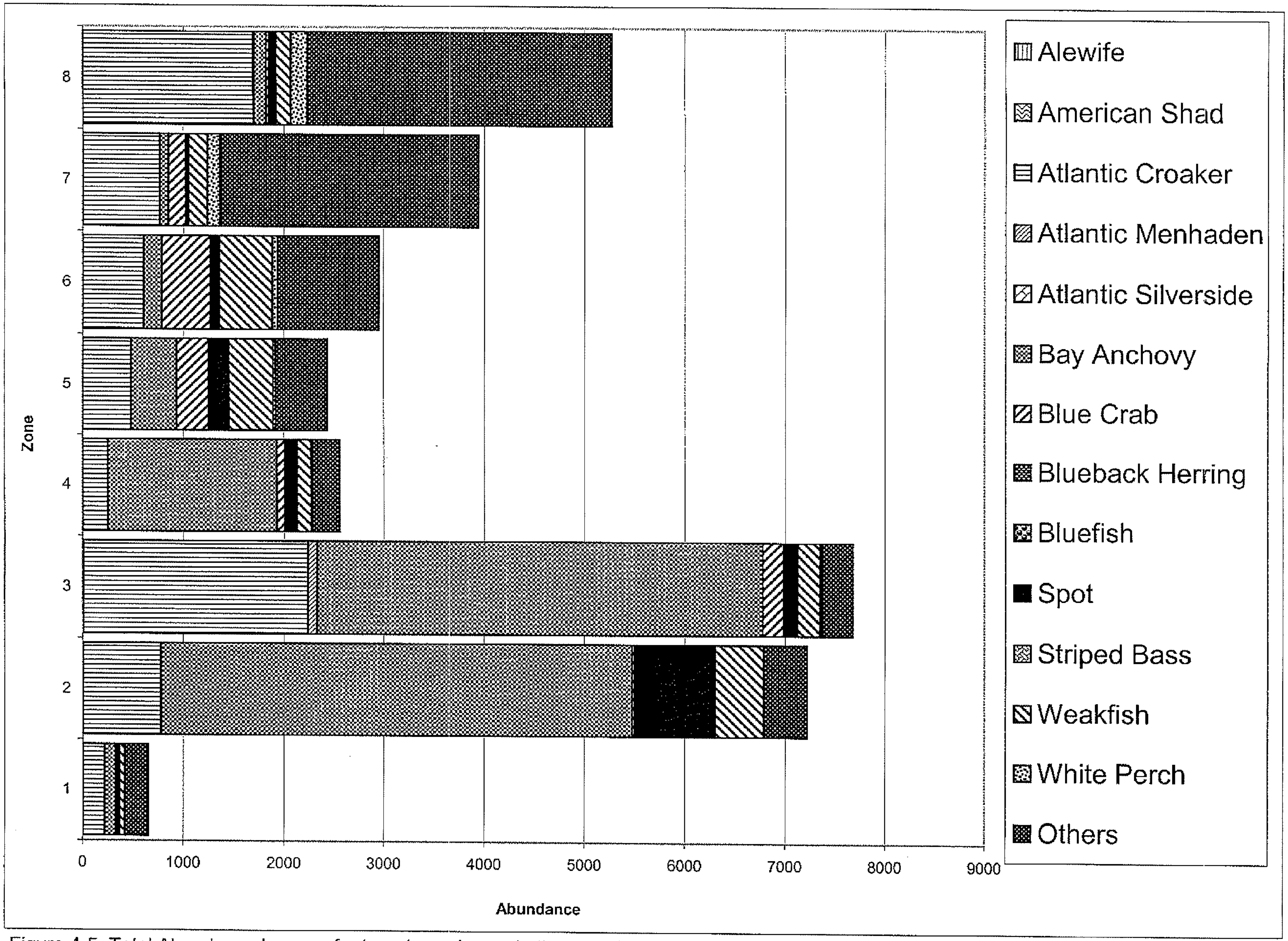
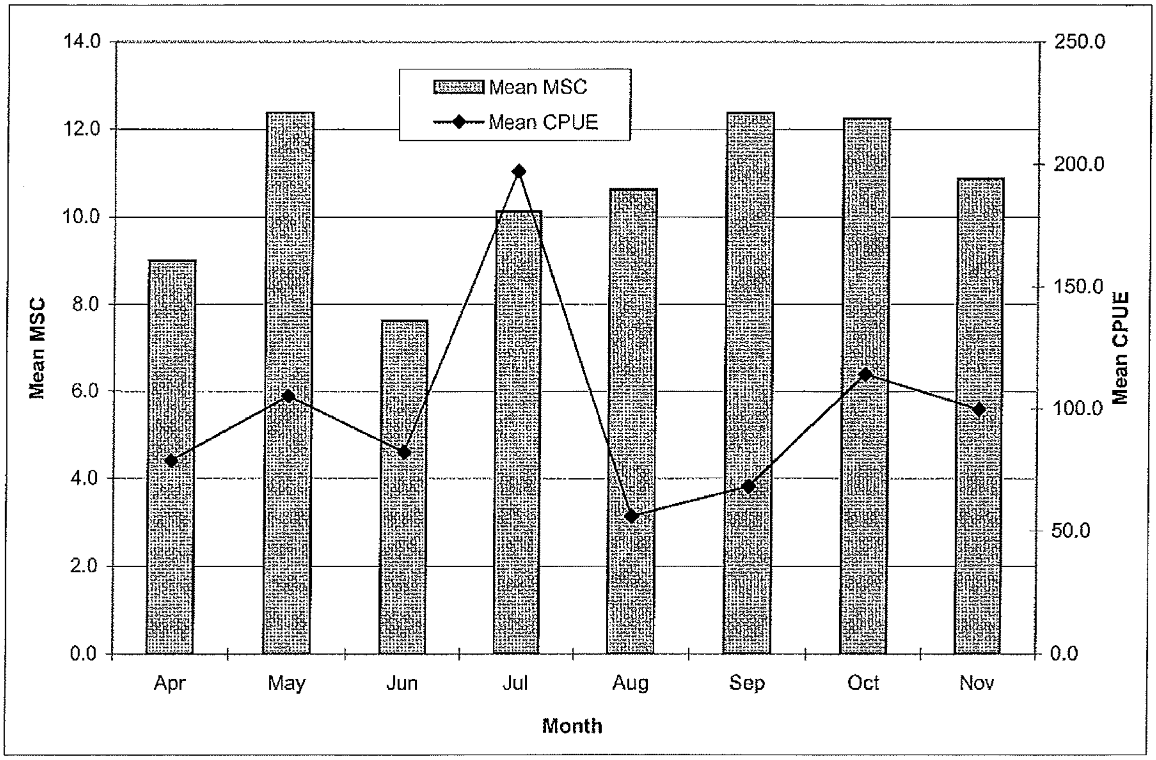
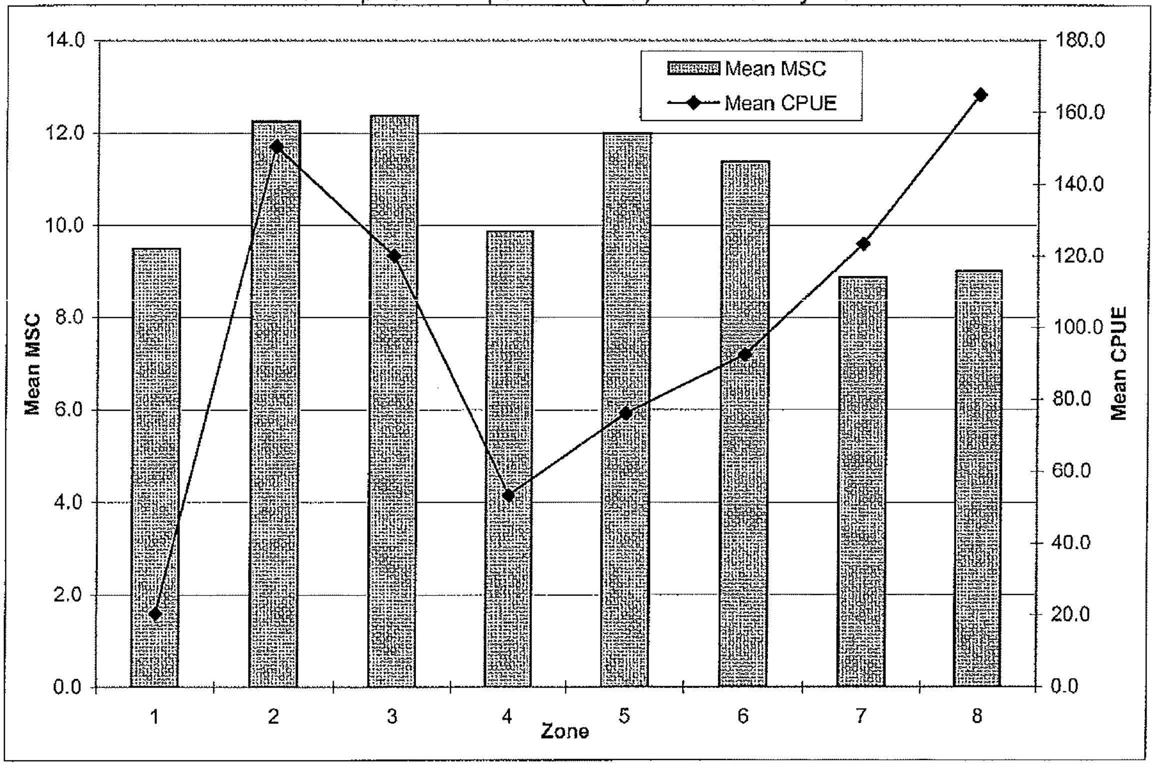


Figure 4-5 Total Abundance by zone for target species and other caught during the Bottom Trawl Effort, April - November 2008



Mean species composition (MSC) and CPUE by Month



Mean species composition (MSC) and CPUE by zone

Figure 4-6 Mean species composition (MSC) and catch per unit effort (CPUE) by zone and by month for all species caught during the Bottom Trawl Effort, April - November 2008

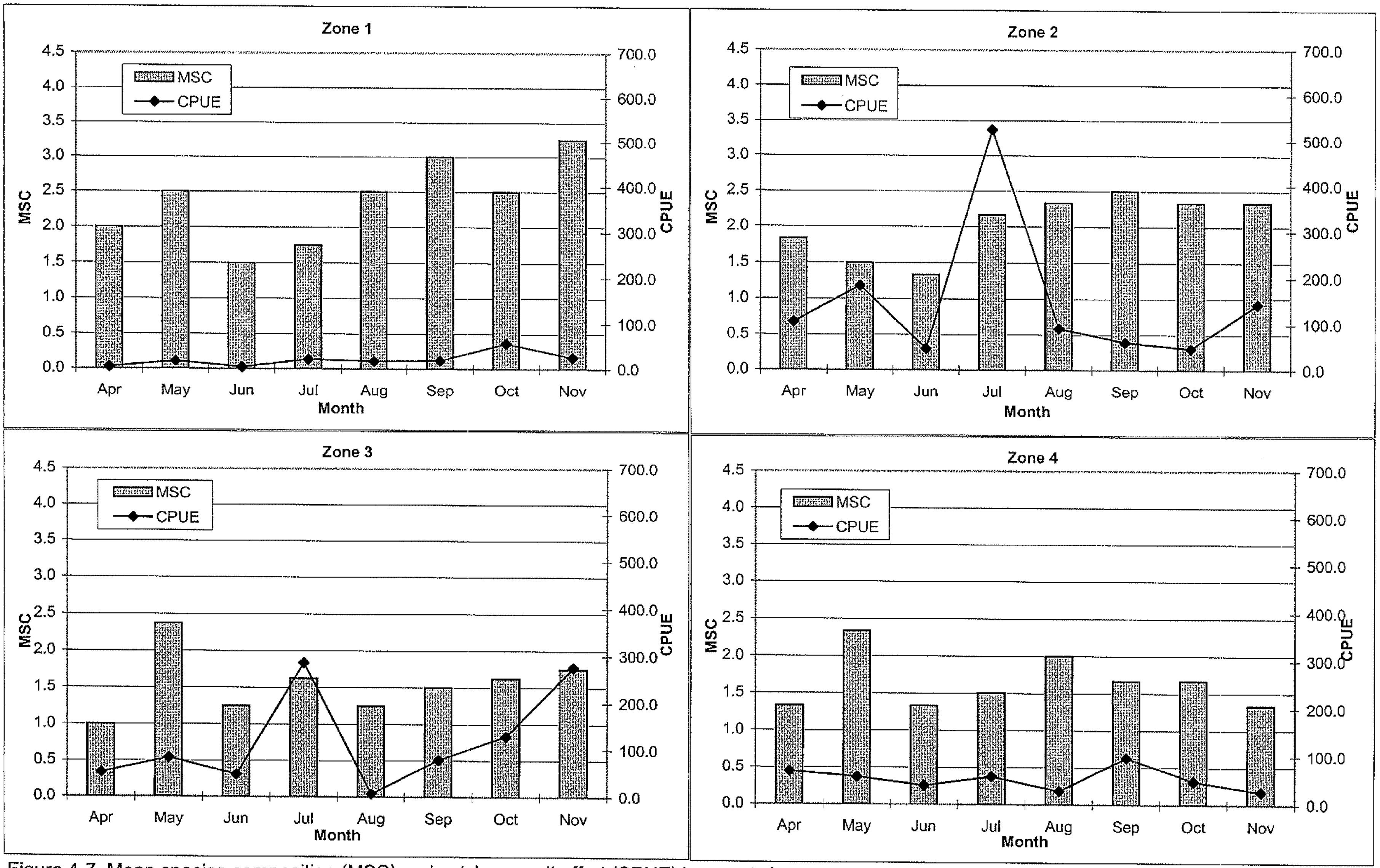


Figure 4-7 Mean species composition (MSC) and catch per unit effort (CPUE) by month for each zone during the Bottom Trawl Effort, April - November 2008

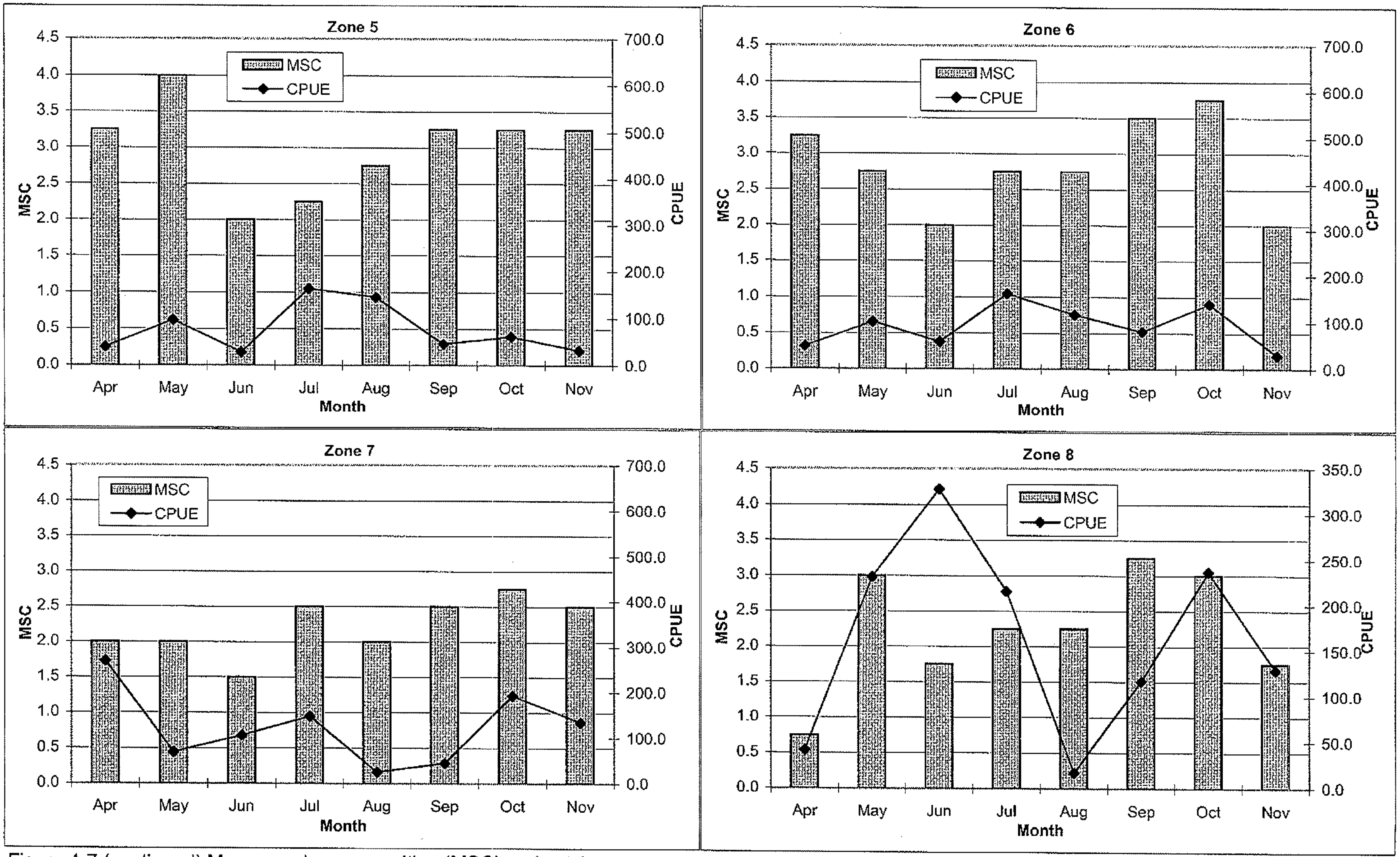


Figure 4-7 (continued) Mean species composition (MSC) and catch per unit effort (CPUE) by month for each zone during the Bottom Trawl Effort, April - November 2008

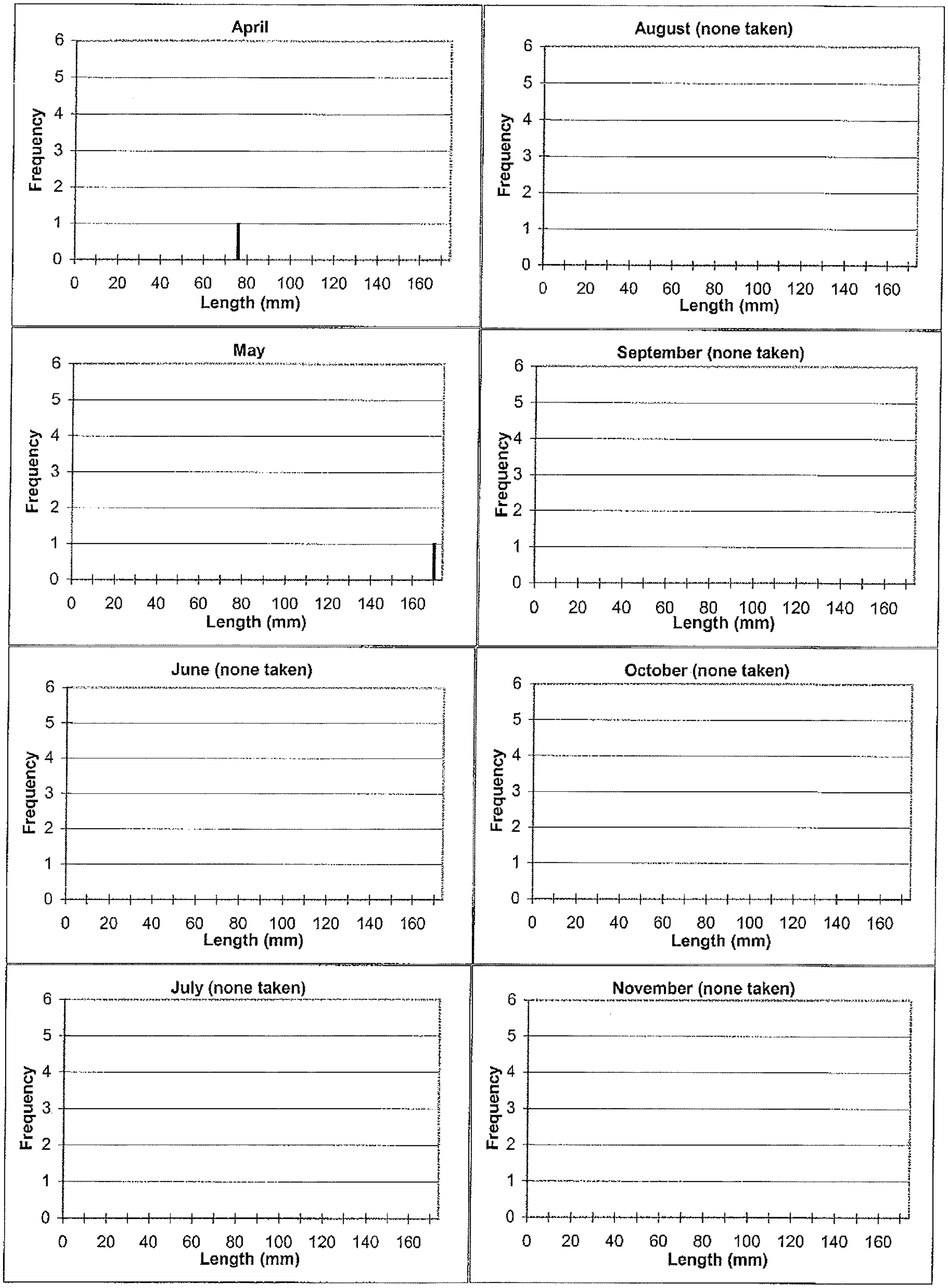


Figure 4-8 Length-frequency distribution of alewife by month during the Bottom Trawl Effort, April - November 2008

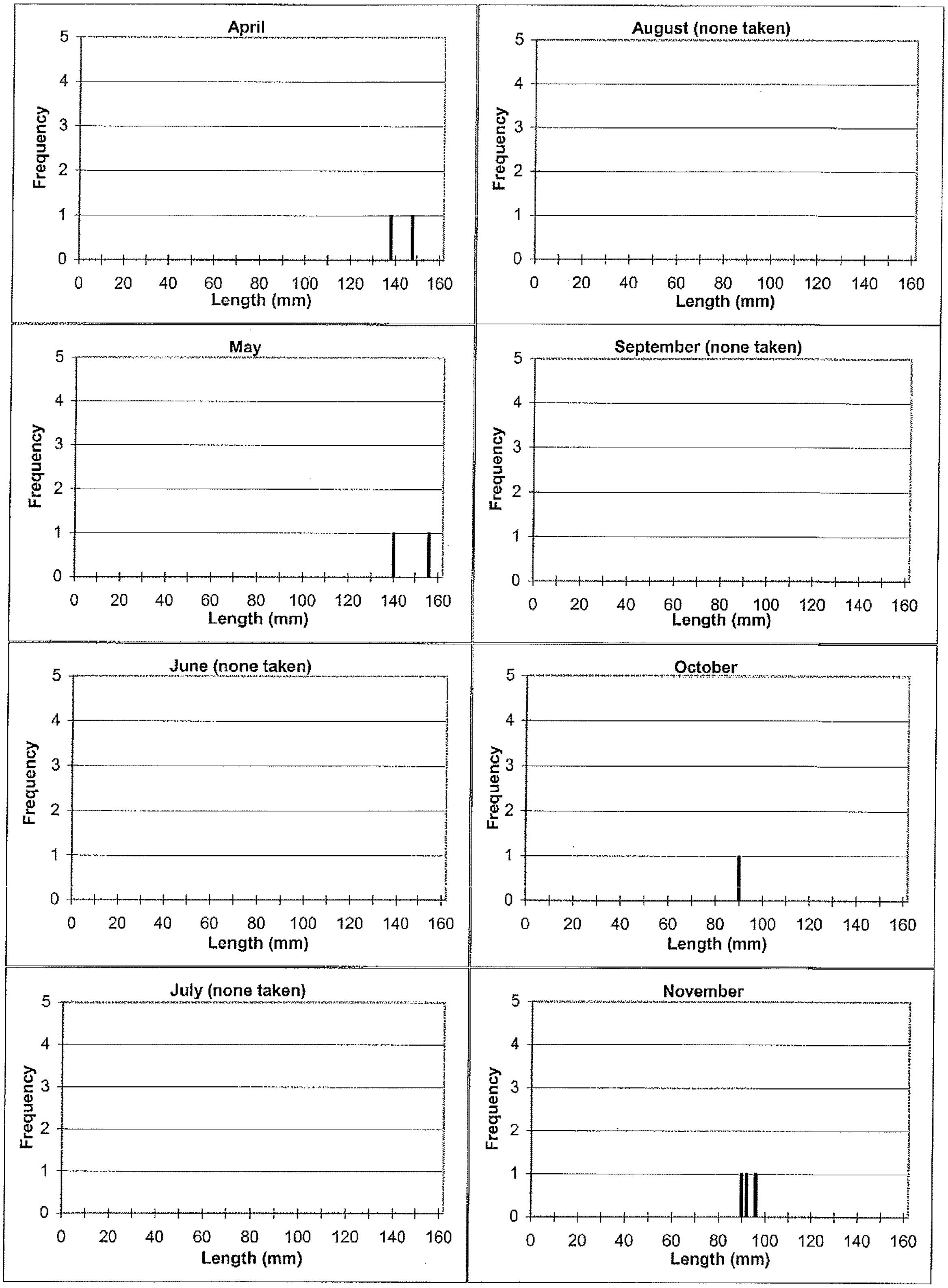


Figure 4-9 Length-frequency distribution of American shad by month during the Bottom Trawl Effort, April - November 2008

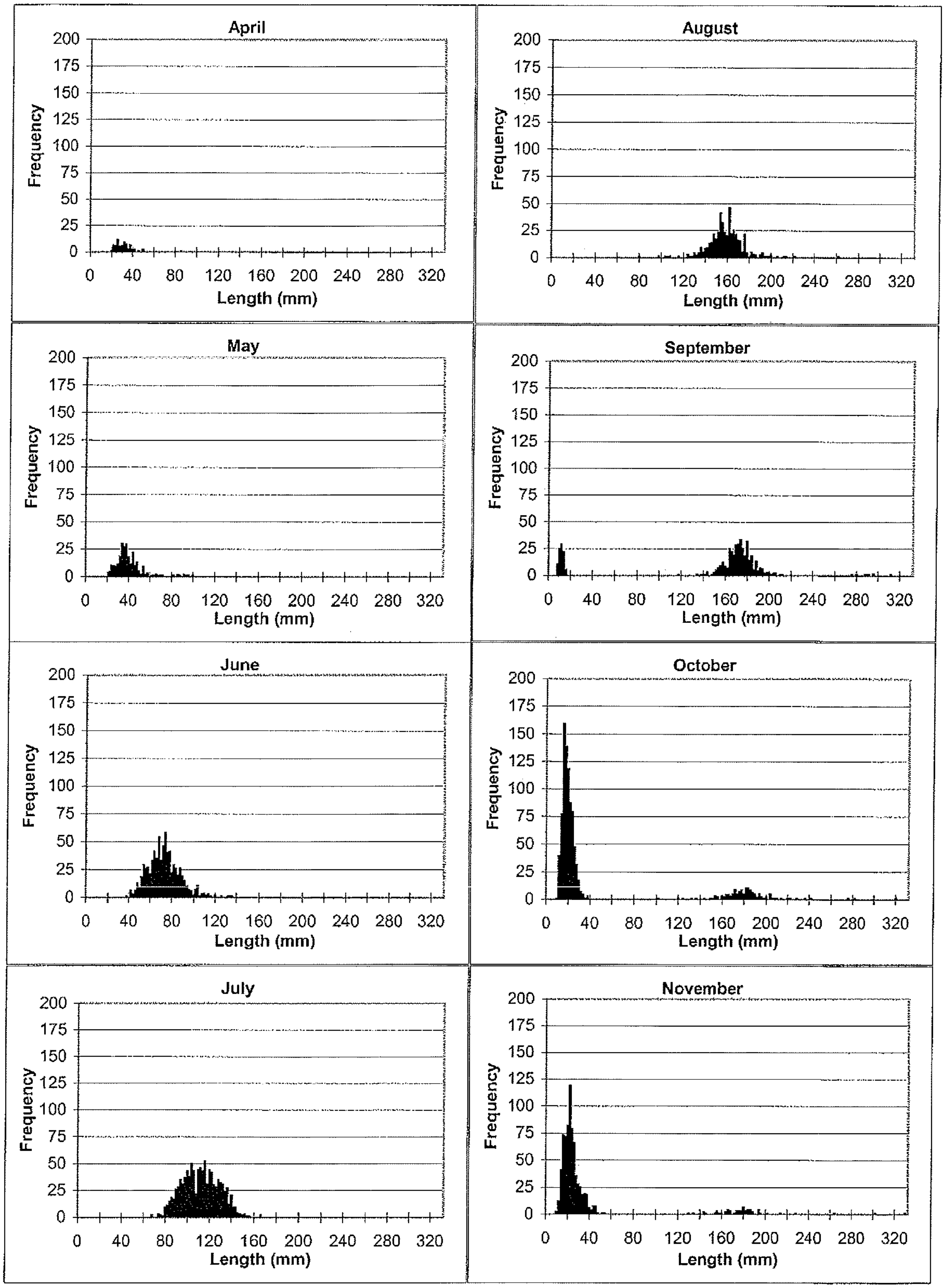


Figure 4-10 Length-Frequency distribution of Atlantic croaker by month during the Bottom Trawl Effort, April - November 2008

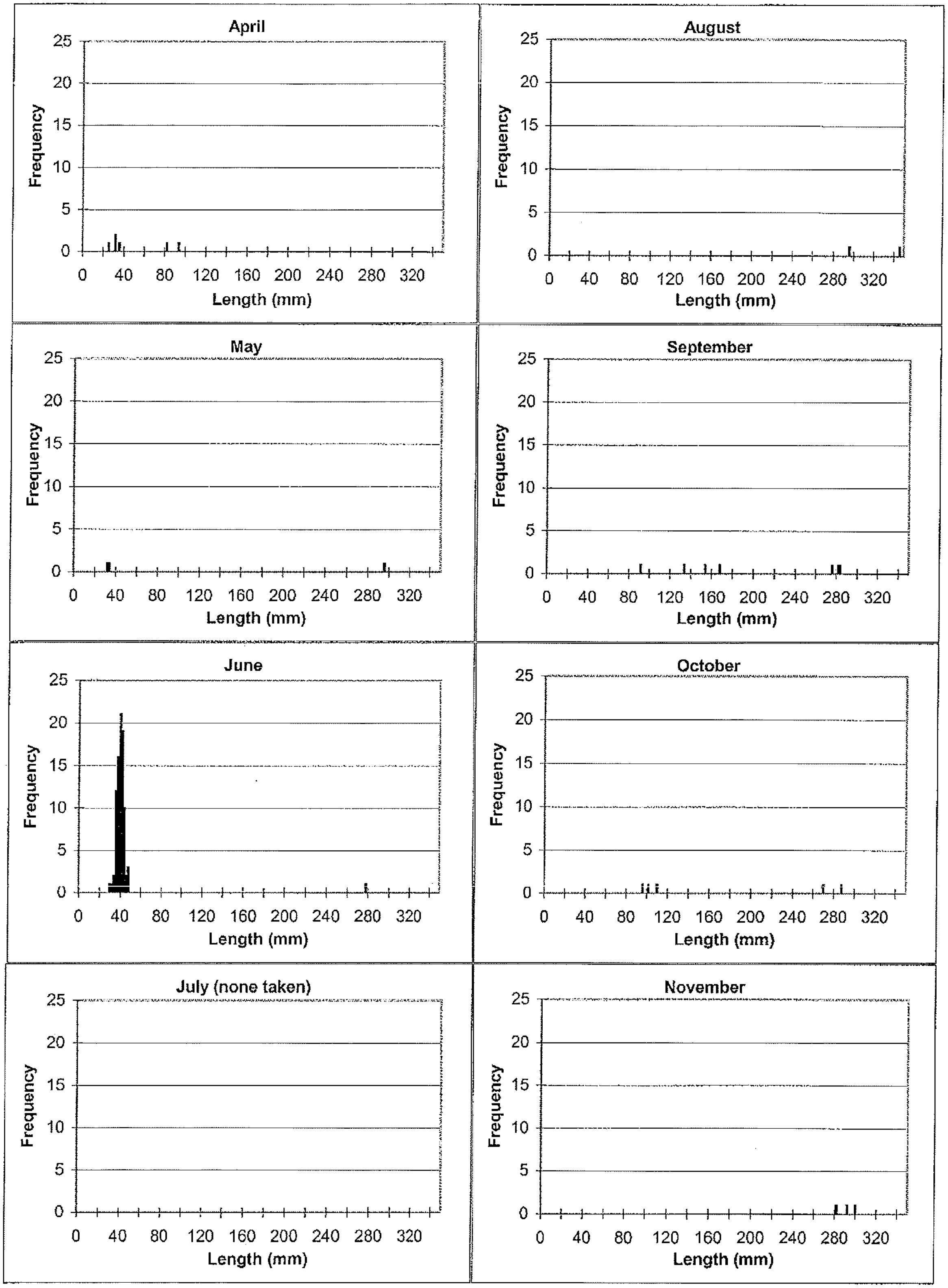


Figure 4-11 Length-Frequency distribution of Atlantic menhaden by month during the Bottom Trawl Effort, April - November 2008

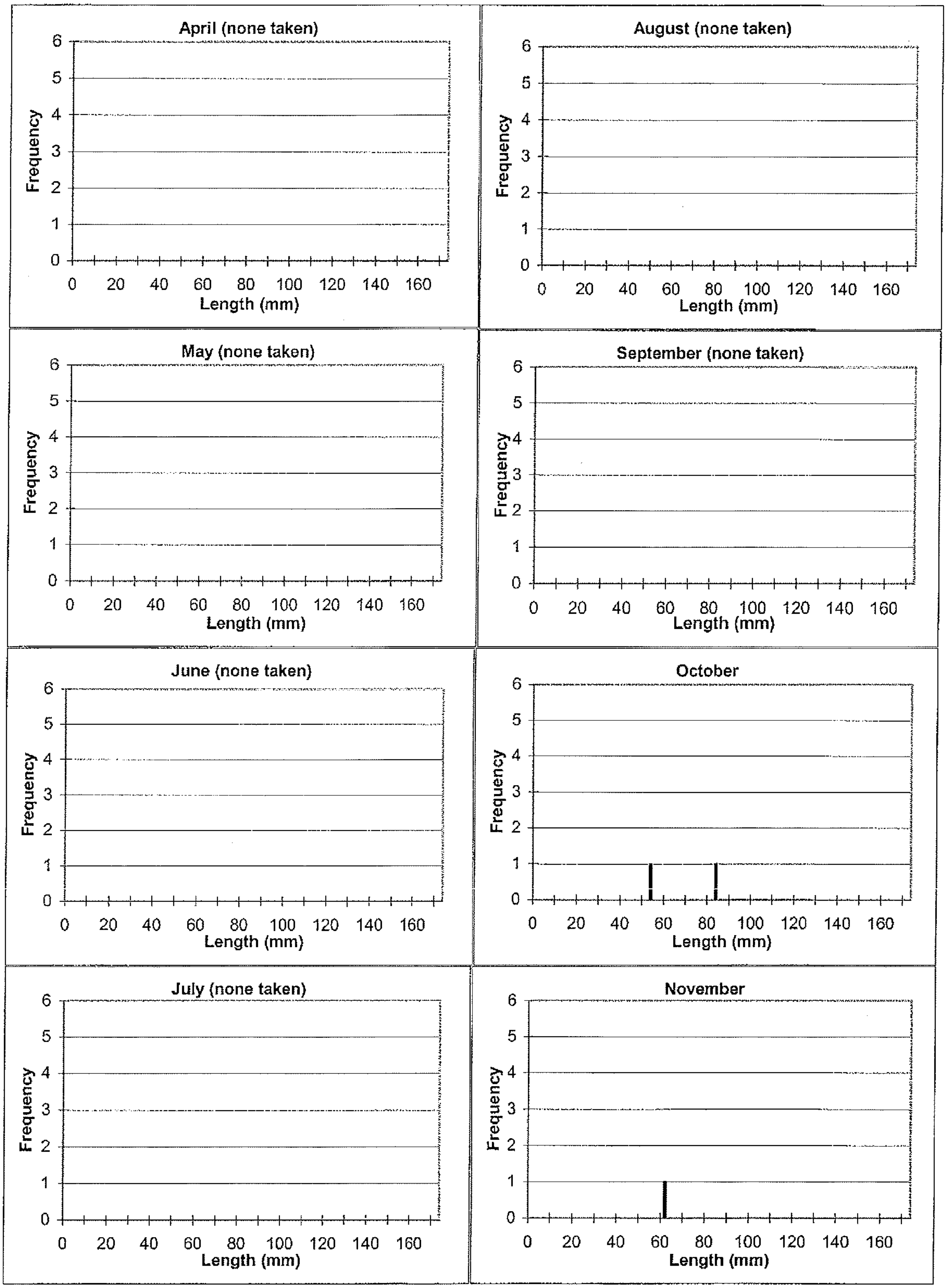


Figure 4-12 Length-frequency distribution of Atlantic silverside by month during the Bottom Trawl Effort, April - November 2008

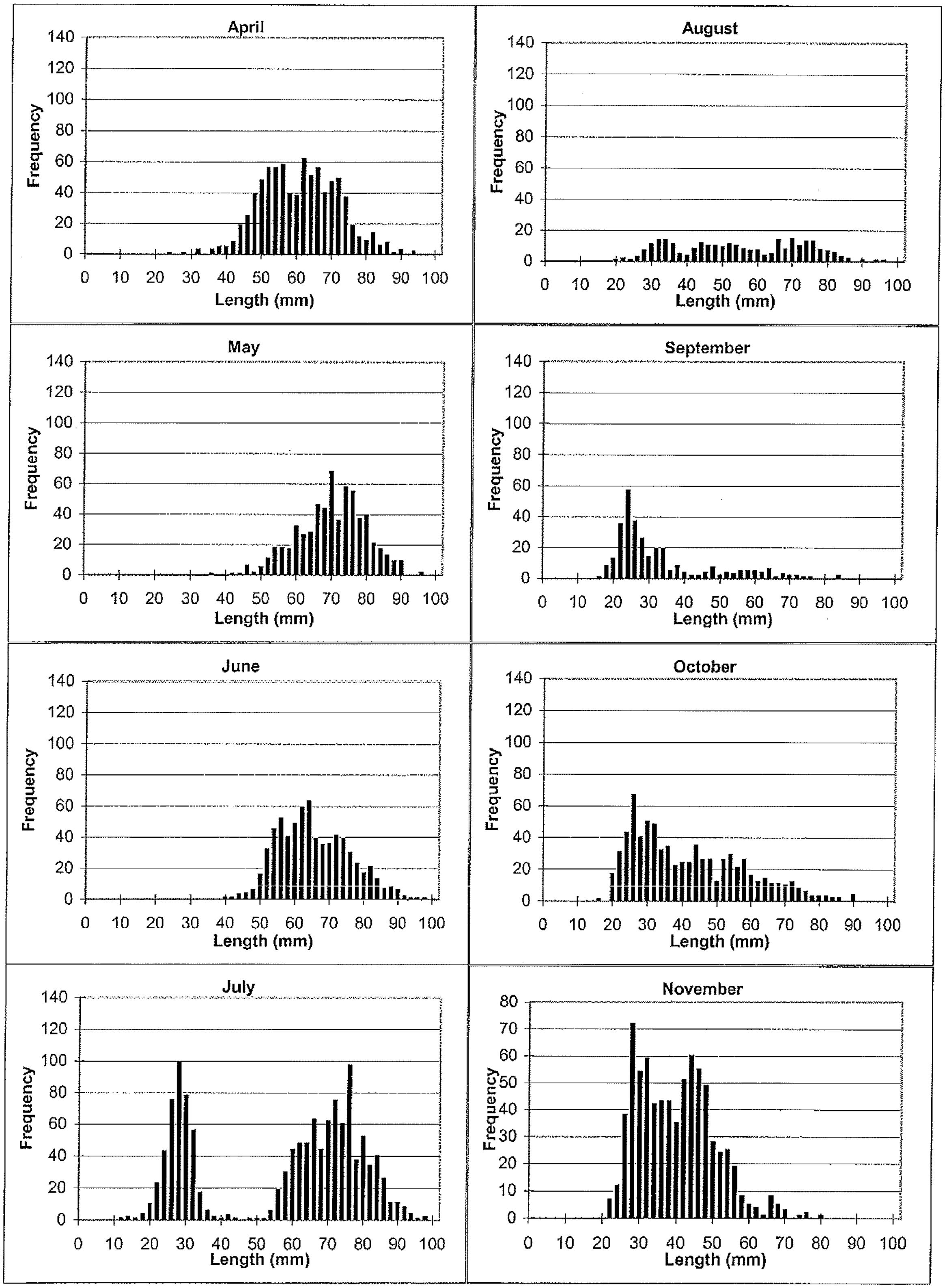


Figure 4-13 Length-Frequency distribution of bay anchovy by month during the Bottom Trawl Effort, April - November 2008

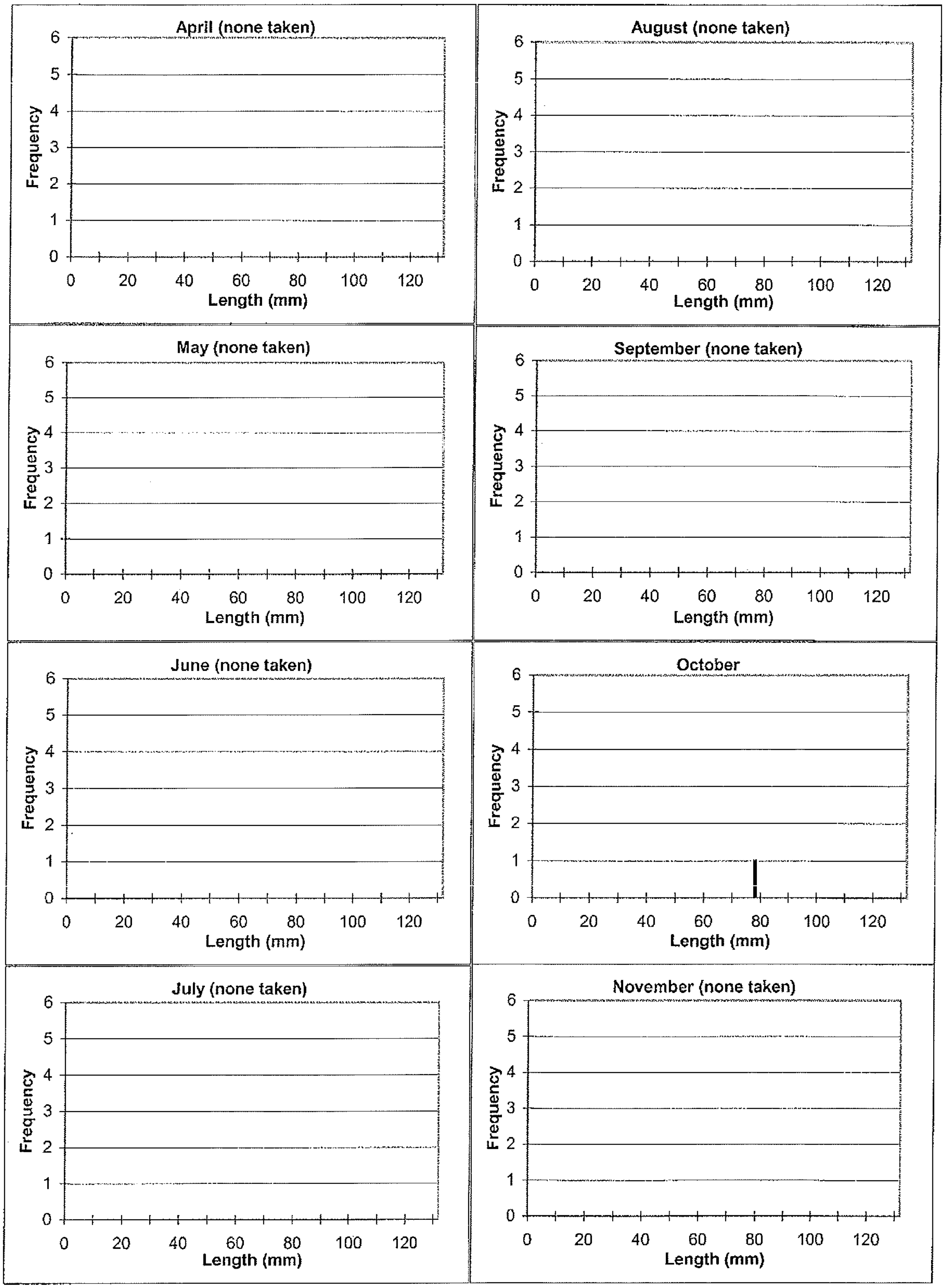
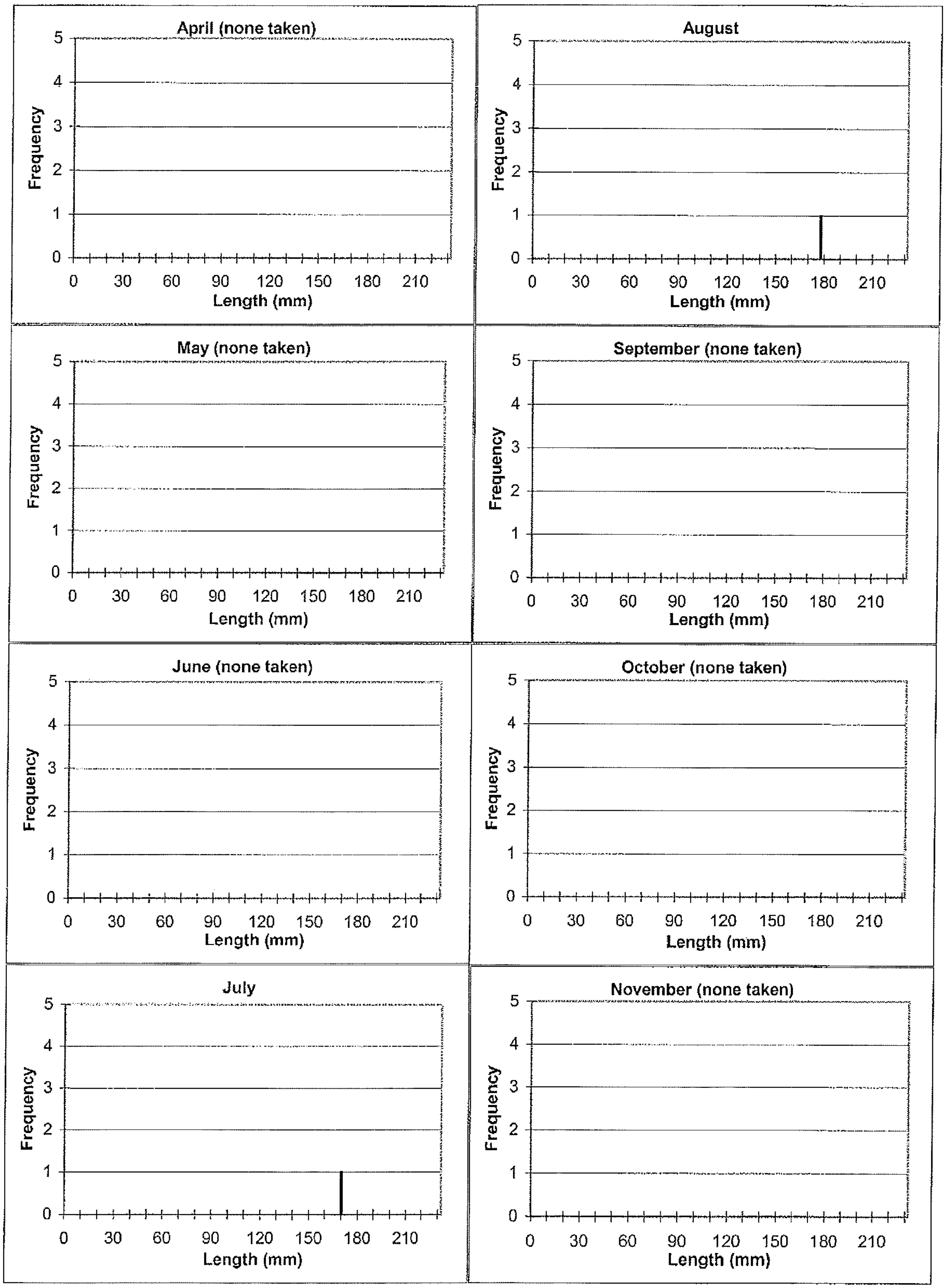


Figure 4-14 Length-frequency distribution of blueback herring by month during the Bottom Trawl Effort, April - November 2008



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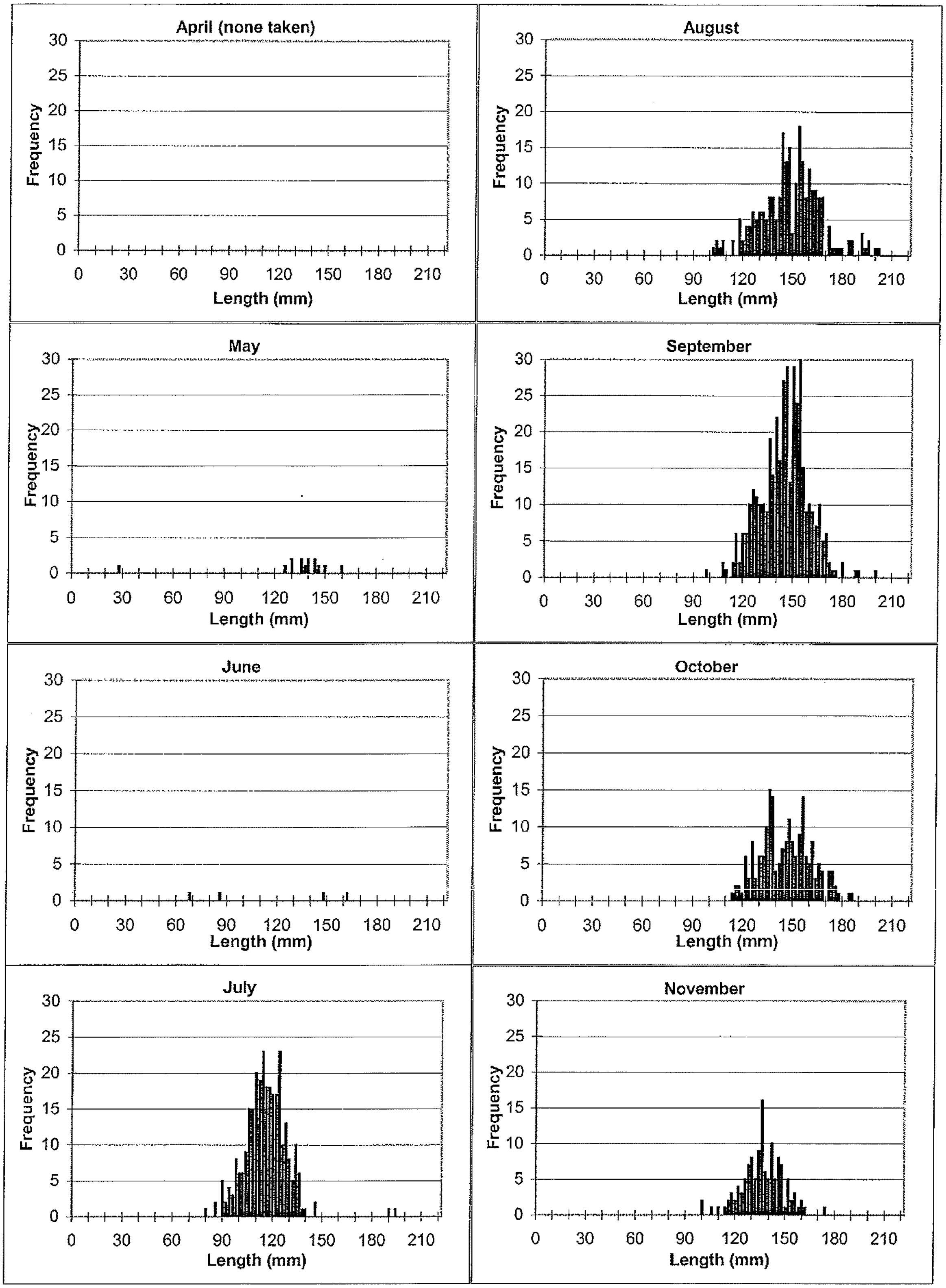

Figure 4-16 Length-frequency distribution of spot by month during the Bottom Trawl Effort,
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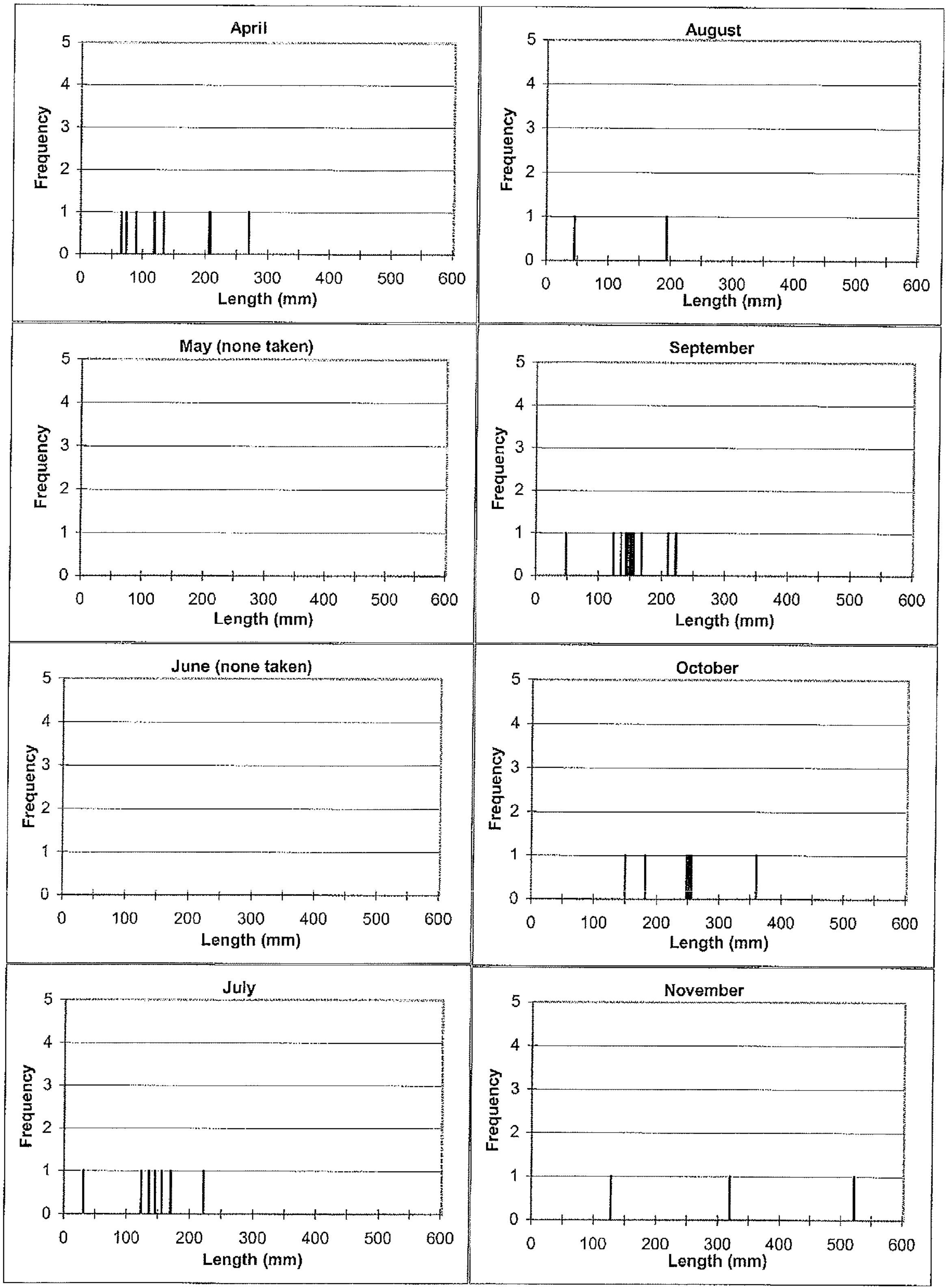

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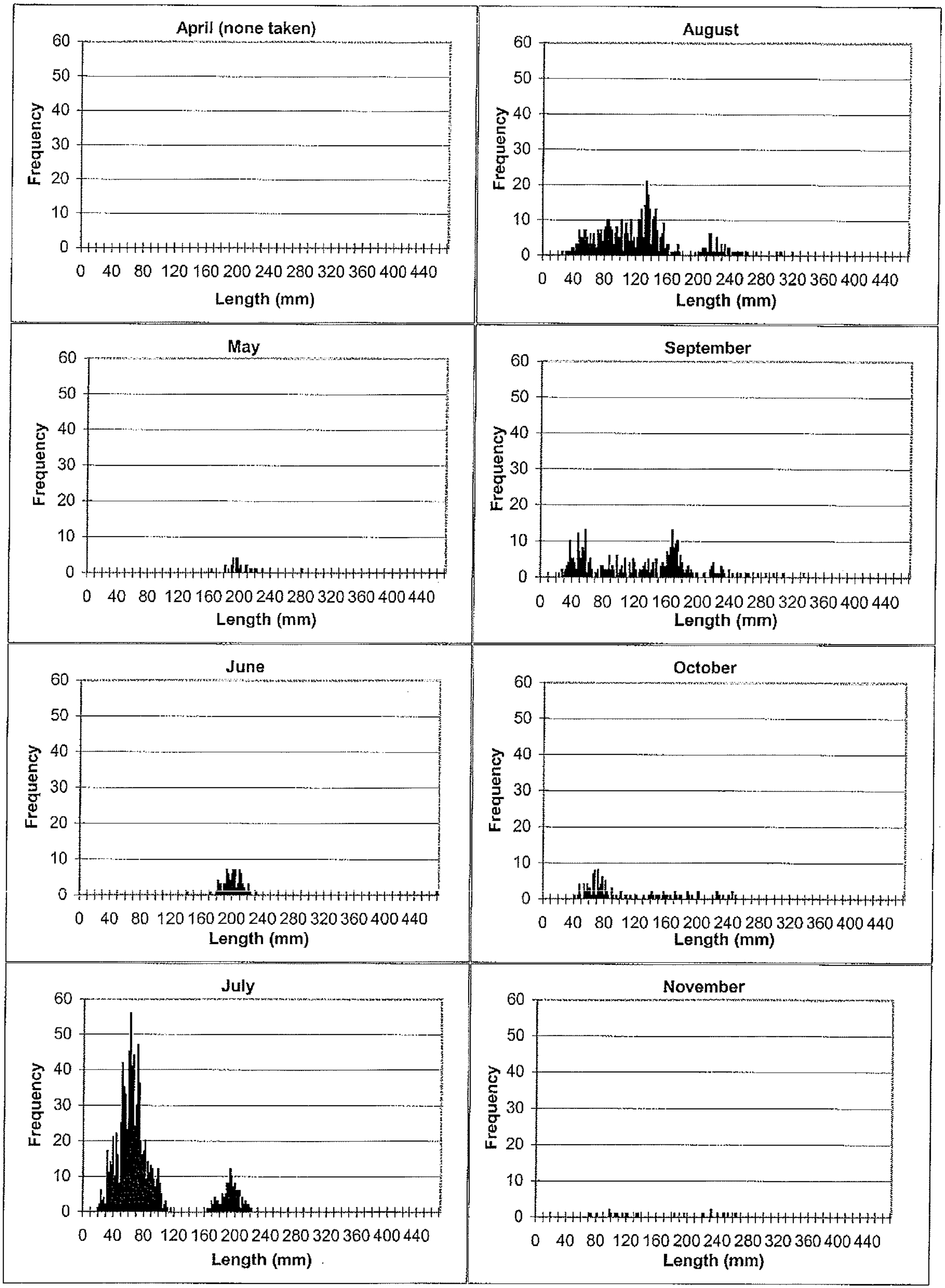

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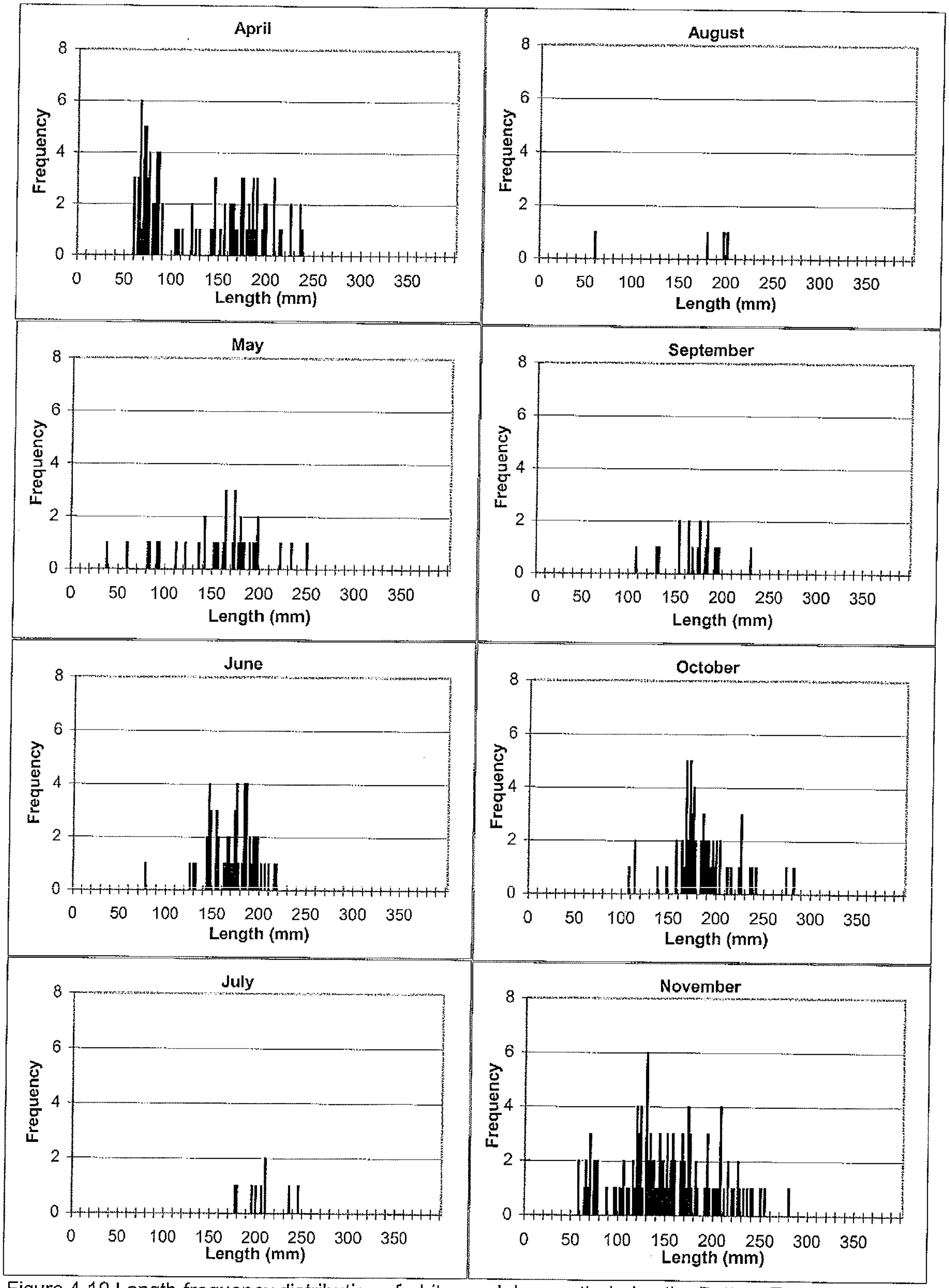

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CHAPTER 5: BAYWIDE BEACH SEINE

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BAYWIDE BEACH SEINE

INTRODUCTION

A number of annual survey programs collect empirical data on the relative abundance of finfish of the Delaware River estuary. Among various finfish studies that have been conducted over the past several decades is the Delaware River Striped Bass Recruitment Study conducted by the New Jersey Department of Environmental Protection (NJDEP). This annual survey, initiated in 1980, entails beach seine sampling throughout the tidal Delaware River from the Chesapeake and Delaware Canal to the fall line at Trenton, New Jersey. While the number of sampling stations has varied over the years, presently 32 stations are sampled with a 100-ft (30.5-m) beach seine on a monthly frequency in June and November, and semimonthly during July through October. Whereas the focus of this survey is to monitor the year-class strength of striped bass (*Morone saxatilis*), relevant abundance data is obtained for other species such as white perch (*Morone americana*), blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), which similarly utilize the shallows within this portion of the River as part of their principal nursery grounds during this temporal period.

PSEG's Baywide Beach Seine Survey was initiated in 1995 to complement the NJDEP seine survey, providing sampling beyond the geographical boundaries of the respective study area to more fully characterize target species abundance and distribution patterns within the estuary. To enhance compatibility with the results being generated from the existing agency sampling program, the sampling gear and deployment procedures for the Baywide Beach Seine Survey were developed following the methods described in Baum (1994), and through personal communications with the principal investigator, Mr. Thomas Baum of NJDEP.

This report constitutes the fourteenth-year progress report for the Baywide Beach Seine Survey. It presents the overall results of sampling and provides discussion regarding the occurrence of the Salem Generating Station "SGS" finfish target species: blueback herring, alewife, American shad (*Alosa sapidissima*), Atlantic menhaden (*Brevoortia tyrannus*), bay anchovy (*Anchoa mitchilli*), Atlantic silverside (*Menidia menidia*), white perch, striped bass, bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus).*

MATERIALS AND METHODS

Beach seine sampling was conducted during daylight once per month in June and November, and twice per month during July through October. Daylight is defined as the period one hour after sunrise to one hour before sunset. Samples were taken at 40 fixed stations in the Delaware Bay and lower River (Figure 5-1). Sampling at all stations was conducted within the period of two hours before to two hours after high slack water specific to that particular location. Sampling at high water increases the probability that individuals collected are more likely to be bay front, shore zone residents rather than marsh tributary transients.

Station spatial distribution was based on a partitioning of the overall study area shoreline into 32 equal-length regions. During the design phase of the study in 1995, the perimeter of the Delaware Bay from Cape May, NJ (rkm 0) to the lower Delaware River at the Chesapeake and Delaware Canal (rkm 100) was divided into 32 equal-length regions. Each region was further partitioned into 0.1-nautical mile segments. One fixed station was established within each of the 32 regions. Eight additional stations were established at bay front locations adjacent to PSEG marsh restoration sites. These 40 fixed stations (identifiable by latitude/longitude coordinates and flagged, labeled markers) have been sampled annually since 1995.

Seine hauls were taken with a 100- x 6-ft (30.5- x 1.8-m) bagged haul seine with a 1/4-inch (6.25 mm) nylon mesh, identical to the gear employed by NJDEP in the beach seine program conducted upstream of the present study. The seine is set perpendicularly from shore, by boat, until the bag is reached, at which time the remainder of the net is set in an arc-like fashion back to shore. The direction of the set was chosen relative to prevailing tidal current, wind and surf conditions to produce the most effective net deployment. The standard sampling effort was a single haul at each station.

With each collection, finfish were identified to the lowest practical taxonomic level (usually species), counted, and measured. A subsample of 100 specimens of each target species was measured to the nearest mm. Fork length (FL) was measured for all species with emarginated or forked caudal fins; for other species, total length (TL) was measured.

Surface measurements of water temperature (ºC), salinity (ppt) and dissolved oxygen (mgℓ) were recorded with each collection, as were water clarity (secchi depth), tidal stage, wave height, and weather conditions. Water quality parameters were measured with a YSI Model 85 OCST meter.

Catch results are summarized by sampling period, river kilometer (rkm) region and "beach type". The data are expressed in terms of total number taken; percent of total catch and mean number of specimens per seine haul. Sampling periods were each of the monthly or twice-monthly collection events; regions were defined as 20-rkm sections measured up the centerline of the estuary; and "beach types" were determined after qualitative assessments of the bottom type within the intertidal zone at the deployment location at each station. For graphic presentation purposes, species' length data was partitioned into 5-mm intervals.

RESULTS AND DISCUSSION

PHYSICAL AND CHEMICAL PARAMETERS

Temperature

The pattern in water temperature observed in 2008 exhibited the typical seasonal pattern found in a temperate climate (Figure 5-2a). Over the period of sampling, mean shore zone water temperature increased from the initial value of 24.9ºC during the second half of June to the seasonal maximum of 27.6°C during the second half of July. Thereafter, mean temperature decreased steadily to a season low of 11.5°C during the first half of November.

The longitudinal differences across this lower 100 rkm of the estuary ranged from 0.6 to 3.6°C during the biweekly sampling periods (Figure 5-2b). The smallest differences within sampling periods occurred during the first half of November. While the largest differences occurred during the second half of June, differences during this period through the first half of August were similarly large, ranging from 3.2 to 3.5°C. During this period mean temperature was lowest in rkm region 0-20.

Salinity

The overall range and mean values of salinity, as observed in the shore zone during the 2008 beach seine sampling season, are presented in Figure 5-3a. The freshwater discharge in Delaware River, as measured at the Trenton, NJ gauging station, ranged from 71.6 (June) to 137.0 (October) percent of normal (www.state.nj.us/drbc/data.htm). The discharges in June, August and September were below normal, and those in July, October and November were essentially normal or above. Within that context and considering the relatively restricted temporal window provided by the five-month sampling season, salinity levels exhibited in 2008 were most likely seasonally "typical" for an average flow-year. Mean values by sampling period ranged from 16.7 to 21.0 ppt, minimum values were 3.7 to 8.1 ppt, and maximum levels were 28.6 to 30.6 ppt.

The longitudinal gradient in salinity, i.e., the differences between minimum and maximum regional means, during the sampling periods ranged from 16.9 ppt in the second half of October to 23.3 ppt in the second half of July (Figure 5-3b).

Dissolved Oxygen

The Delaware Bay generally is considered to be well oxygenated throughout the year, and the high degree of tidal-driven mixing results in a nearly homogeneous vertical distribution of dissolved oxygen in the water column (PSE&G 1984). Smith (1987) and Michels (1995) concluded that dissolved oxygen levels in the Delaware Bay are not limiting to normal finfish species distributions. The minimum dissolved oxygen value, measured during the study period, of 4.0 mg/ℓ was recorded at Station 24 during the second half of June. Mean dissolved oxygen by sampling period ranged from 6.3, during the second half of September, to 9.2 mg/ℓ, during the first half of November (Figure 5-4a).

Regional mean dissolved oxygen concentrations are depicted in Figure 5-4b. During a given sampling period, the greatest regional difference of 3.0 mg/ℓ was recorded during the first half of August. The greatest difference in mean dissolved oxygen within a region was recorded in region rkm 81-100 with a range of 3.6 mg/ℓ. The smallest difference in mean dissolved oxygen within a region was recorded in region rkm 0-20 with a range of 2.4 mg/ℓ.

CATCH COMPOSITION

Totals of 15,559 specimens of 38 finfish species and 304 blue crab (*Callinectes sapidus*) were collected in the 400 seine samples during 2008 (Table 5-1). Atlantic silverside was the most abundant species taken in the seine catch (n=7,329), comprising 47.1 percent of the annual sample (Table 5-2). Historically, Atlantic silverside has been predominant in the shore zone of the lower Delaware Estuary (Daiber 1954; DeSylva *et al.* 1962; PSEG 1996-2008). Bay anchovy, with a catch of 4,015 specimens, ranked second and comprised 25.8 percent of the catch. Spot (n=1,037), striped killifish (*Fundulus majalis*; n=902) and Atlantic menhaden (n=778) comprised 6.7, 5.8 and 5.0 percent of the total catch, respectively (Tables 5-1, 5-2). Weakfish and Atlantic croaker were the only other species to individually represent at least one percent of the total catch. Nearly 45 percent, (17 of 38), of the species taken were represented by 10 or fewer specimens. A total of seven species was taken during all 10 sampling events; 10 species were taken in all regions; 14 species were taken at all beach types (Tables 5-3, 5-4). Only five species were collected during all sampling periods, in all regions and at all beach types: Atlantic silverside, bay anchovy, spot, Atlantic croaker and striped bass. These species may be characterized as the ubiquitous core of the seasonal baywide, shore zone community in 2008.

The component of the seine catch composition represented by the target species temporally, regionally and relative to beach type is provided in Tables 5-2, 5-3 and 5-4, respectively. Temporally, Atlantic silverside was the predominant target species during 8 of 10 sampling periods, comprising from 27.4 to 74.0 percent of the catch (Table 5-2). They ranked second to bay anchovy during the second halves of September and October. Fittingly as second most abundant species overall, bay anchovy ranked second during 5 of 10 sampling periods, comprising from 17.1 to 35.2 percent of the catch during those periods. However as inferred above, they were the most abundant species during the second halves of September and October, comprising 52.0 and 60.6 percent of the catch, respectively. Spot, Atlantic menhaden and weakfish were the only other target species which comprised more than 10 percent in any given sampling period. Spot comprised from 10.3 to 15.4 percent of the catch during the sampling periods in July and August, and ranked second during the second half of July. Atlantic menhaden was the second most abundant species during the second half of June, comprising 31.1 percent of the catch. It comprised ≤ 7.1 percent of the catch in sampling periods thereafter. Weakfish was ranked second in the first half of July, comprising 21.3 percent of the catch, but it comprised≤ 4.4 percent of the catch in sampling periods thereafter. Atlantic croaker, striped bass, bluefish, white perch, American shad, and blueback herring were collected during the 2008 sampling season, but comprised less than five percent of the catch during any given sampling period. Alewife was not collected during the 2008 sampling season.

Regionally, Atlantic silverside was the predominant species in the three regions rkm 0-60 comprising from 41.0 to 57.2 percent of the catch in those regions, and was secondarily abundant in the two remaining regions rkm 61-100 (Table 5-3). Bay anchovy was the predominant species in the two regions rkm 61-100, representing 50.0 and 84.3 percent, respectively. They were ranked second to Atlantic silverside in regions rkm 0-20 and 41-60. Spot, Atlantic menhaden and weakfish were the only other target species to comprise > 5 percent of the catch in a given sampling region. Spot comprised from 8.2 to 8.5 percent of the catch in rkm regions 0-60; Atlantic menhaden comprised 9.5 percent in rkm 21-40; and weakfish comprised 5.3 and 5.7 percent in rkm 0-20 and 41-60, respectively.

At the five beach types, Atlantic silverside was the predominant target species at all beach types except peat, comprising from 28.7 to 61.9 percent of the total catch, and was secondarily abundant at the peat beaches at 35.9 percent (Table 5-4). Bay anchovy was the predominant target species at the peat beaches comprising 38.8 percent of the catch, and was secondarily abundant at the sand and sand/peat beaches, comprising from 26.9 to 31.4 percent at those beach types. Spot was secondarily abundant at the peat/mud and mud beaches, comprising 10.7 and 22.6 percent of the catches there. Atlantic menhaden and weakfish were the only other target species to comprise more than 5 percent of the catch at a given beach type. Atlantic menhaden comprised 9.8 percent of the catch at peat and mud beaches, and 6.3 percent at sand/peat beaches. Weakfish comprised 7.1 percent of the catch at mud beaches.

SPECIES RICHNESS AND NUMERIC ABUNDANCE

As a result of the predominance of the Atlantic silverside and bay anchovy (72.9 percent of the catch), the measure of numeric abundance relative to time, region and beach type largely reflects the pattern of occurrence of these species across these gradients. Overall finfish abundance in the shore zone, as measured by mean catch per haul, was highest at 57.6 during the second half of August (Figure 5-5a). There were secondary peaks during the second halves of June, July and September, and during the first half of November, with mean catches ranging from 42.9 to 48.6. During the other sampling periods, mean catches ranged from 25.4 during the second half of October to 33.8 during the first half of October. Regionally, finfish abundance was highest in the region rkm 21-40 with a mean catch per haul of 51.2, and lowest in region rkm 81-100 with a mean catch of 25.7 (Figure 5-5b). Relative to beach type, abundance was highest at the peat/mud beaches with a mean catch of 76.4, and secondarily high at the mud beaches with a catch of 63.8 (Figure 5-5c). The mean catch per haul for the peat beach type was the lowest at 28.7.

Over the sampling season, species richness (N) was equally high at 24 species taken during the first half of July and during both collection periods in August (Figure 5-5a). It was lowest during the first half of November at 14 species, and ranged from 16 to 22 species during the remaining sampling periods. Regionally, species richness was similarly high in rkm 0-20 and 21-40 with 28 and 29 species taken, respectively (Figure 5-5b). Species richness decreased thereafter in the three regions rkm 41-100 with 26, 20 and 13 species, respectively. Relative to beach type, species richness was highest at the mud/peat beaches with 34 species taken (Figure 5-5c). At the other beach types, richness was similar ranging from 19 to 24.

SPECIES ACCOUNTS

The following species accounts present the sampling results specific to each of the SGS target finfish species. These data summaries describe periods of occurrence, temporal and spatial abundance patterns, size distribution and inferred age composition. Graphic presentations of abundance and length-frequency data were prepared for those target species represented by at least ten specimens collected.

American shad, Blueback herring and Alewife

Totals of four American shad and three blueback herring were taken in this study during 2008 (Table 5-1). No alewife were collected in 2008.

Atlantic menhaden

During 2008, a total of 778 Atlantic menhaden was taken, comprising 5.0 percent of the total catch (Tables 5-1 and 5-2). They were taken in all but three sampling periods, and were most abundant during the second half of June, with a mean catch of 15.1 specimens per haul, comprising 31.1 percent of the catch during that period (Table 5-2 and Figure 5-6a). Thereafter, the mean catches were ≤ 2.2. Atlantic menhaden ranged in length from 28 to 293 mm FL (Figure 5-7), and all except five were age 0+ (Able and Fahay 1998). Atlantic menhaden was taken in all regions, and was most abundant in region rkm 21-40 with a mean catch of 4.9 (Figure 5-6b). The catches in the remaining regions were ≤ 0. 9. Atlantic menhaden was taken at all beach types. Their abundance was highest at the mud beach type with a mean catch of 6.3 per haul; it was intermediately high at the peat/mud, peat and sand/peat beach types with mean catches ranging from 2.3 to 2.8 per haul; and it was lowest at the sand beaches at 0.4 (Figure 5-6c).

Bay anchovy

A total of 4,015 bay anchovy was taken, comprising 25.8 percent of the 2008 seine catch (Tables 5-1 and 5-2). As a characteristically ubiquitous species within the study area, bay anchovy was taken during all sampling periods, in all regions, and at all beach types (Figure 5-8). Bay anchovy abundance was highest during the second half of September, when the mean catch per haul was 22.3 (Figure 5-8a). Their abundance was secondarily high during the second halves of August and October, with mean catches per haul of 15.4 during both periods. The catch per unit effort was ≤ 11.9 during all remaining sampling periods. Bay anchovy ranged in length from 22 to 94 mm FL (Figure 5-9), including individuals age 0+ and older (PSE&G 1999a). Based on the sub sample measured, all bay anchovy taken during first two collection periods were age 1+ and older with modal lengths of 63 and 73 mm FL, respectively. During the period from the second half of July through the second half of August, ages 0+ and 1+ were more or less evenly represented in the collections. Thereafter, age 0+ of the 2008 year-class was predominant comprising from 61 to 97 percent of the catch, with modal lengths remaining stable at 43 or 48 mm FL. Overall, age 0+ individuals comprised about 63 percent of the species' catch. Bay anchovy abundance was highest in the region rkm 81-100 with a mean catch of 21.6 per haul, and it was secondarily high in rkm 61-80 at 17.9 (Figure 5-8b). In other regions, mean catches ranging from 3.7 to 8.9. Bay anchovy abundance was similarly high at the peat and sand/peat beach types, with a mean catches of 11.2 and 13.7 per haul, respectively (Figure 5-8c). At the other beach types, mean catches ranging from 3.9 to 8.7.

Atlantic silverside

Atlantic silverside was the most abundant species collected during 2008 with a total of 7,329 specimens taken and comprised 47.1 percent of the total catch (Table 5-1 and 5-2). As one of the ubiquitous core species group, Atlantic silverside was taken during all sampling periods, in all regions, and at all beach types (Figure 5-10). Their abundance was highest during the first half of November, when the mean catch per haul was 33.8 (Figure 5-10a). Atlantic silverside abundance was secondarily high during the second halves of July and August, with mean catches per haul of 28.9 and 26.2, respectively. The catch per unit effort was ≤ 19.1 during all remaining sampling periods. Atlantic silverside ranged in length from 23 to 129 mm FL (Figure 5-11), including individuals age 0+ to potentially age 2 (Conover and Ross 1982). Although age composition for this species is difficult to infer from length data alone, it appears that age 1+ (2007 year class) was the predominate age class during the first collection period, with a modal length of 73 mm FL and comprising 97 percent of the catch (Able and Fahay 1998). In collection periods thereafter, age 0+ were predominant comprising from 82 to 100 percent of the subsample measured. The modal length generally increased from 53 to 73 mm TL, during the period from the first half of July through the first half of October, but decreased to 63 mm FL during the second half of October and the first half of November (Figure 5-11). Atlantic silverside abundance was highest in rkm region 21-40 with a mean catch of 29.3 per haul (Figure 5-10b). Abundance was intermediately high in rkm regions 0-20 and 61-80, with catches of 17.2 and 14.5, respectively. In the remaining regions, mean catches were ≤ 11.8. Atlantic silverside abundance was highest at the peat/mud beach type with a catch per haul of 47.3, intermediately high at the sand/peat (22.9) and mud (18.3) beach types and lowest at the peat (10.3) beach type (Figure 5-10c).

White perch

A total of 50 white perch was taken in the 2008 seine program (Table 5-1). White perch was taken during all but three sampling periods (Figure 5-12). The relatively low catch was not unexpected since the principal summer nursery and feeding grounds occur in the tributaries of the Estuary and in the Delaware River above the upstream limits of the study area. By contrast, the NJDEP seine effort in the river upstream has yielded, with essentially the same level of effort, annual catches of 1,808 – 13,791 white perch over the past 15 years 1993-2008 (Baum 1993-1996; Baum *et al*. 1997-2005; Muffley *et al.* 2006; Muffley and Corbett 2007 and 2008; Baum, pers. comm., preliminary 2008 catch data).

White perch abundance was highest during the first half of November with a catch per haul of 0.5 (Figure 5-12a). The catch per unit effort was ≤ 0.2 during all remaining sampling periods. White perch ranged in length from 61 to 310 mm FL (Figure 5-13), including individuals age 0+ to potentially age 6+ or older (Clark 1998). The length frequency distribution is generally unremarkable, reflecting scattered unitary frequencies. However, it would appear that only two individuals collected were age 0+. White perch abundance was highest in rkm region 41-60 with a mean catch of 0.3 per haul (Figure 5-12b). In the remaining regions, mean catches were ≤ 0.1. White perch was most abundant at the peat beach type with a mean catch of 0.3; at all other beach types catches were ≤ 0.1 (Figure 5-12c).

Striped bass

During 2008, a total of 98 striped bass was taken (Table 5-1). As one of the ubiquitous core species group, striped bass was taken during all sampling periods, in all regions, and at all beach types (Figure 5-14). Striped bass abundance was equally high during the first halves of July and August, with mean catches of 0.5; during the other collection periods of the sampling season, the mean catches ranging from 0.1 to 0.3 per haul (Figure 5-14a). Striped bass ranged in length from 32 to 610 mm FL (Figure 5-15), including individuals age 0+ to potentially age 5+ (Baum et al. 2004). The length frequency distribution is generally unremarkable, reflecting scattered unitary frequencies. Specimens age 0+ comprised 23 percent of the total catch. Striped bass abundance was highest in rkm region 41-60 with a mean catch of 0.5 per haul (Figure 5-14b). In all other regions, the mean catches were ≤ 0.3 per haul. Striped bass abundance was highest at the mud beach type with a mean catch of 0.7 (Figure 5-14c). At the other beach types, mean catch ranged from 0.1 to 0.3.

Bluefish

During 2008, a total of 71 bluefish was taken (Table 5-1). Bluefish was taken during all sampling periods except the first half of November, in all regions, and at all beach types (Figure 5-16). Their abundance was highest during the second half of June at 0.5 specimens per haul (Figure 5-16a). In all other sampling periods in which bluefish was taken, the catch per haul was ≤ 0.3. Bluefish ranged in length from 52 to 222 mm FL, and all were age 0+ (Figure 5-17); Able and Fahay 1998). Bluefish was most abundant in region rkm 0-20 with a mean catch per haul of 0.5 (Figure 5-16b). In all other regions, the mean catches were 0.1 per haul. Bluefish was most abundant at the sand beach type with a mean catch of 0.3, and mean catches at the other beaches were ≤ 0.2 (Figure 5-16c).

Weakfish

During 2008, a total of 467 weakfish was taken (Table 5-1). Weakfish was taken during all but one sampling period (November), in all regions except rkm 81-100 and at all beach types (Figure 5-18). Weakfish abundance reached the seasonal peak of 6.6 during the first half of July (Figure 5-18a). The catch per unit effort was≤ 2 .1 during all remaining sampling periods. Weakfish ranged in length from 23 to 330 mm TL, including age 0+ and 1+ individuals (Figure 5-19; Michels 1997). All but six specimens were age 0+. The modal lengths were 53 and 73 mm TL during the July collection periods, when 74 percent of measurements were recorded. Thereafter, the catch was small and the length frequency distribution is unremarkable. Weakfish abundance was highest in the rkm region 0-20, with a mean catch of 2.0 per haul (Figure 5-18b). In regions rkm 21-40 and 41-60, catches were 1.3 and 1.6, respectively. Weakfish was most abundant at the mud beach type with a mean catch of 4.6, was similarly and intermediately abundant at the sand and peat beach types with respective catches of 1.3 and 1.0, and was least abundant at the sand/peat beach type with a catch of 0.6 (Figure 5-18c).

Spot

A total of 1,037 spot was taken in 2008 (Table 5-1). As one of the ubiquitous core species group, spot was taken during all sampling periods, in all regions, and at all beach types (Figure 5-20). During the first four collection periods (i.e., second half of June through the first half of August, their abundance was secondarily high, with similar mean catches ranging from 3.7 to 5.0 specimens per haul (Figure 5-20a). Their seasonal peak in abundance of 6.8 specimens per haul was reached in the second half of August. Thereafter, abundance steadily decreased, with mean catches of ≤ 1.3. Spot ranged in length from 14 to 240 mm TL, and age 0+ comprised 92 percent of the catch (Figure 5-21; Able and Fahay 1998, PSEG 1984). The modal length generally increased from 18 to 138 mm TL, during the period from the second half of June through the first half of August; the distribution was bimodal during the second half of August with modes at 73 and 153 mm TL. Thereafter, the catch was small and the length frequency distribution is unremarkable. Spot was most abundant in rkm region 21-40 with a mean catch per haul of 4.4; was secondarily abundant in regions rkm 0-20 and 41-60, with a mean catches of 3.1 and 2.5, respectively; and was least abundant in rkm regions 61-80 and 81-100 with mean catches of 0.6 and 0.3 per haul, respectively (Figure 5-20b). Spot was most abundant at the mud beach type with a mean catch of 14.4 per haul, and they were secondarily abundant at the peat/mud beaches, with a mean catch of 8.1(Figure 5-20c). Mean catches at the other beaches were ≤ 2.1.

Atlantic croaker

During 2008, a total of 285 Atlantic croaker was taken (Table 5-1). As one of the ubiquitous core species group, they were taken during all sampling periods, in all regions, and at all beach types (Figure 5-22). During the first two collection periods (i.e., second half of June and the first half of July, their abundance was secondarily high, with similar mean catches ranging of 1.3 and 1.0 specimens per haul (Figure 5-22a). Thereafter, abundance steadily decreased, with mean catches ranging from 0.8 to 0.1. Their seasonal peak in abundance of 1.8 specimens per haul was reached as the catch spiked in the first half of November. They ranged in length from 12 to 199 mm TL (Figure 5-23). During the period from the second half of June through the first half of October, all individuals measured were age 1+, and modal length generally increased during the period from 88 to 153 mm TL (PSEG 1984; Figure 5-23). During the second half of October and the first half of November, all individuals measured were age 0+, the modal length was 23 mm TL. Atlantic croaker was most abundant in the region rkm 0-20 with a mean catch of 1.7 per haul (Figure 5-22b). Mean catches in the other regions were ≤ 0. 8. Mean catches of Atlantic croaker was highest at the peat/mud beach type with a catch per haul of 1.8, intermediately high at the sand and peat beach types with catches of 0.8 and 0.6, respectively, and similarly low at the sand/peat and mud beach types with a mean catches of 0.4 and 0.3, respectively (Figure 5-22c).

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Table 5-1. Number of finfish and blue crab, by sampling period, taken by seine in the Delaware Bay and River during 2008.

Species		JUN 16-30	JUL 1-15	JUL 16-31	AUG 1-15	AUG 16-31	SEP 1-15	SEP 16-30	OCT 1-15	OCT 16-31	NOV 1-15	Total
Southern stingray	*Dasyatis americana*	0	0	0	0	1	0	0	0	0	0	1
Cownose ray	*Rhinoptera bonasus*	0	0	0	1	0	0	0	0	0	0	1
American eel	*Anguilla rostrata*	0	5	0	0	0	0	0	1	0	0	6
American shad	*Alosa sapidissima*	0	0	0	0	0	0	1	0	2	1	4
Blueback herring	*Alosa aestivalis*	0	0	0	0	0	0	0	0	0	3	3
Atlantic menhaden	*Brevoortia tyrannus*	604	87	27	22	13	0	23	2	0	0	778
Gizzard shad	*Dorosoma cepedianum*	1	1	1	2	0	0	1	1	1	6	14
Striped anchovy	*Anchoa hepsetus*	3	0	9	12	23	10	11	3	0	0	71
Bay anchovy	*Anchoa mitchilli*	274	160	98	183	616	390	892	476	614	312	4015
Channel catfish	*Ictalurus punctatus*	4	0	0	0	1	0	0	0	0	0	5
Striped cusk-eel	*Ophidion marginatum*	4	8	14	0	0	0	0	0	0	0	26
Halfbeak	*Hyporhamphus meeki*	1	0	0	2	0	0	0	0	0	0	3
Atlantic needlefish	*Strongylura marina*	1	1	1	0	5	1	5	0	0	0	14
Sheepshead minnow	*Cyprinodon variegatus*	0	1	0	0	0	0	2	3	4	6	16
Mummichog	*Fundulus heteroclitus*	0	0	5	1	2	0	0	0	2	0	10
Striped killifish	*Fundulus majalis*	8	26	245	100	199	67	99	58	60	40	902
Rough silverside	*Membras martinica*	0	0	0	0	0	2	0	0	0	0	2
Atlantic silverside	*Menidia menidia*	763	419	1157	434	1050	590	596	691	278	1351	7329
White perch	*Morone americana*	7	5	0	1	0	0	4	6	8	19	50
Striped bass	*Morone saxatilis*	12	21	8	19	7	5	7	5	6	8	98
Bluefish	*Pomatomus saltatrix*	18	7	8	9	6	6	2	13	2	0	71
Crevalle jack	*Caranx hippos*	0	0	0	0	1	0	0	2	0	0	3
Lookdown	*Selene vomer*	0	0	6	1	0	0	1	0	0	0	8
Florida pompano	*Trachinotus carolinus*	0	0	0	0	2	1	2	0	0	0	5
Permit	*Trachinotus falcatus*	0	1	1	1	3	0	0	1	0	0	7
Pigfish	*Orthopristis chrysoptera*	0	0	0	1	0	0	0	0	0	0	1
Weakfish	*Cynoscion regalis*	5	263	85	40	29	5	13	24	3	0	467
Silver perch	*Bairdiella chrysoura*	20	9	1	2	5	1	2	2	0	0	42

Species		**JUN 16-30**	**JUL 1-15**	**JUL 16-31**	**AUG 1-15**	**AUG 16-31**	**SEP 1-15**	**SEP 16-30**	**OCT 1-15**	**OCT 16-31**	**NOV 1-15**	**Total**
Spot	*Leiostomus xanthurus*	161	146	199	163	271	53	23	18	2	1	1037
Southern kingfish	*Menticirrhus americanus*	0	0	0	0	1	0	0	0	0	0	1
Northern kingfish	*Menticirrhus saxatilis*	0	1	7	13	9	13	11	15	15	2	86
Atlantic croaker	*Micropogonias undulatus*	51	41	33	28	30	14	2	9	7	70	285
Black drum	*Pogonias cromis*	0	19	6	2	16	3	0	5	2	1	54
White mullet	*Mugil curema*	1	1	4	14	7	9	14	17	8	6	81
Summer flounder	*Paralichthys dentatus*	6	3	2	0	2	0	4	1	0	0	18
Hogchoker	*Trinectes maculatus*	0	4	21	9	3	3	1	0	0	0	41
Northern puffer	*Sphoeroides maculatus*	0	1	0	1	0	0	0	0	0	0	2
Striped burrfish	*Chilomycterus schoepfi*	0	2	0	0	0	0	0	0	0	0	2
	Total	1944	1232	1938	1061	2302	1173	1716	1353	1014	1826	15559
Blue crab	*Callinectes sapidus*	19	49	37	28	40	30	50	46	4	1	304

Table 5-2. Percent composition, by sampling period, for finfish taken in the 2008 baywide seine survey**.**

Species	**JUN 16-30**	**JUL 1-15**	**JUL 16-31**	**AUG 1-15**	**AUG 16-31**	**SEP 1-15**	**SEP 16-30**	**OCT 1-15**	**OCT 16-31**	**NOV 1-15**	**total**
Atlantic silverside	**39.2**	**34.0**	**59.7**	**40.9**	**45.6**	**50.3**	**34.7**	**51.1**	**27.4**	**74.0**	**47.1**
Bay anchovy	**14.1**	**13.0**	**5.1**	**17.2**	**26.8**	**33.2**	**52.0**	**35.2**	**60.6**	**17.1**	**25.8**
Spot	**8.3**	**11.9**	**10.3**	**15.4**	**11.8**	**4.5**	**1.3**	**1.3**	**0.2**	**0.1**	**6.7**
Striped killifish	0.4	2.1	12.6	9.4	8.6	5.7	5.8	4.3	5.9	2.2	5.8
Atlantic menhaden	**31.1**	**7.1**	**1.4**	**2.1**	**0.6**		**1.3**	**0.1**			**5.0**
Weakfish	**0.3**	**21.3**	**4.4**	**3.8**	**1.3**	**0.4**	**0.8**	**1.8**	**0.3**		**3.0**
Atlantic croaker	**2.6**	**3.3**	**1.7**	**2.6**	**1.3**	**1.2**	**0.1**	**0.7**	**0.7**	**3.8**	**1.8**
Striped bass	**0.6**	**1.7**	**0.4**	**1.8**	**0.3**	**0.4**	**0.4**	**0.4**	**0.6**	**0.4**	**0.6**
Northern kingfish		0.1	0.4	1.2	0.4	1.1	0.6	1.1	1.5	0.1	0.6
White mullet	0.1	0.1	0.2	1.3	0.3	0.8	0.8	1.3	0.8	0.3	0.5
Bluefish	**0.9**	**0.6**	**0.4**	**0.8**	**0.3**	**0.5**	**0.1**	**1.0**	**0.2**		**0.5**
Striped anchovy	0.2		0.5	1.1	1.0	0.9	0.6	0.2			0.5
Black drum		1.5	0.3	0.2	0.7	0.3		0.4	0.2	0.1	0.3
White perch	**0.4**	**0.4**		**0.1**			**0.2**	**0.4**	**0.8**	**1.0**	**0.3**
Silver perch	1.0	0.7	0.1	0.2	0.2	0.1	0.1	0.1			0.3
Hogchoker		0.3	1.1	0.8	0.1	0.3	0.1				0.3
Striped cusk-eel	0.2	0.6	0.7								0.2
Summer flounder	0.3	0.2	0.1		0.1		0.2	0.1			0.1
Sheepshead minnow		0.1					0.1	0.2	0.4	0.3	0.1
Atlantic needlefish	0.1	0.1	0.1		0.2	0.1	0.3				0.1
Gizzard shad	0.1	0.1	0.1	0.2			0.1	0.1	0.1	0.3	0.1
Mummichog			0.3	0.1	0.1				0.2		0.1
Lookdown			0.3	0.1			0.1				0.1
Permit		0.1	0.1	0.1	0.1			0.1			<0.1
American eel		0.4						0.1			<0.1
Channel catfish	0.2				<0.1						<0.1
Florida pompano					0.1	0.1	0.1				<0.1
American shad							**0.1**		**0.2**	**0.1**	**<0.1**
Blueback herring										**0.2**	**<0.1**
Crevalle jack					<0.1			0.1			<0.1
Halfbeak	0.1			0.2							<0.1
Rough silverside						0.2					<0.1
Striped burrfish		0.2									<0.1
Northern puffer		0.1		0.1							<0.1
Cownose ray				0.1							<0.1
Pigfish				0.1							<0.1
Southern kingfish					<0.1						<0.1
Southern stingray					<0.1						<0.1

Table 5-3. Percent composition, by river kilometer region, for finfish taken in the 2008 baywide seine survey.

Common Name	0-20	21-40	41-60	61-80	81-100	Total
Atlantic silverside	**46.3**	**57.2**	**41.0**	**40.6**	**7.7**	**47.1**
Bay anchovy	**21.7**	**7.2**	**30.8**	**50.0**	**84.3**	**25.8**
Spot	**8.2**	**8.5**	**8.5**	**1.6**	**1.0**	**6.7**
Striped killifish	3.2	10.2	3.7	1.8		5.8
Atlantic menhaden	**1.2**	**9.5**	**1.1**	**2.5**	**0.6**	**5.0**
Weakfish	**5.3**	**2.6**	**5.7**	**0.7**		**3.0**
Atlantic croaker	**4.5**	**1.5**	**2.1**	**0.2**	**1.7**	**1.8**
Striped bass	**0.5**	**0.3**	**1.6**	**0.7**	**0.5**	**0.6**
Northern kingfish	1.1	0.6	0.3	0.3	0.1	0.6
White mullet	1.7	0.4	0.5	0.1		0.5
Bluefish	**1.3**	**0.2**	**0.4**	**0.4**	**0.4**	**0.5**
Striped anchovy	0.9	0.2	0.6	0.2	2.2	0.5
Black drum	0.3	0.5	0.6	<0.1		0.3
White perch	**0.1**	**0.1**	**1.2**	**0.3**	**0.3**	**0.3**
Silver perch	1.2	0.1	<0.1	0.1		0.3
Hogchoker		0.2	1.3		0.3	0.3
Striped cusk-eel	0.9	<0.1				0.2
Summer flounder	0.6		<0.1	<0.1		0.1
Sheepshead minnow	0.1	0.2				0.1
Atlantic needlefish	0.3	<0.1	0.2			0.1
Gizzard shad		<0.1	0.2	0.1	0.5	0.1
Mummichog	0.1	0.1				0.1
Lookdown	0.3	<0.1				0.1
Permit	0.1	0.1				<0.1
American eel		0.1	0.1			<0.1
Channel catfish				0.2		<0.1
Florida pompano	0.1	<0.1	<0.1			<0.1
American shad			**<0.1**	**0.1**		**<0.1**
Blueback herring					**0.4**	**<0.1**
Crevalle jack				0.1		<0.1
Halfbeak	<0.1	<0.1	<0.1			<0.1
Rough silverside		<0.1	<0.1			<0.1
Striped burrfish	<0.1	<0.1				<0.1
Northern puffer	<0.1		<0.1			<0.1
Cownose ray		<0.1				<0.1
Pigfish	<0.1					<0.1
Southern kingfish	<0.1					<0.1
Southern stingray	<0.1		<0.1			<0.1

Table 5-4. Percent composition, by beach type, for finfish taken in the 2008 baywide seine survey.

Common Name	SAND	SAND/PEAT	PEAT	PEAT/MUD	MUD	Total
Atlantic silverside	**47.4**	**52.3**	**35.9**	**61.9**	**28.7**	**47.1**
Bay anchovy	**26.9**	**31.4**	**38.8**	**8.5**	**6.1**	**25.8**
Spot	**6.5**	**1.2**	**4.1**	**10.7**	**22.6**	**6.7**
Striped killifish	4.3	3.8	1.0	11.4	18.7	5.8
Atlantic menhaden	**1.1**	**6.3**	**9.8**	**3.0**	**9.8**	**5.0**
Weakfish	**3.9**	**1.4**	**3.5**	**0.9**	**7.1**	**3.0**
Atlantic croaker	**2.4**	**0.9**	**2.2**	**2.4**	**0.5**	**1.8**
Striped bass	**1.0**	**0.4**	**0.5**	**0.1**	**1.0**	**0.6**
Northern kingfish	0.8	0.8	<0.1	0.2	0.9	0.6
White mullet	1.0	0.3	0.1	0.2	0.5	0.5
Bluefish	**0.8**	**0.4**	**0.2**	**0.1**	**0.2**	**0.5**
Striped anchovy	0.9	0.2	0.4	0.1	0.1	0.5
Black drum	0.2		0.4	0.1	2.4	0.3
White perch	0.1	0.2	1.1	<0.1	0.2	0.3
Silver perch	0.6	<0.1	0.2	0.1	0.1	0.3
Hogchoker	0.1		1.1		0.5	0.3
Striped cusk-eel	0.5			<0.1		0.2
Summer flounder	0.3					0.1
Sheepshead minnow	0.1	0.1		0.1	0.3	0.1
Atlantic needlefish	0.2	0.1	<0.1			0.1
Gizzard shad	0.1	<0.1	0.2		0.1	0.1
Mummichog	0.2	<0.1			0.1	0.1
Lookdown	0.2					0.1
Permit	0.1	<0.1				<0.1
American eel	<0.1		0.1	<0.1	0.2	<0.1
Channel catfish	0.1	0.1				<0.1
Florida pompano	0.1			<0.1		<0.1
American shad	**<0.1**	**<0.1**	**0.1**			**<0.1**
Blueback herring			**0.1**			**<0.1**
Crevalle jack	0.1					<0.1
Halfbeak	<0.1	<0.1				<0.1
Rough silverside			<0.1		0.1	<0.1
Striped burrfish	<0.1				0.1	<0.1
Northern puffer	<0.1	<0.1				<0.1
Cownose ray			<0.1			<0.1
Pigfish	<0.1					<0.1
Southern kingfish	<0.1					<0.1
Southern stingray			<0.1			<0.1

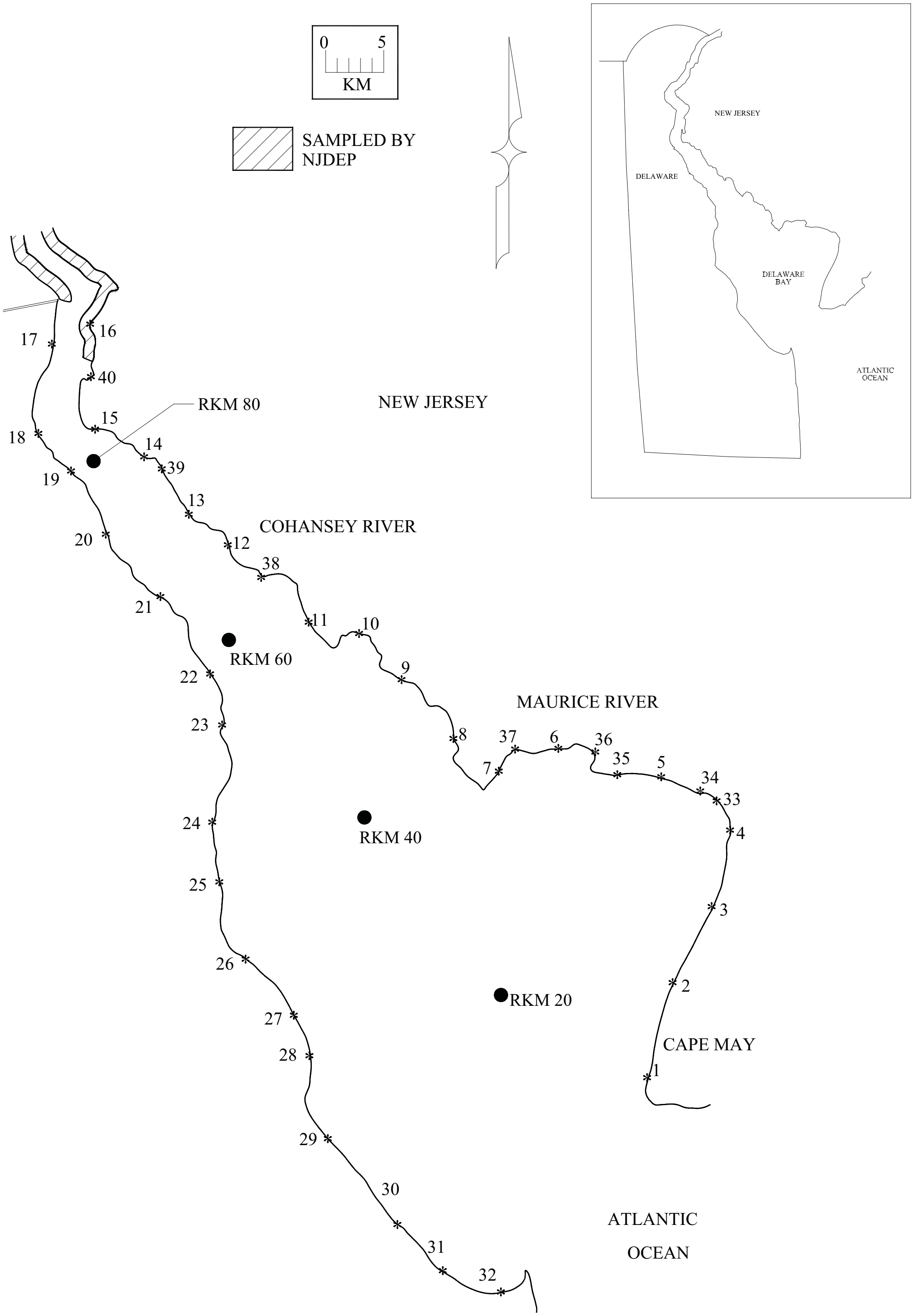
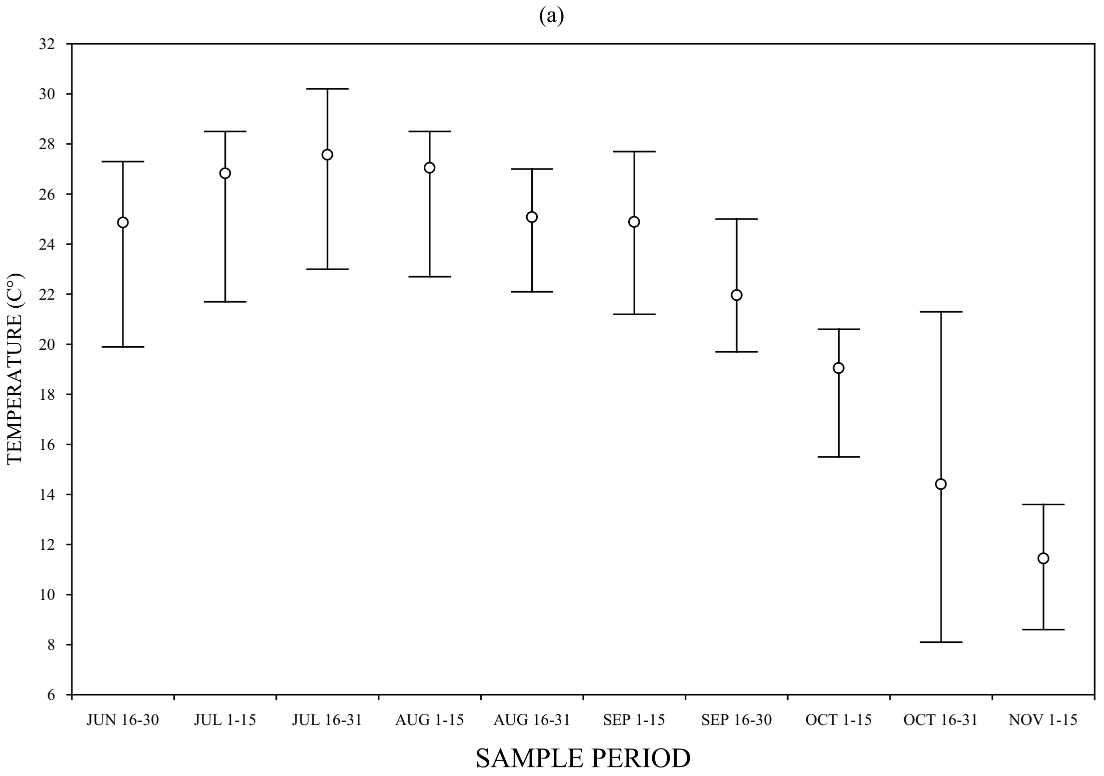


Figure 5-1 Baywide beach seine station locations.



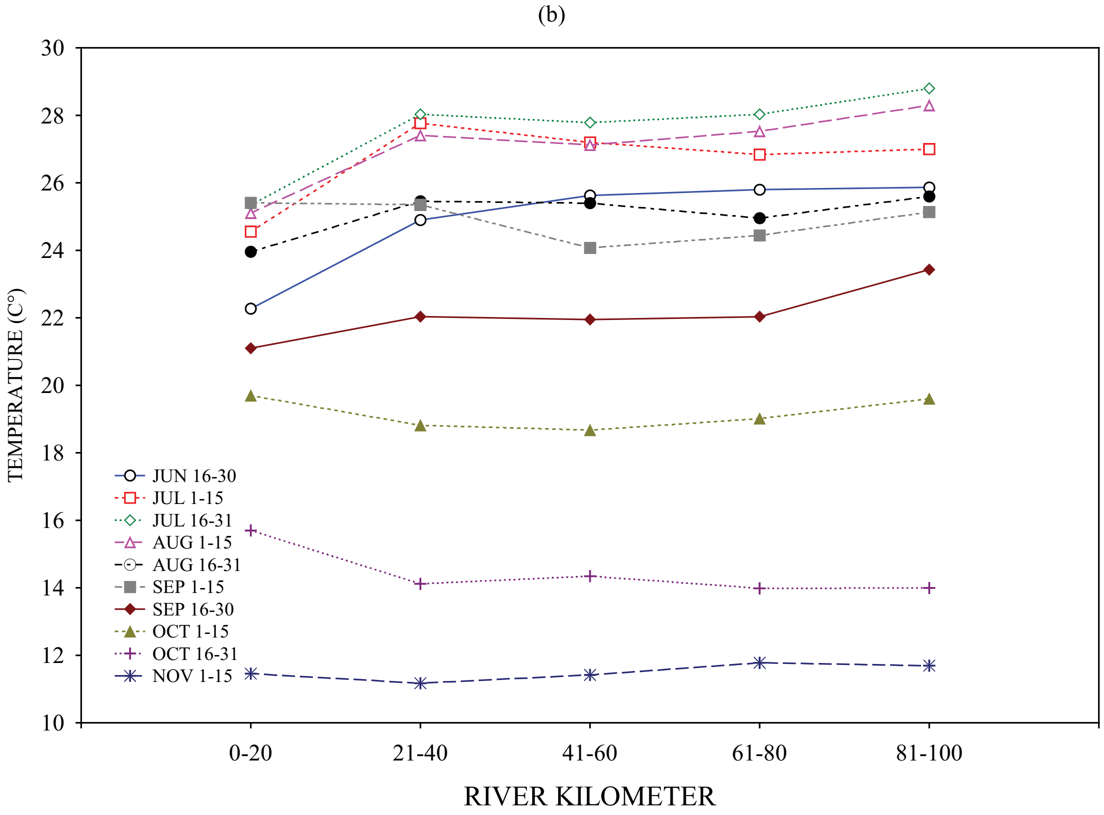


Figure 5-2 Mean temperature by sampling period (a) showing minimum and maximum values, and by river kilometer (b) as observed during the 2008 baywide seine survey.

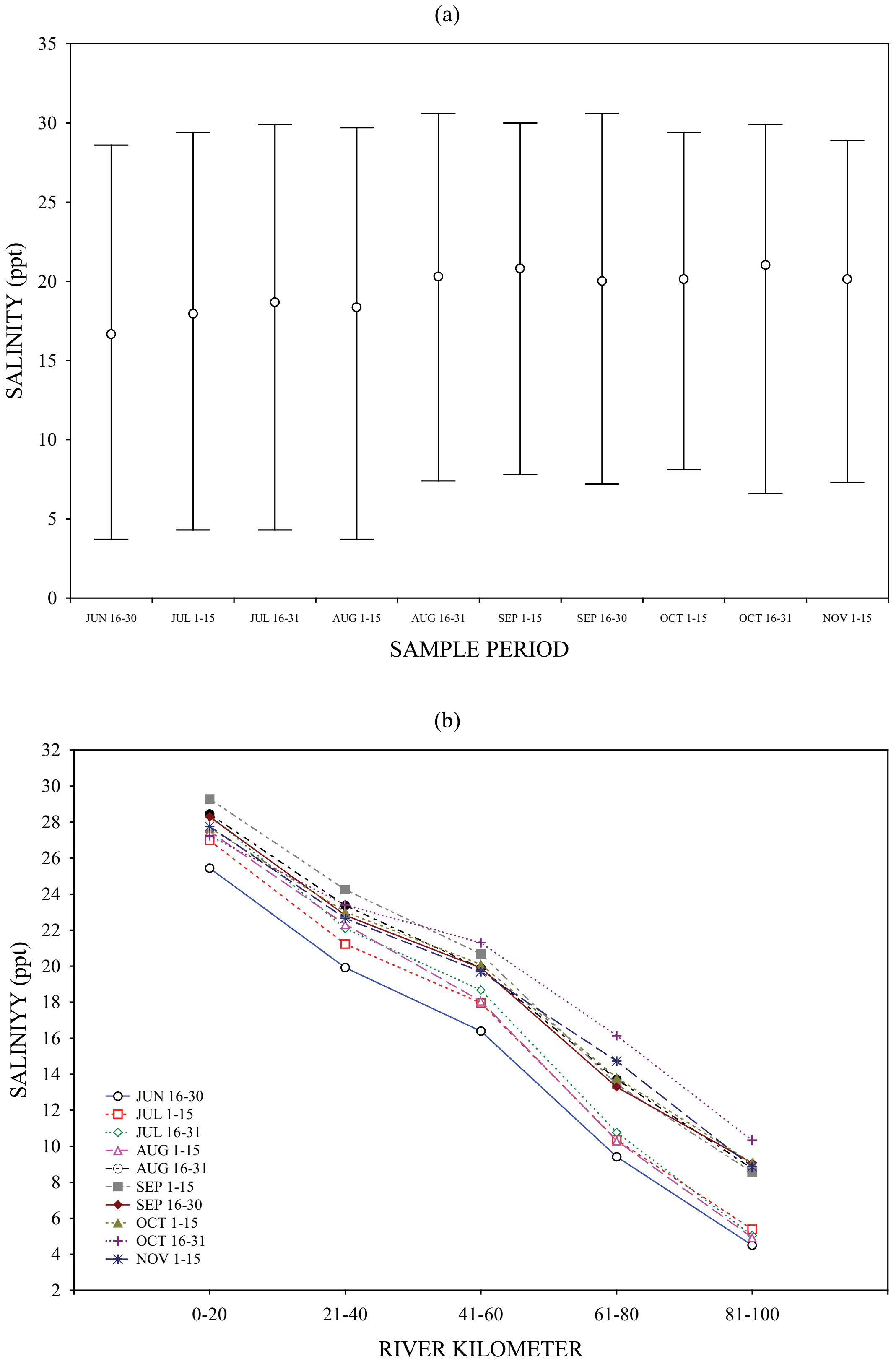


Figure 5-3 Mean salinity by sampling period (a) showing minimum and maximum values, and by river kilometer (b) as observed during the 2008 baywide seine survey.

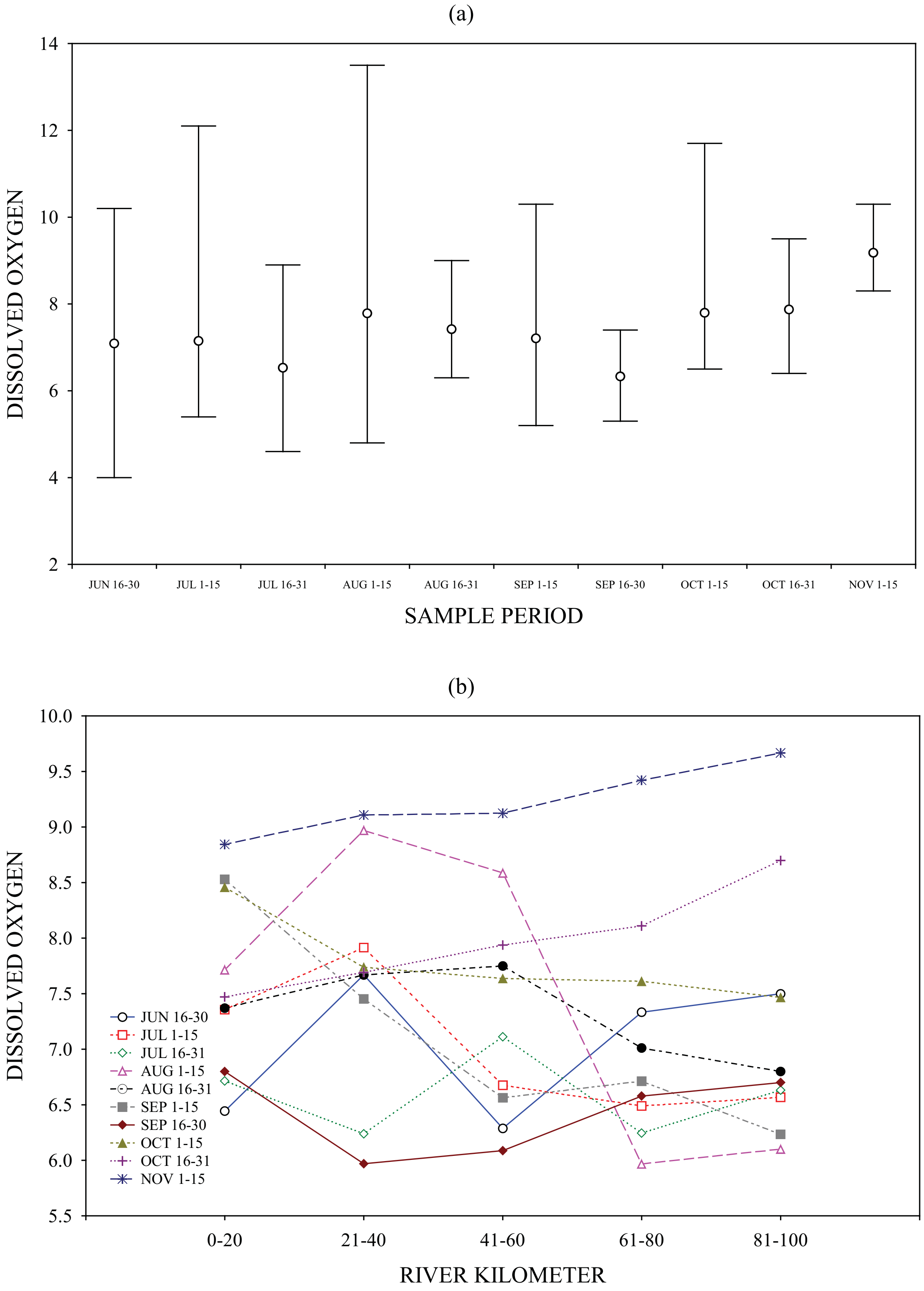


Figure 5-4 Mean dissolved oxygen by sampling period (a) showing minimum and maximum values, by river kilometer (b) as observed during the 2008 baywide seine survey.

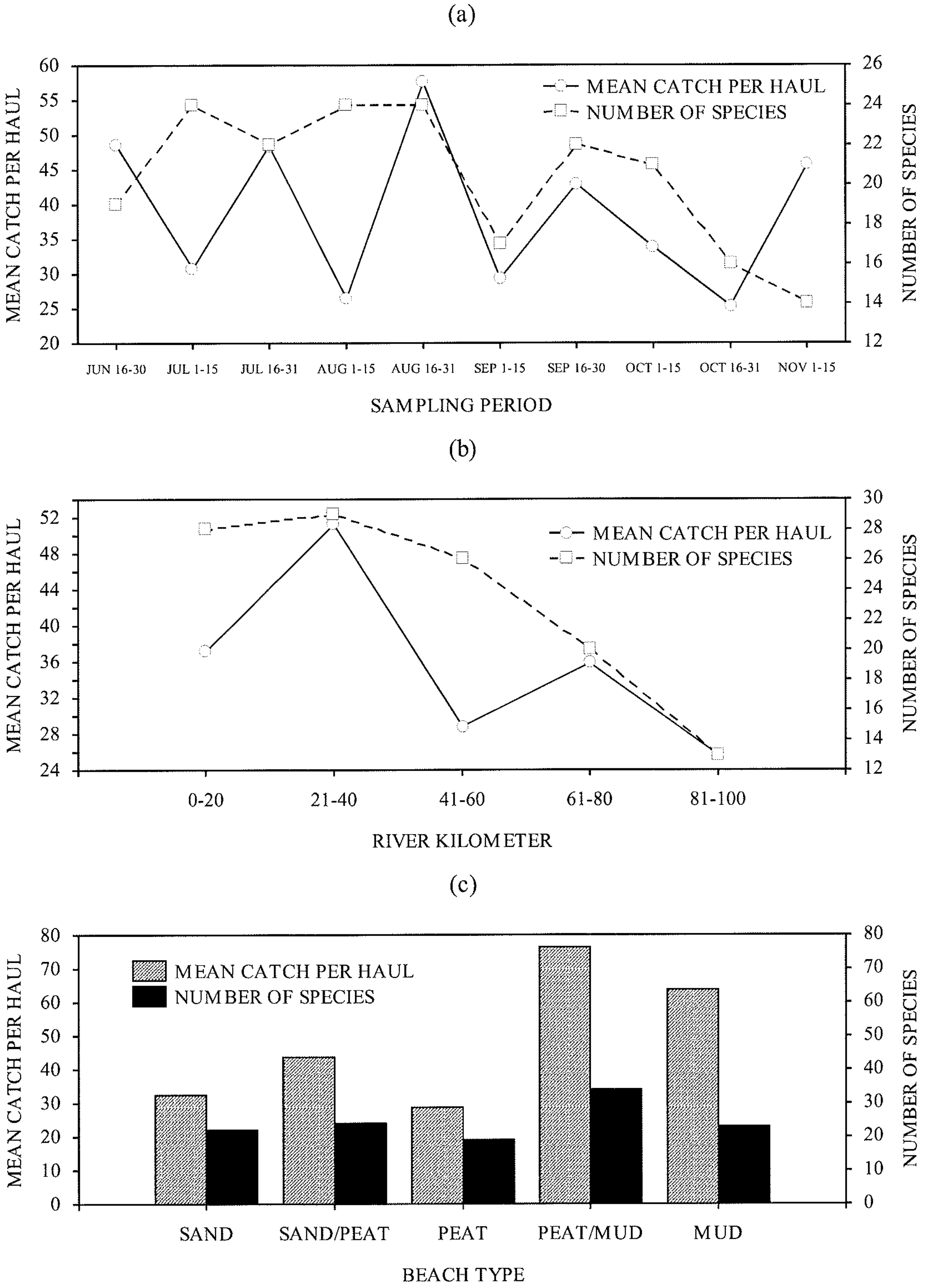


Figure 5-5 Mean abundance and species richness by sampling period (a), river kilometer (b), and beach type (c) as observed during the 2008 baywide seine survey.

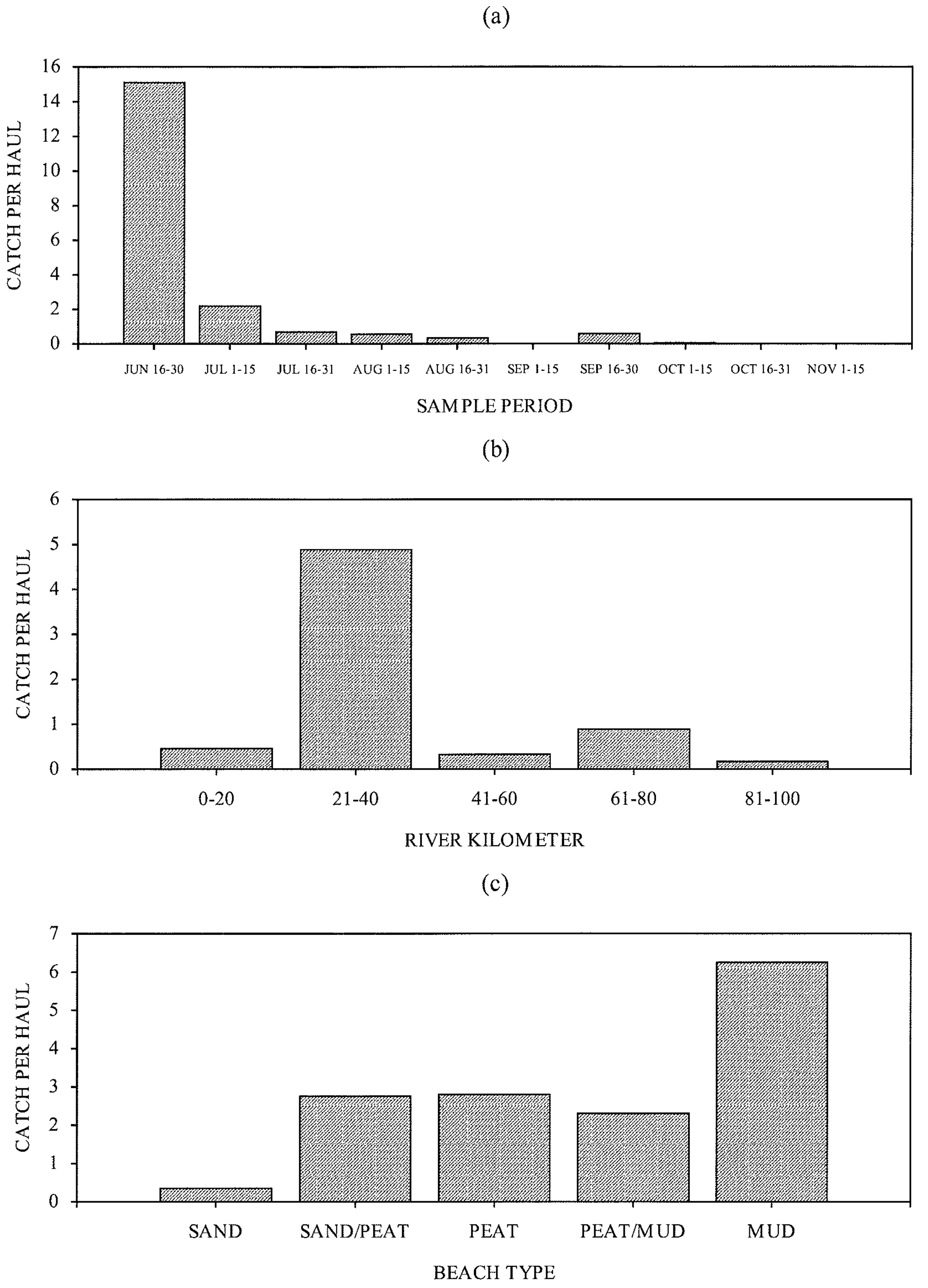


Figure 5-6 Mean catch per haul of Atlantic menhaden by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.

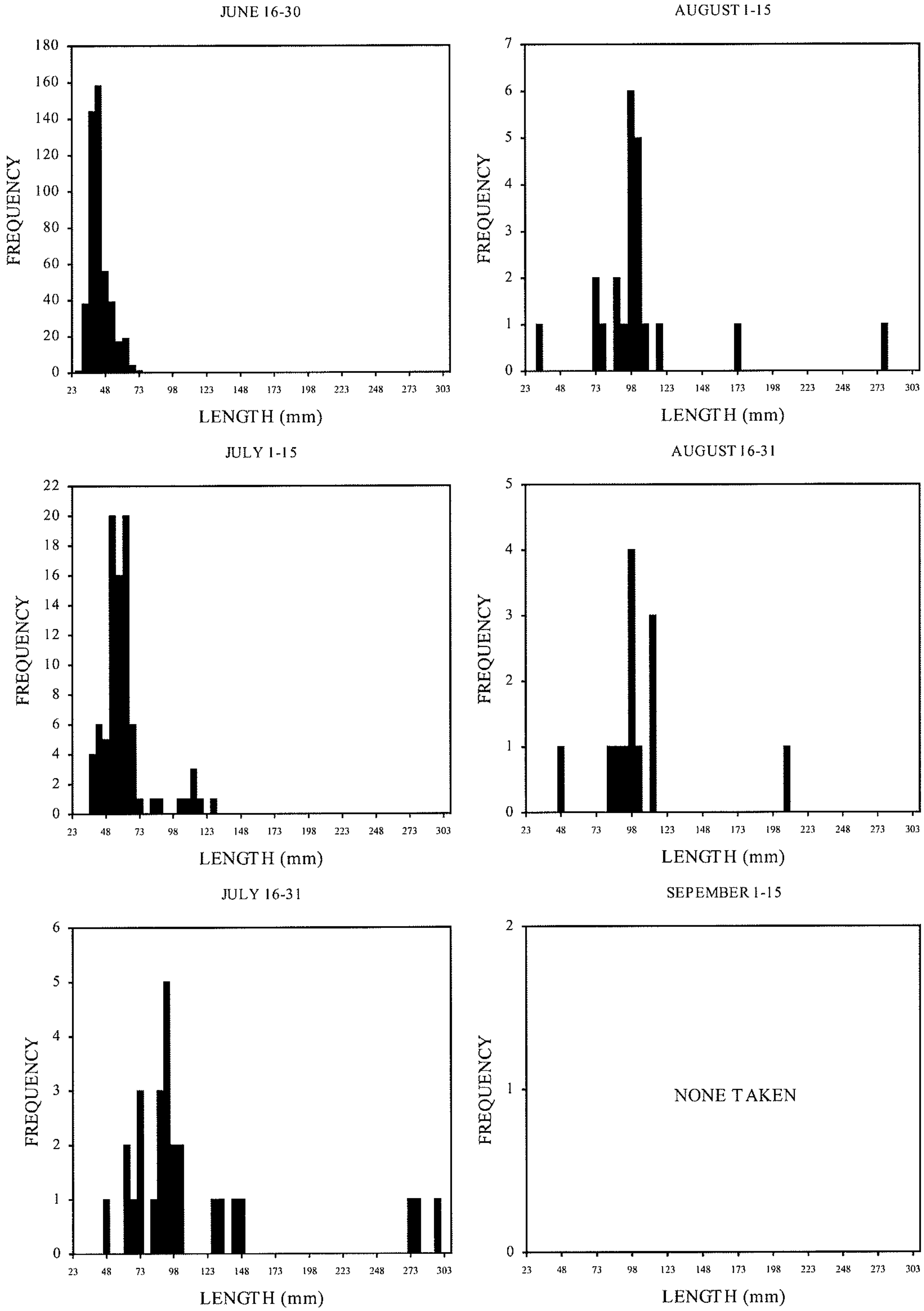
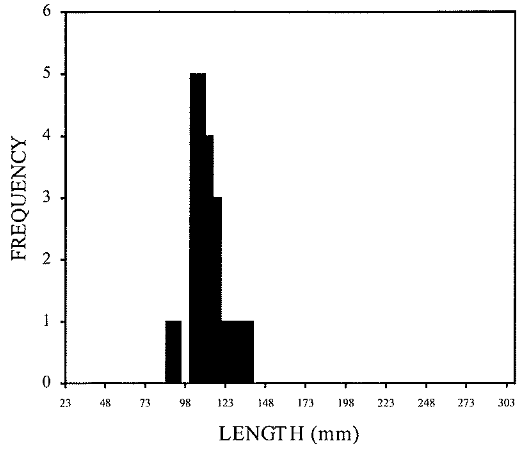
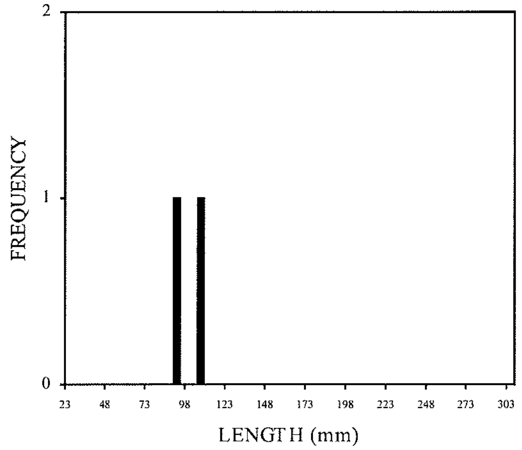


Figure 5-7 Length-frequency distribution by sampling period for Atlantic menhaden taken during the 2008 baywide seine survey.

SEPEMBER 16-30



OCTOBER 1-15



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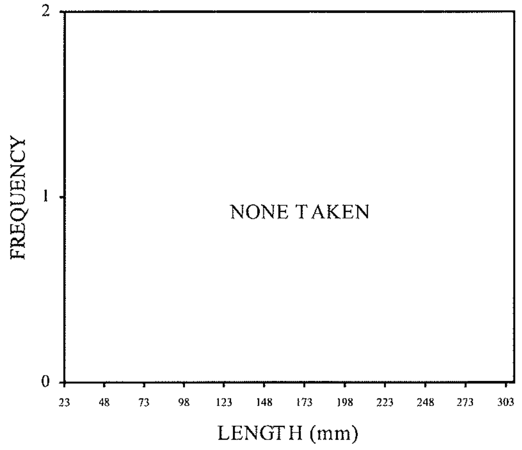

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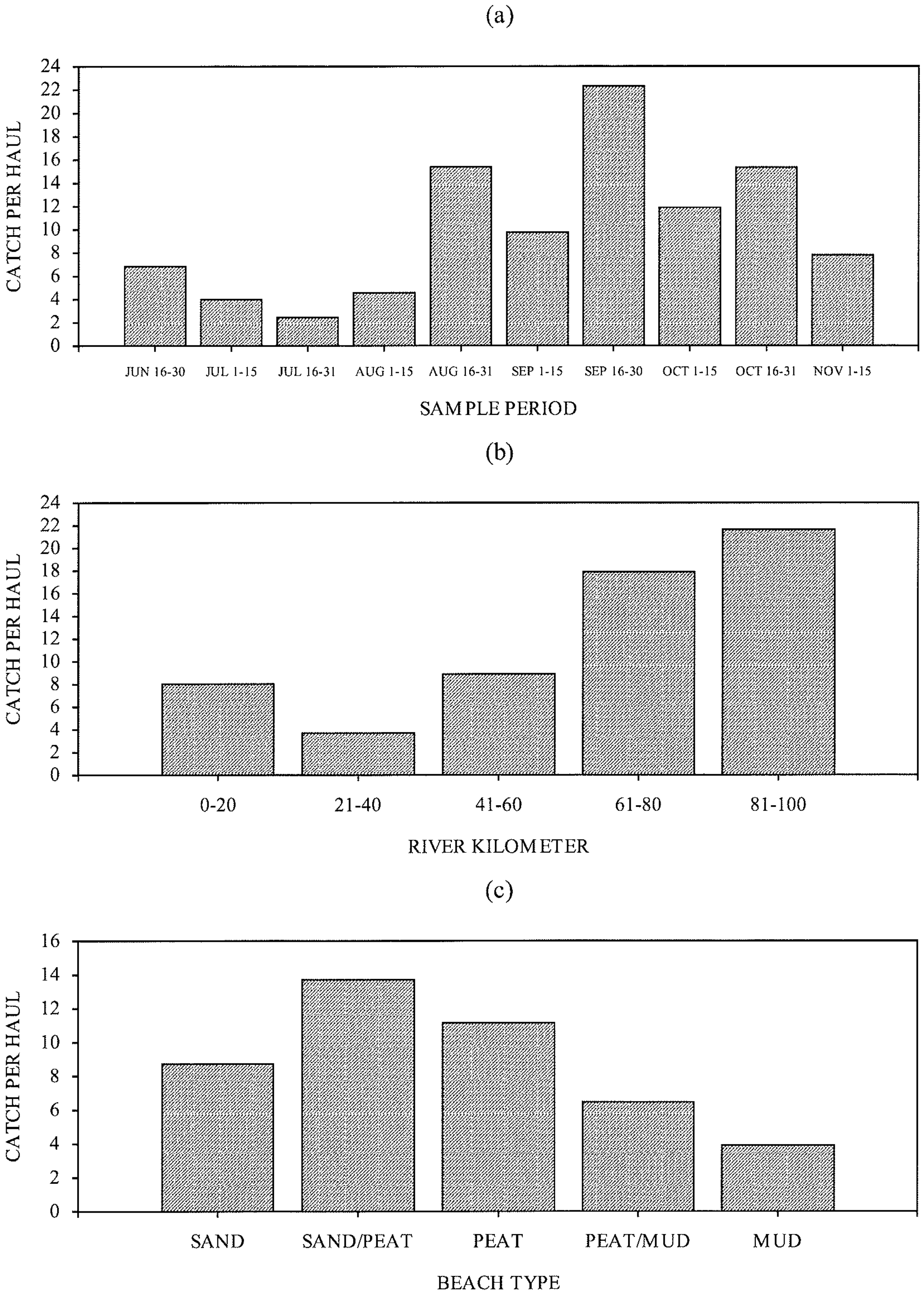


Figure 5-8 Mean catch per haul of bay anchovy by sampling period (a), river kilometer (b), and beach type (c) as observed during the 2008 baywide beach seine survey.

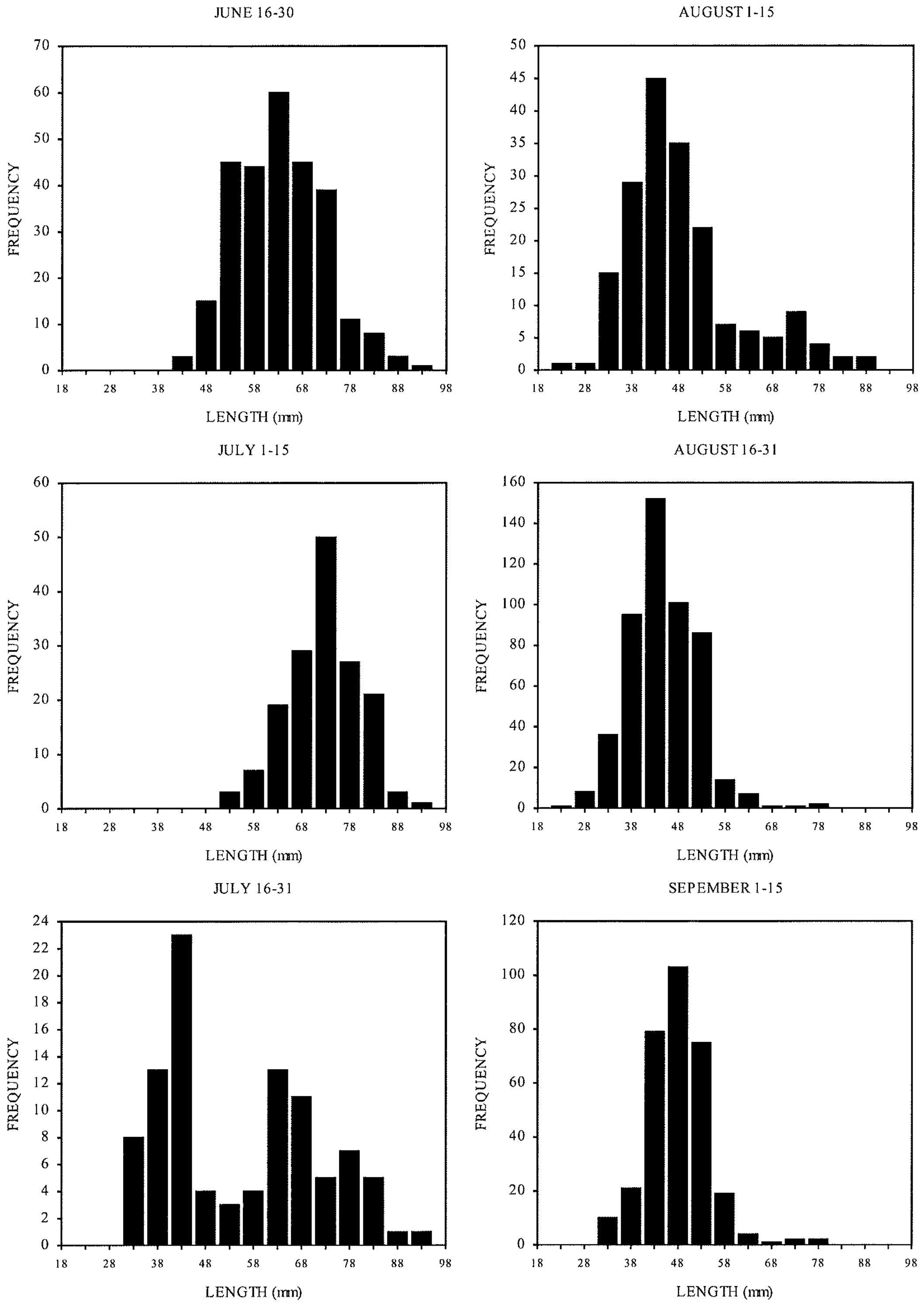
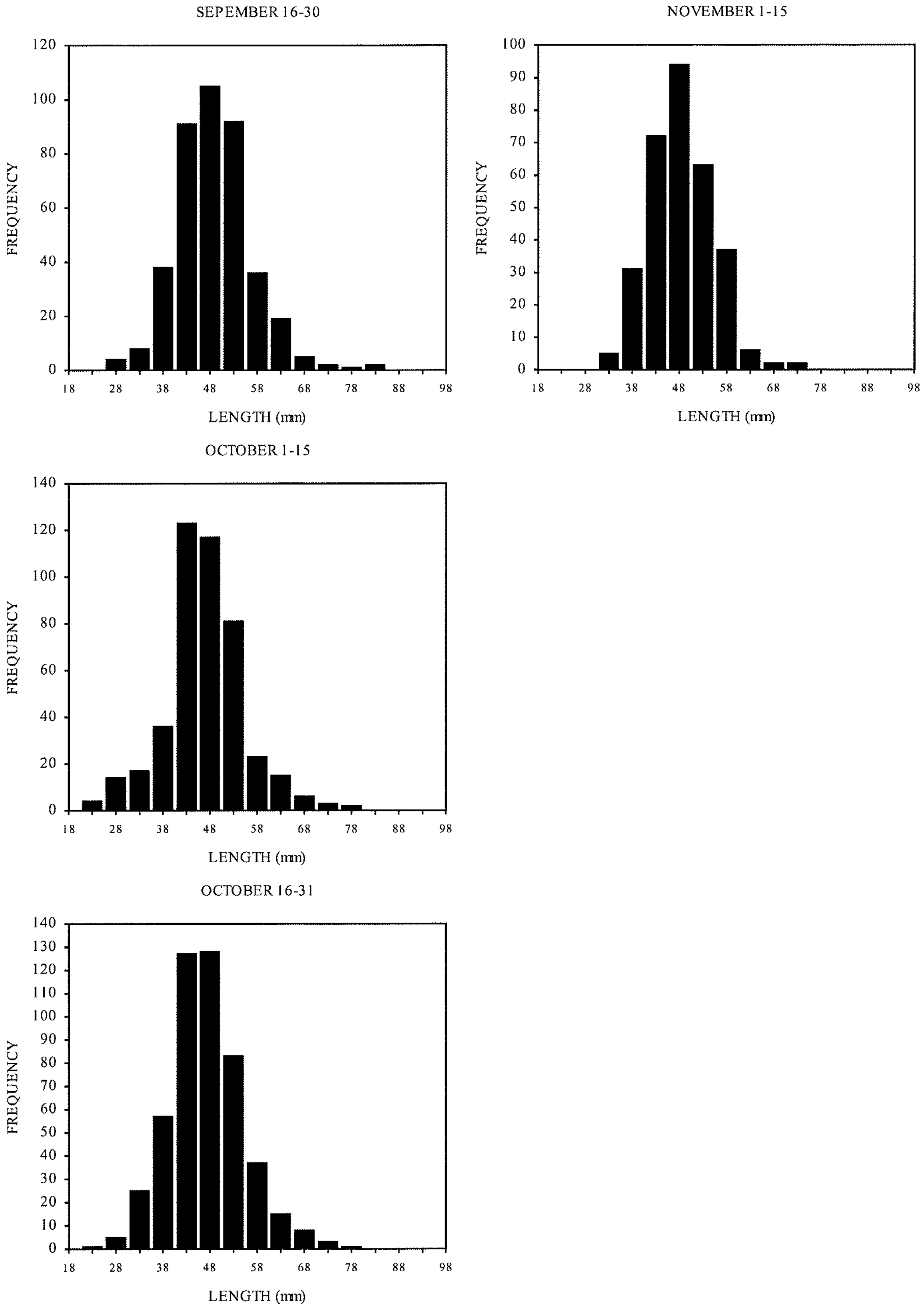


Figure 5-9 Length-frequency distribution by sampling period for bay anchovy taken during the 2008 baywide seine survey.



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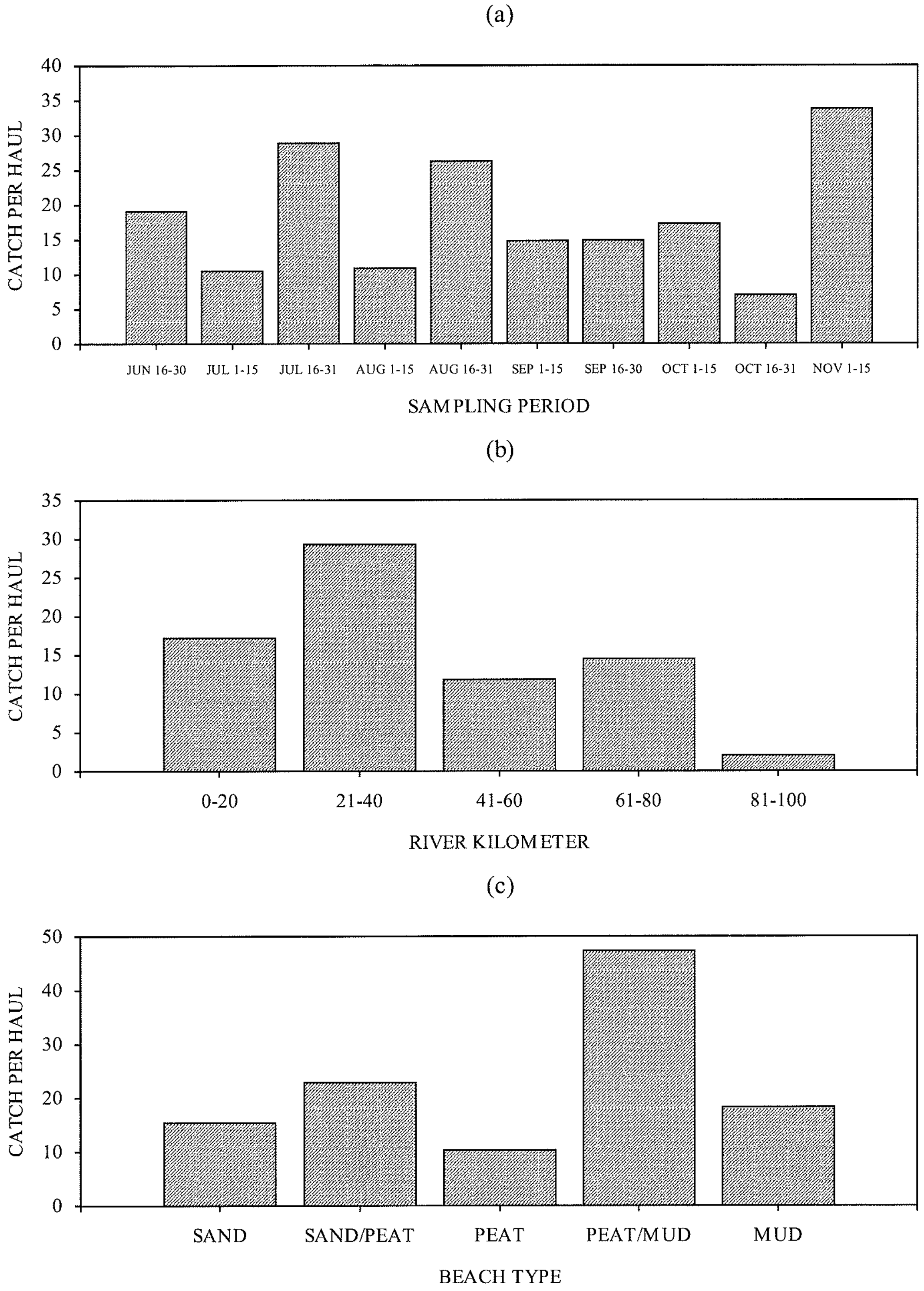


Figure 5-10 Mean catch per haul of Atlantic silverside by sampling period (a), river kilometer (b), and beach type (c) as observed during the 2008 baywide beach seine survey.

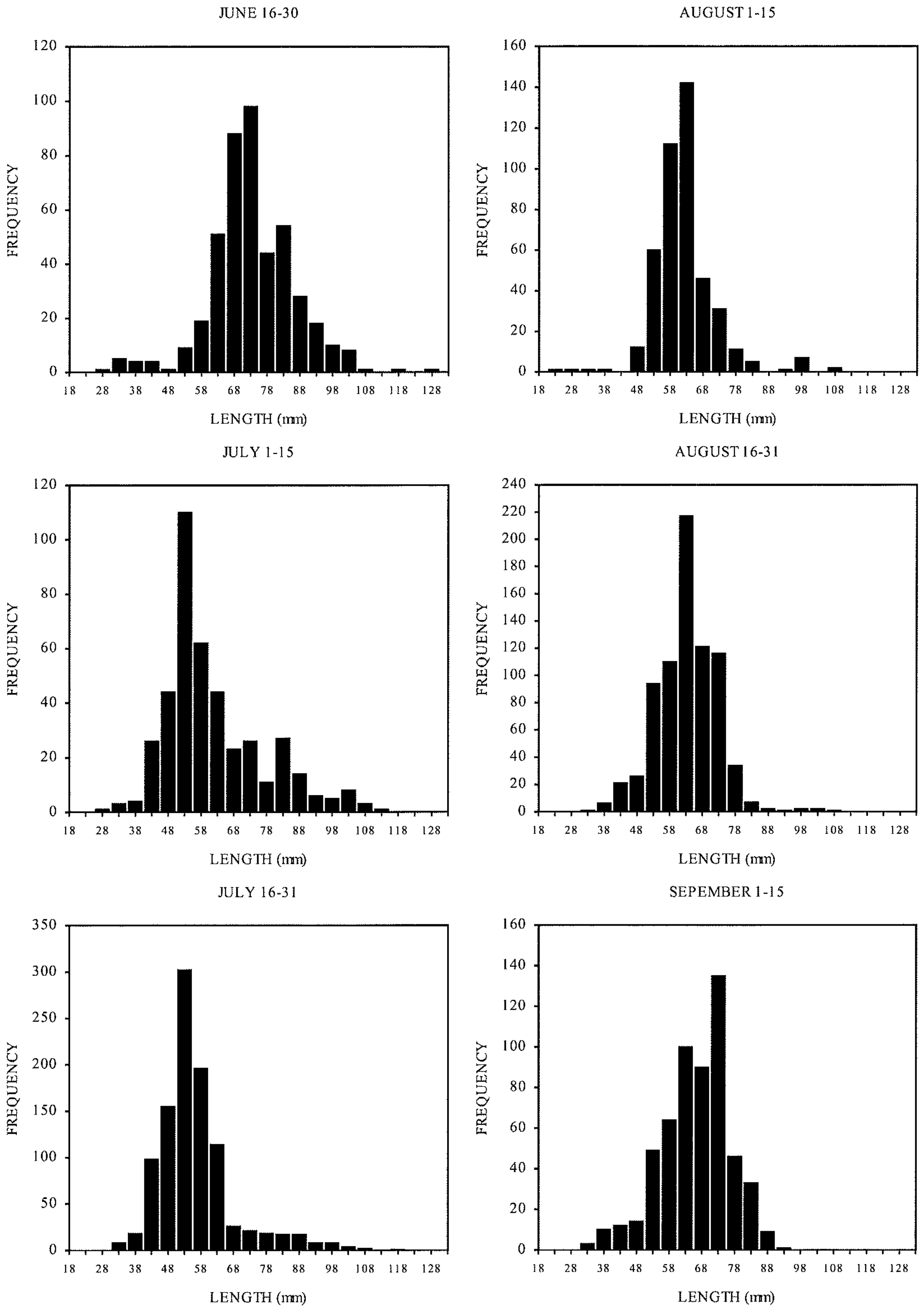
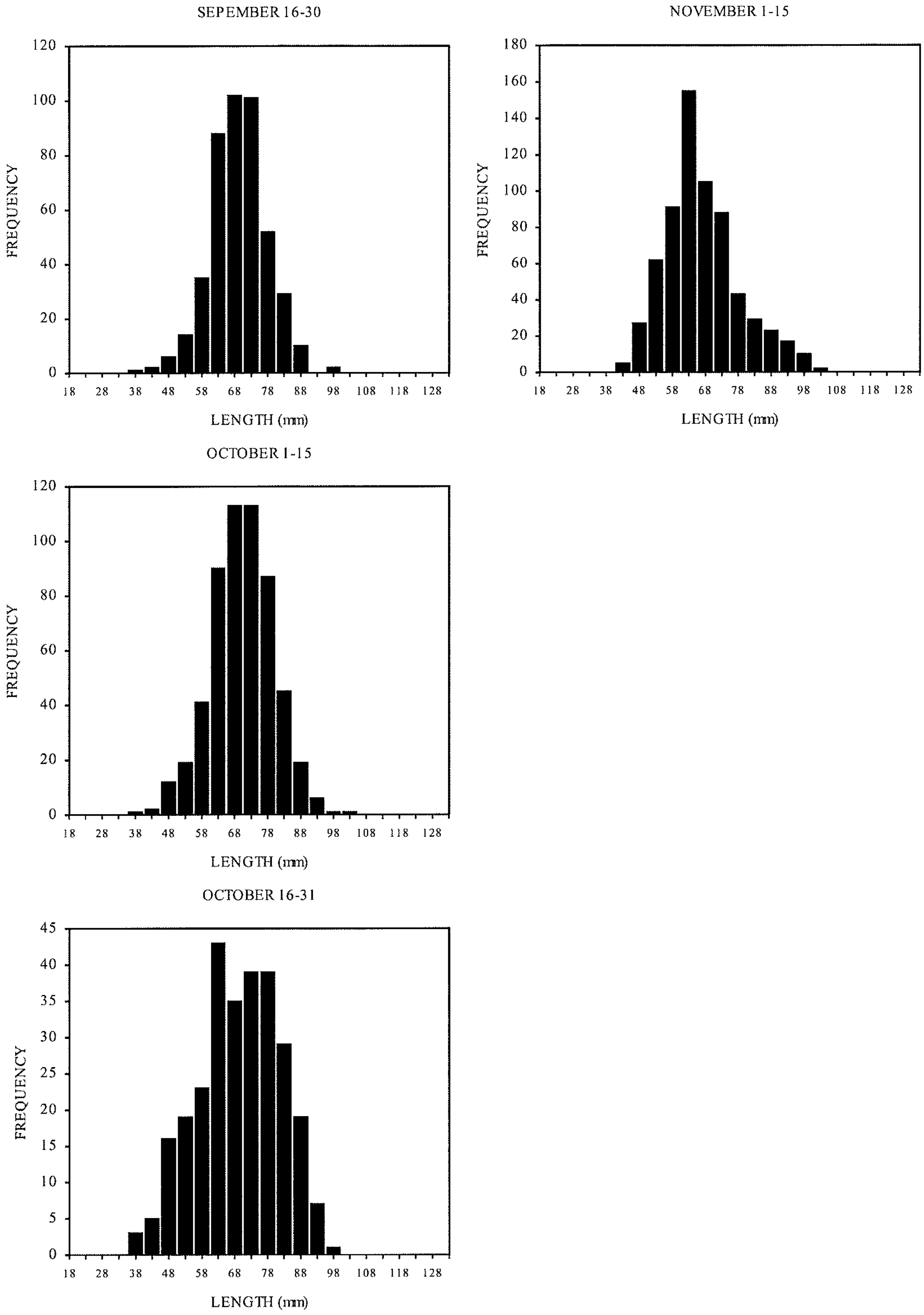


Figure 5-11 Length-frequency distribution by sampling period for Atlantic silverside taken during the 2008 baywide seine survey.



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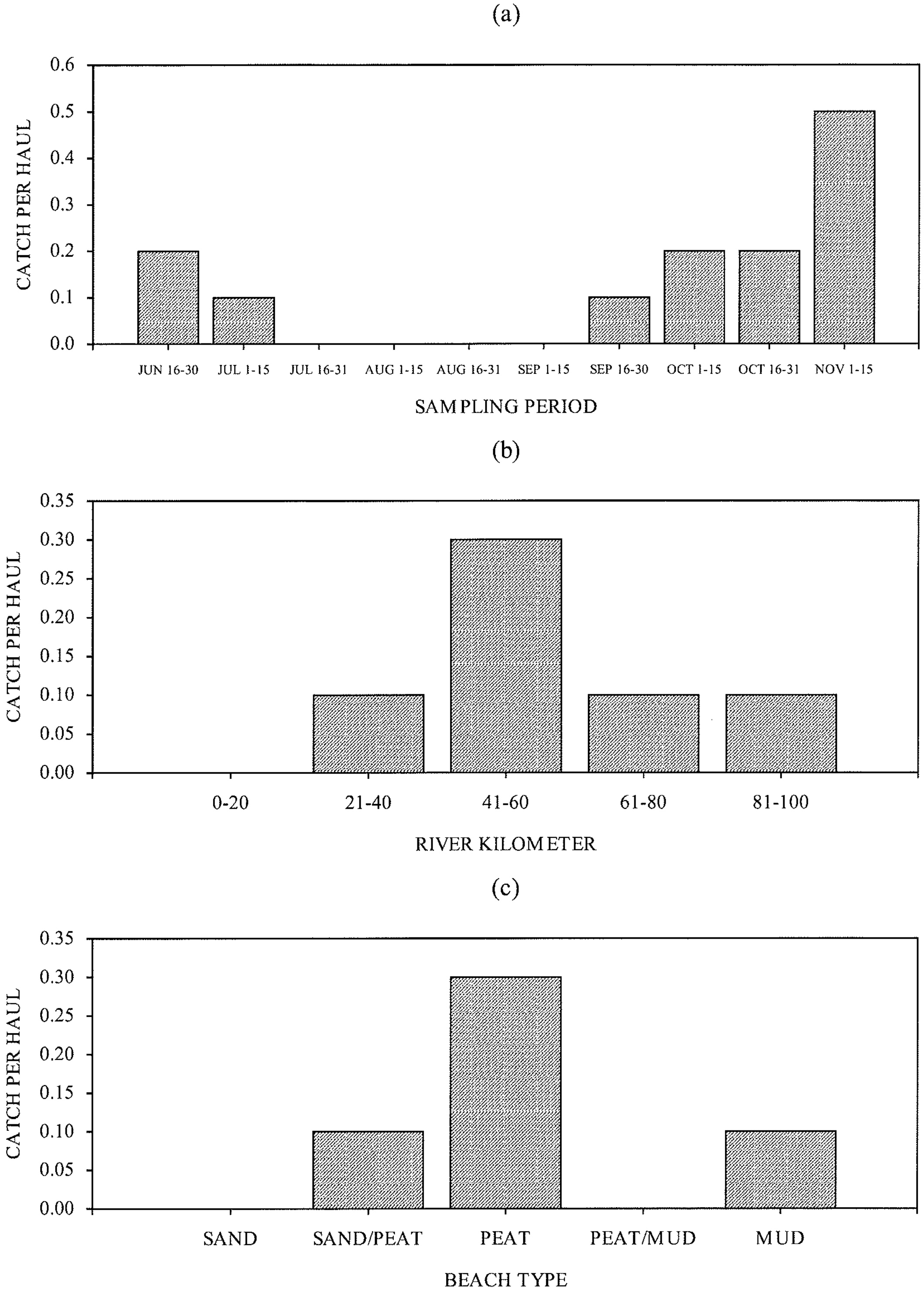


Figure 5-12 Mean catch per haul of white perch by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.

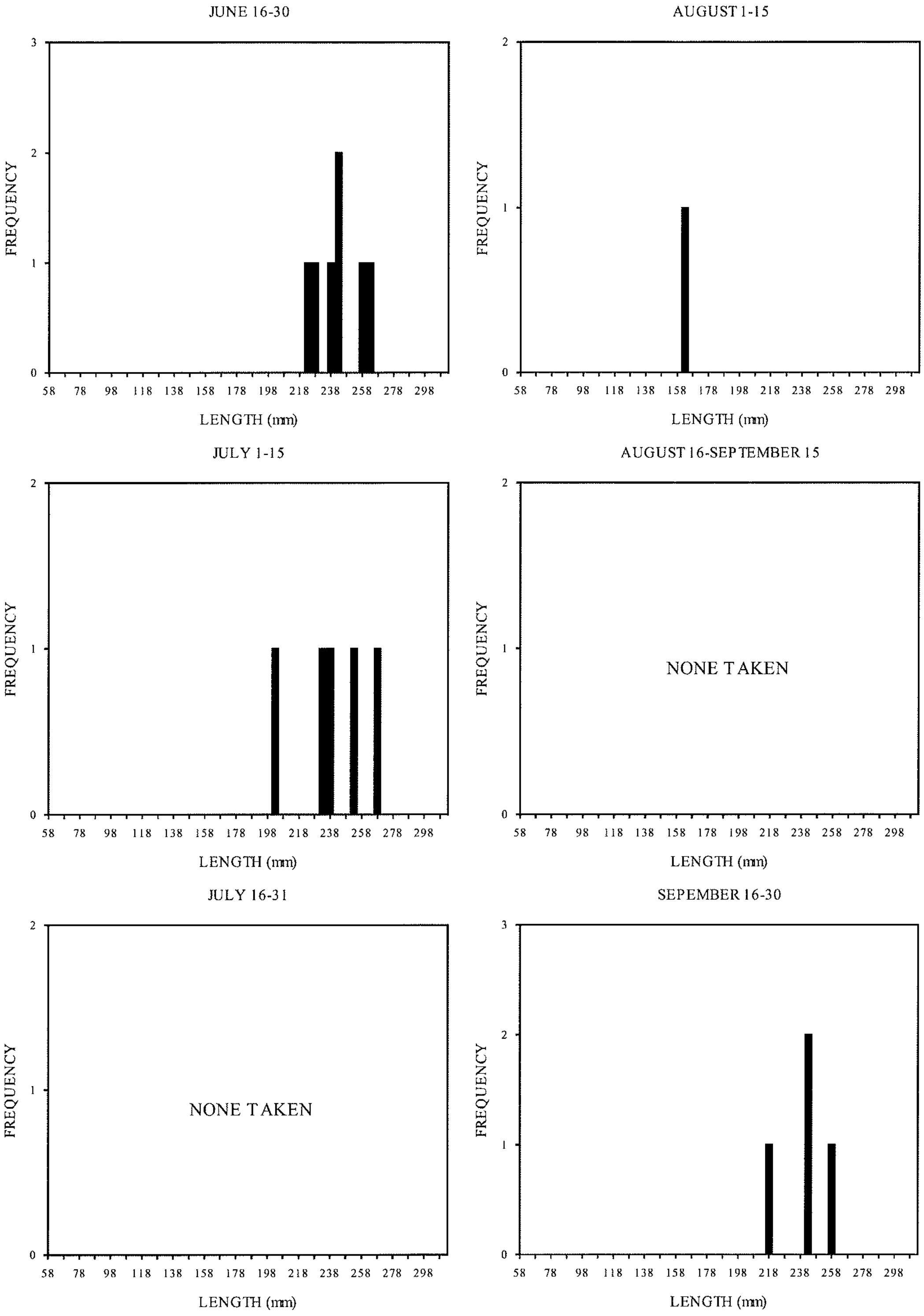
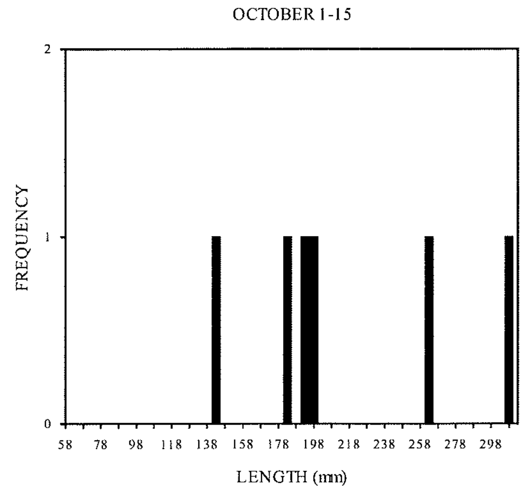
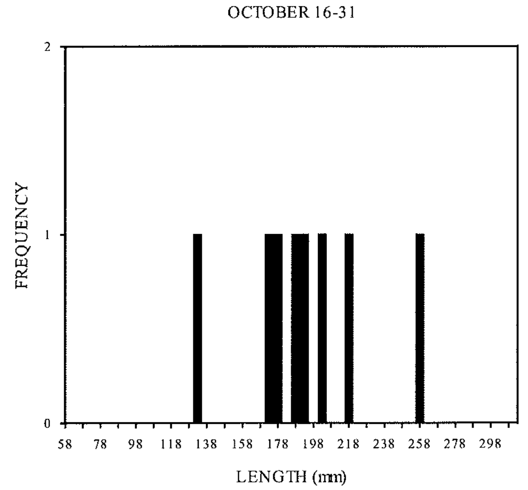
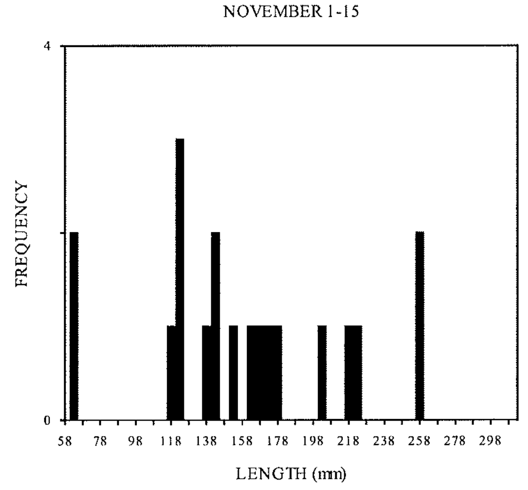


Figure 5-13 Length-frequency distribution by sampling period for white perch taken during the 2008 baywide seine survey.







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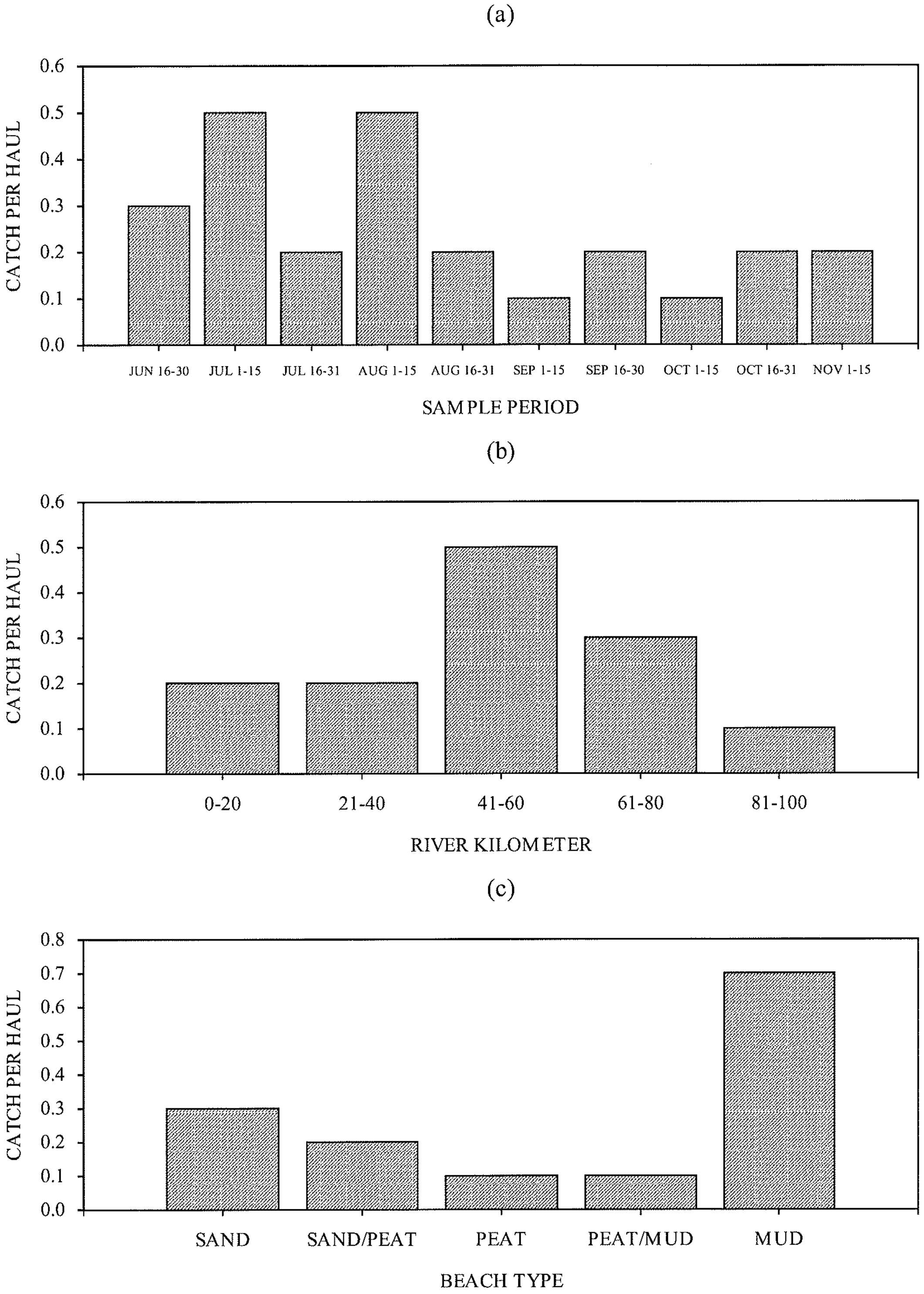
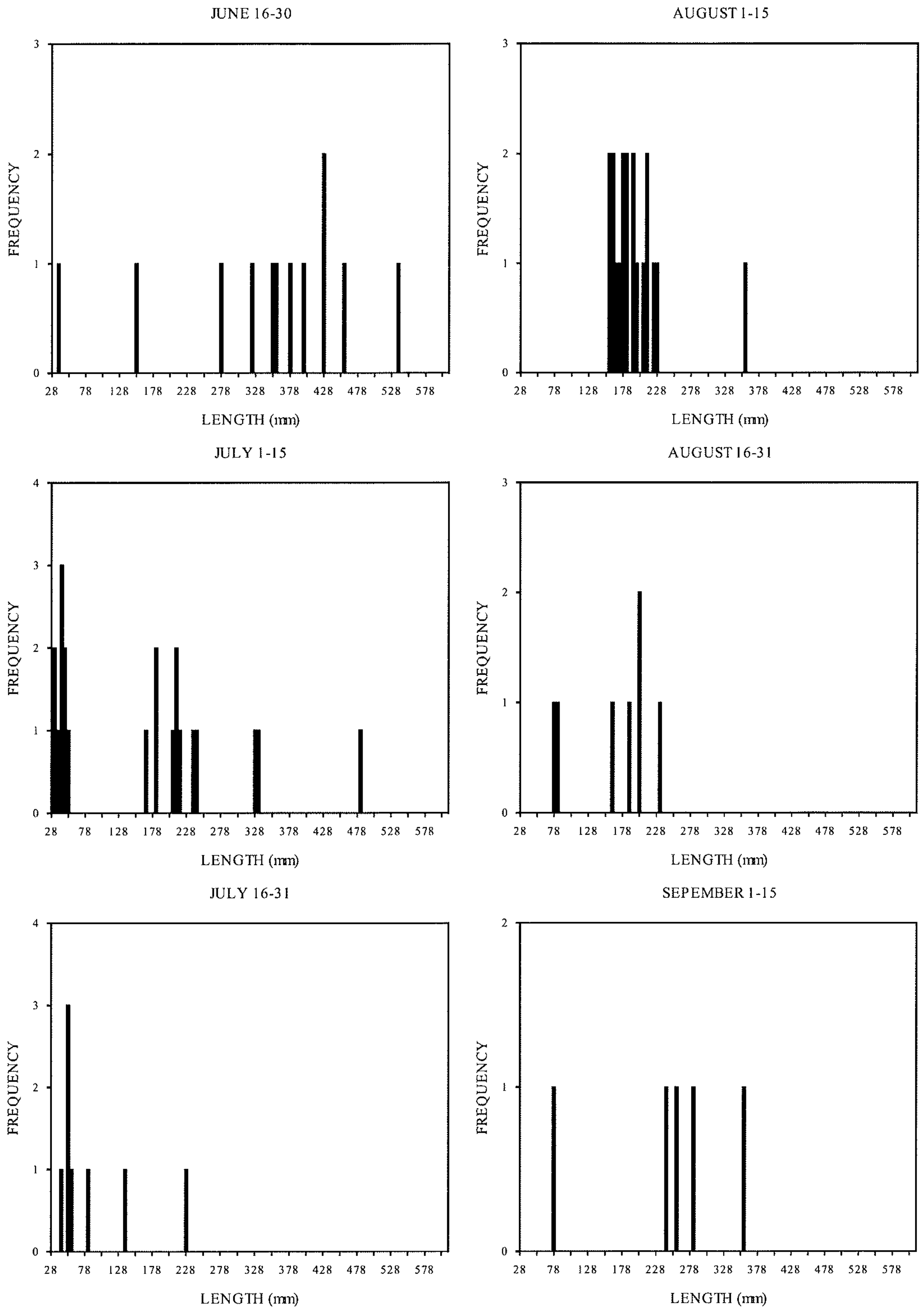


Figure 5-14 Mean catch per haul of striped bass by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.



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JULY 1-15

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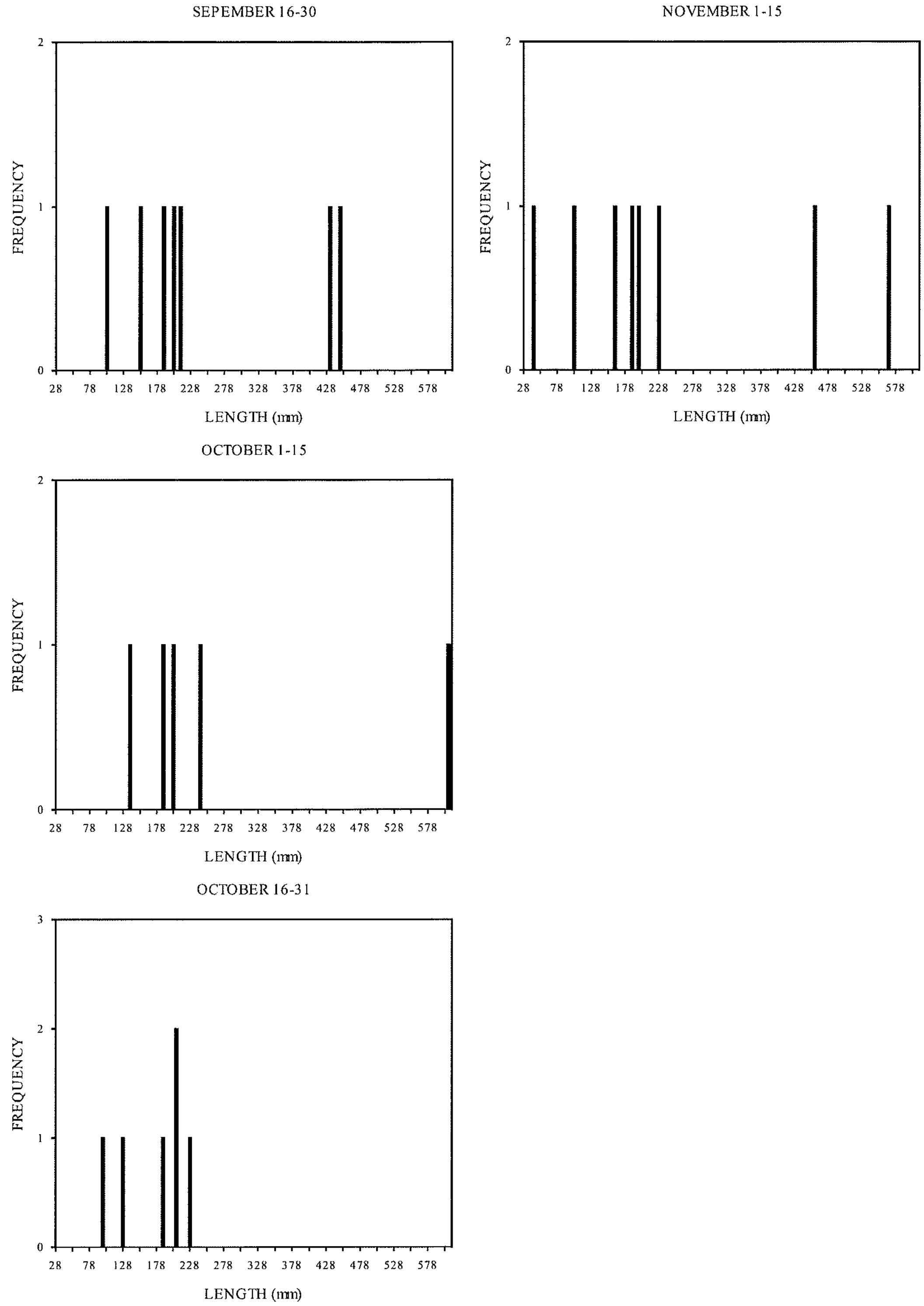
Figure 5-15 Length-frequency distribution by sampling period for striped bass taken during the 2008 baywide seine survey.



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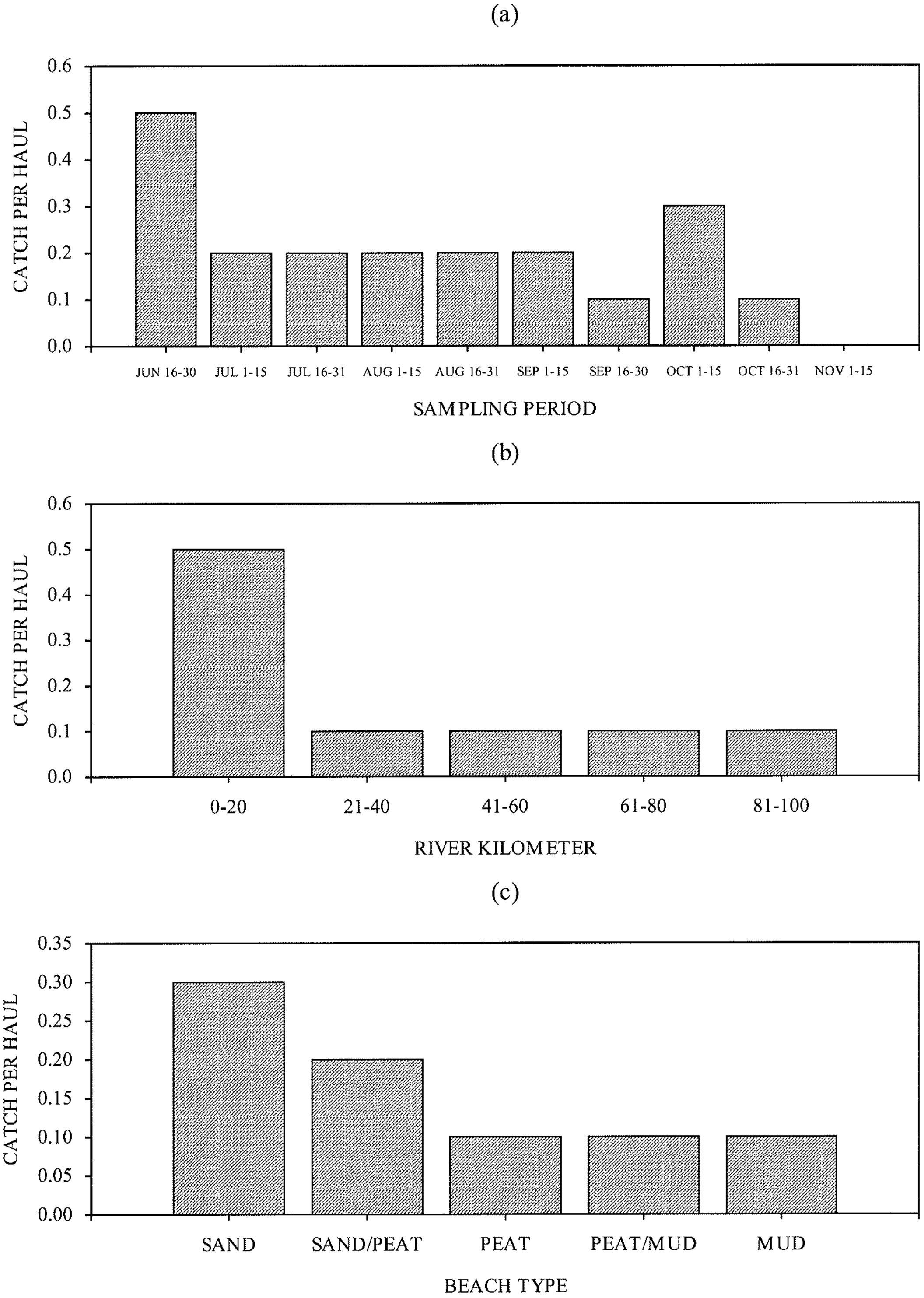


Figure 5-16 Mean catch per haul of bluefish by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.

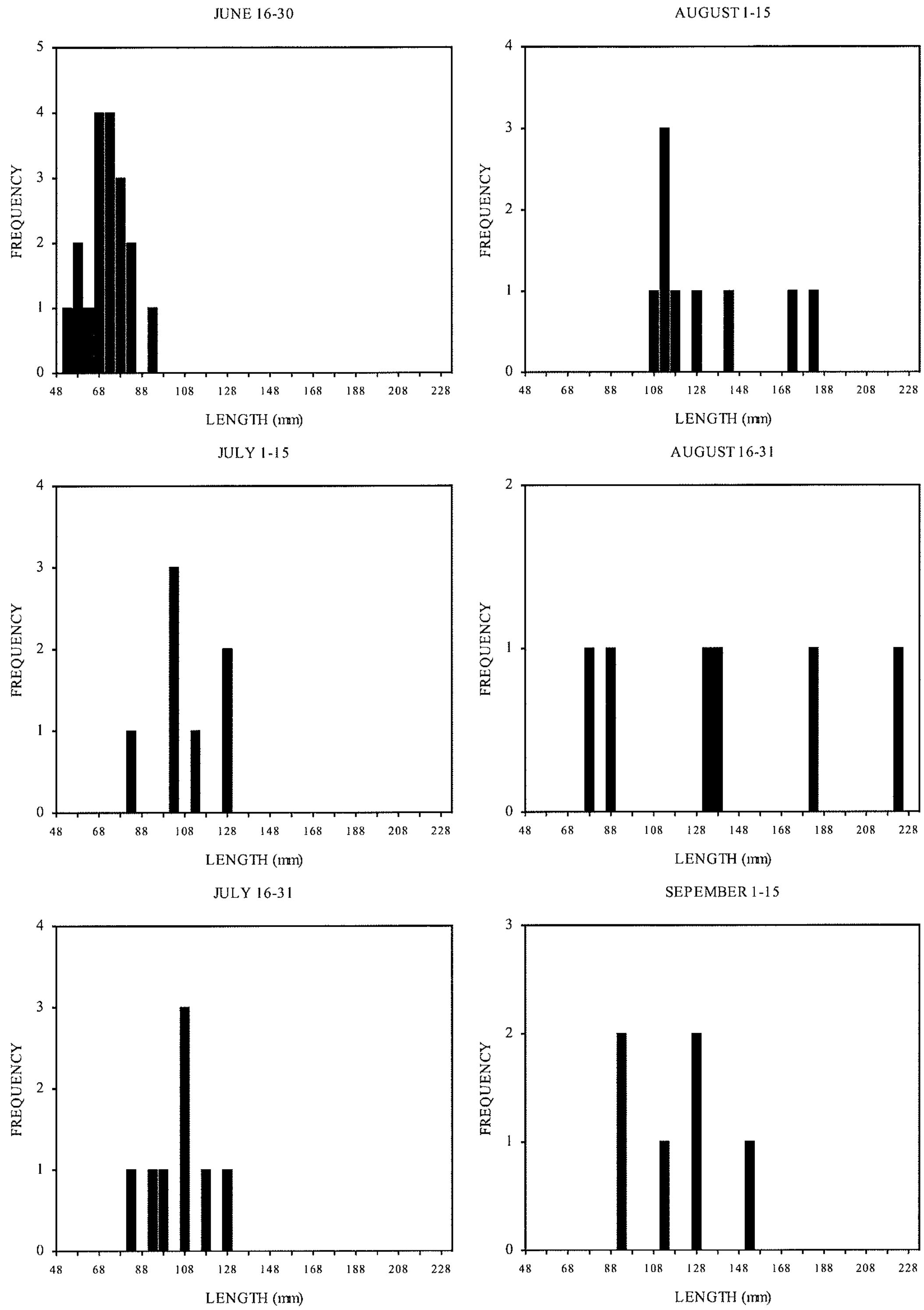
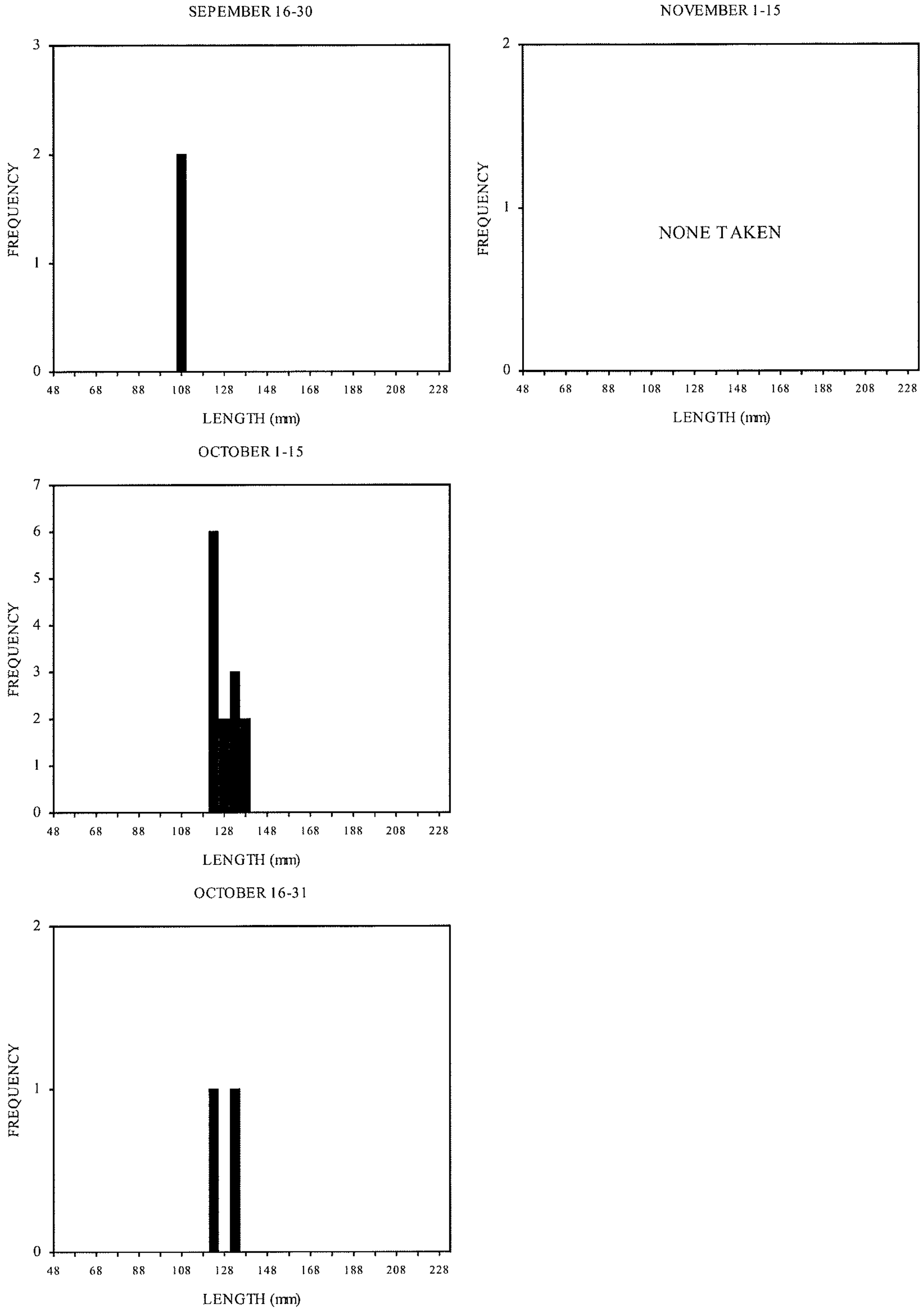


Figure 5-17 Length-frequency distribution by sampling period for bluefish taken during the 2008 baywide seine survey.



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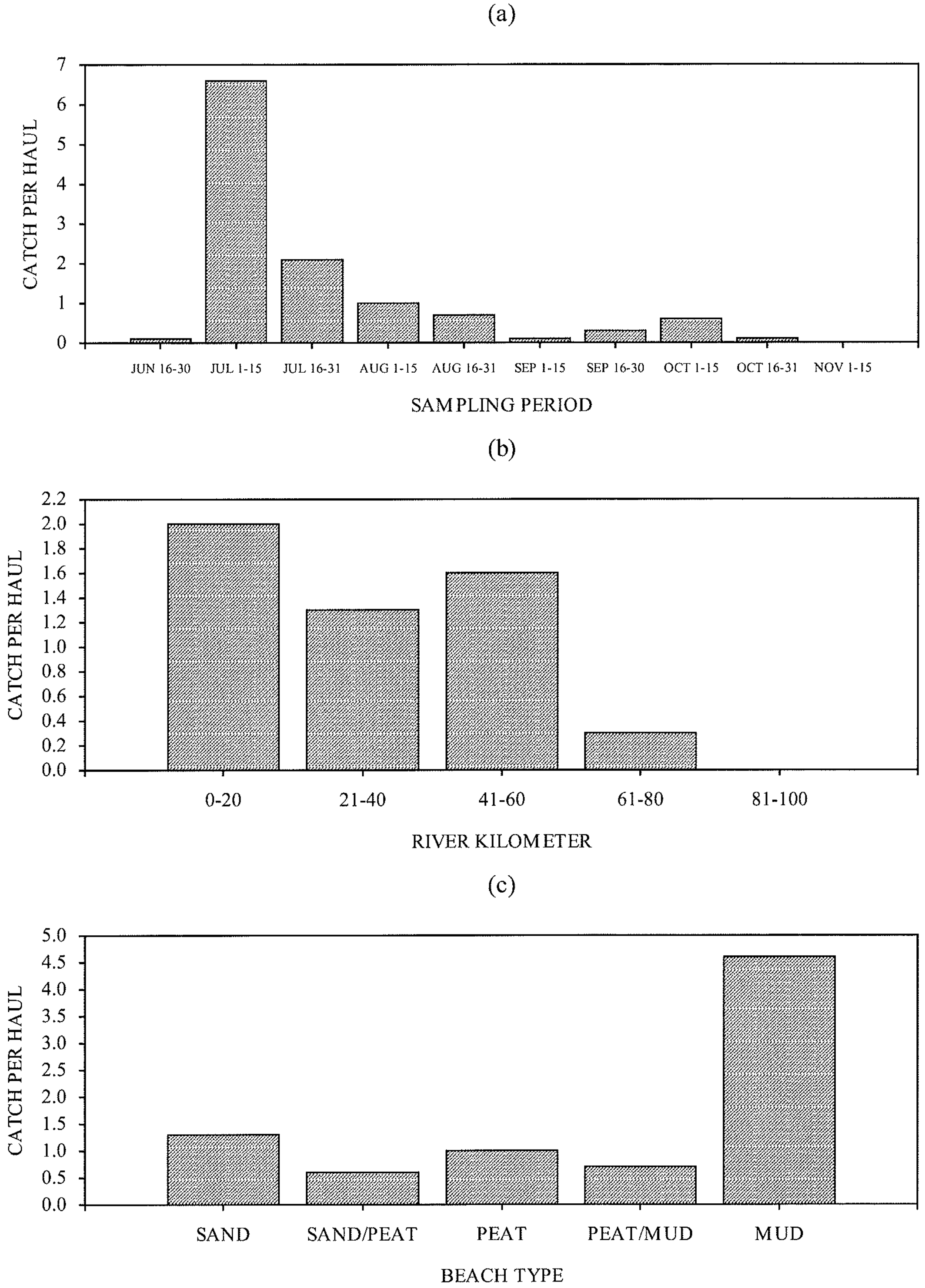


Figure 5-18 Mean catch per haul of weakfish by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.

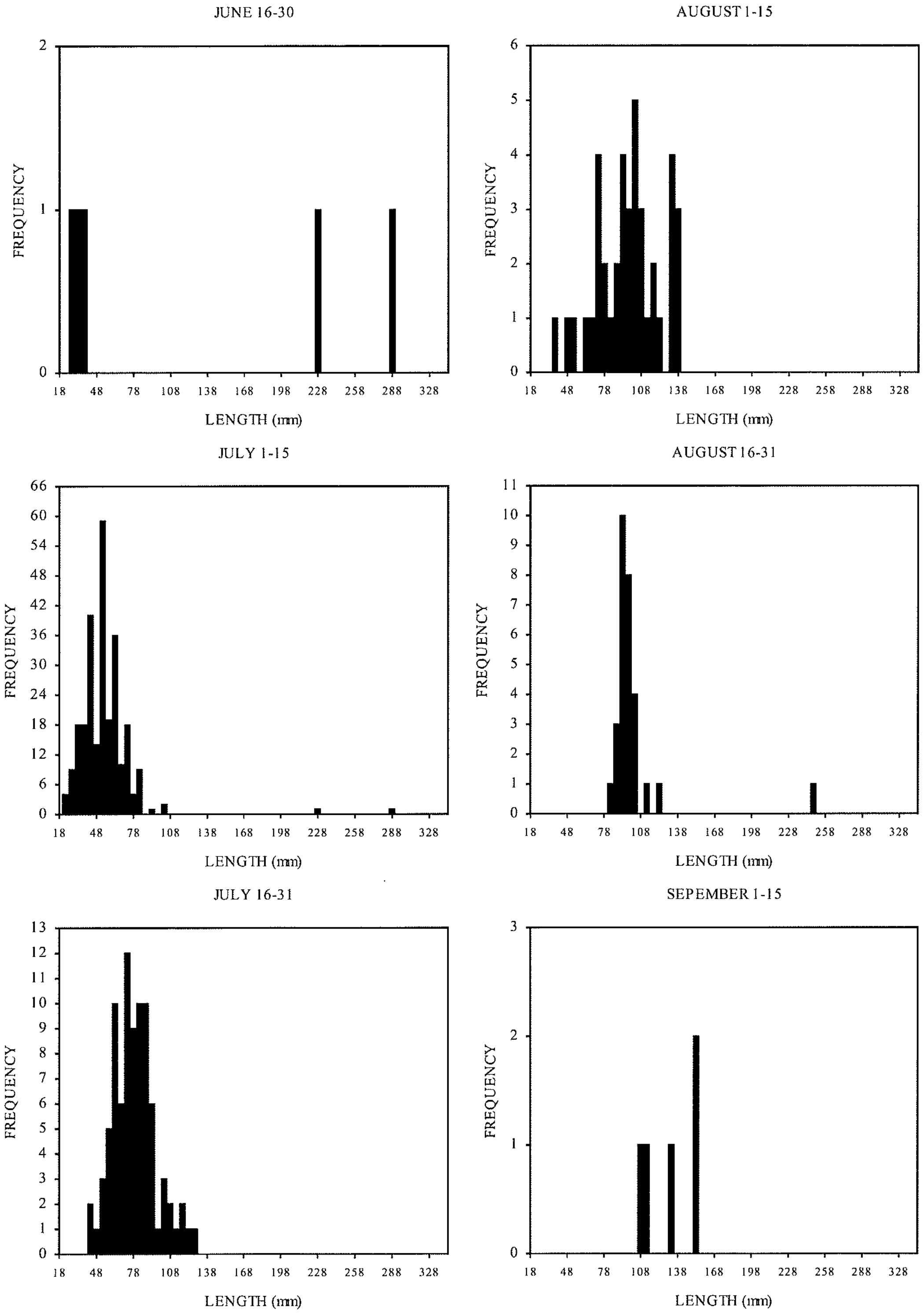
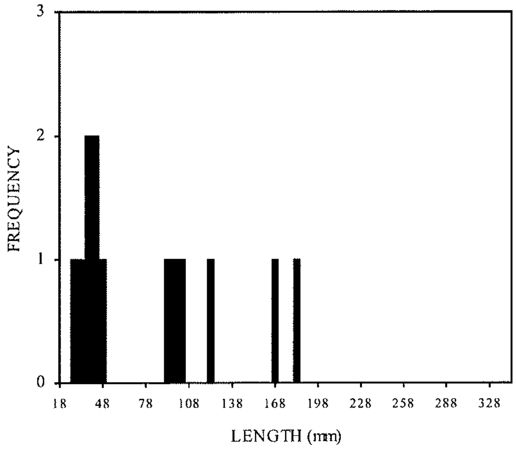
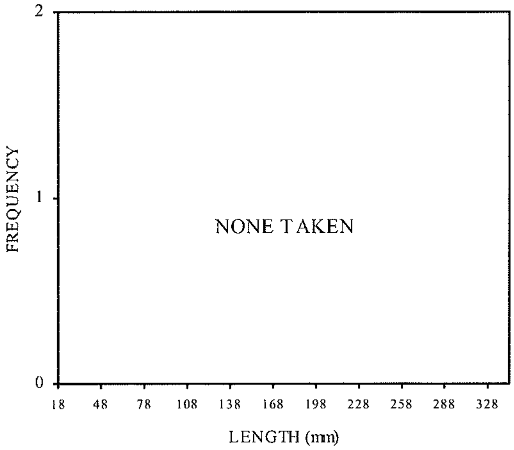


Figure 5-19 Length-frequency distribution by sampling period for weakfish taken during the 2008 baywide seine survey.

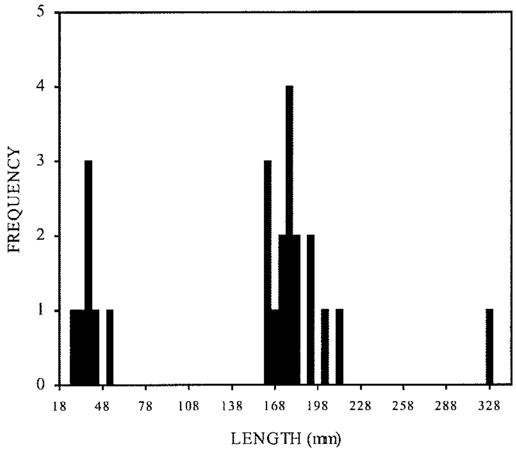
SEPEMBER 16-30



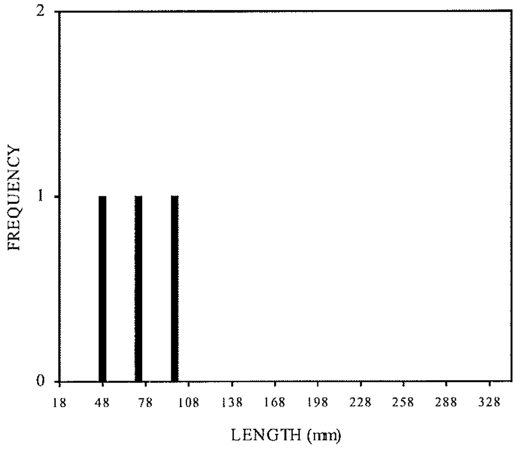
NOVEMBER 1-15



OCTOBER 1-15



OCTOBER 16-31



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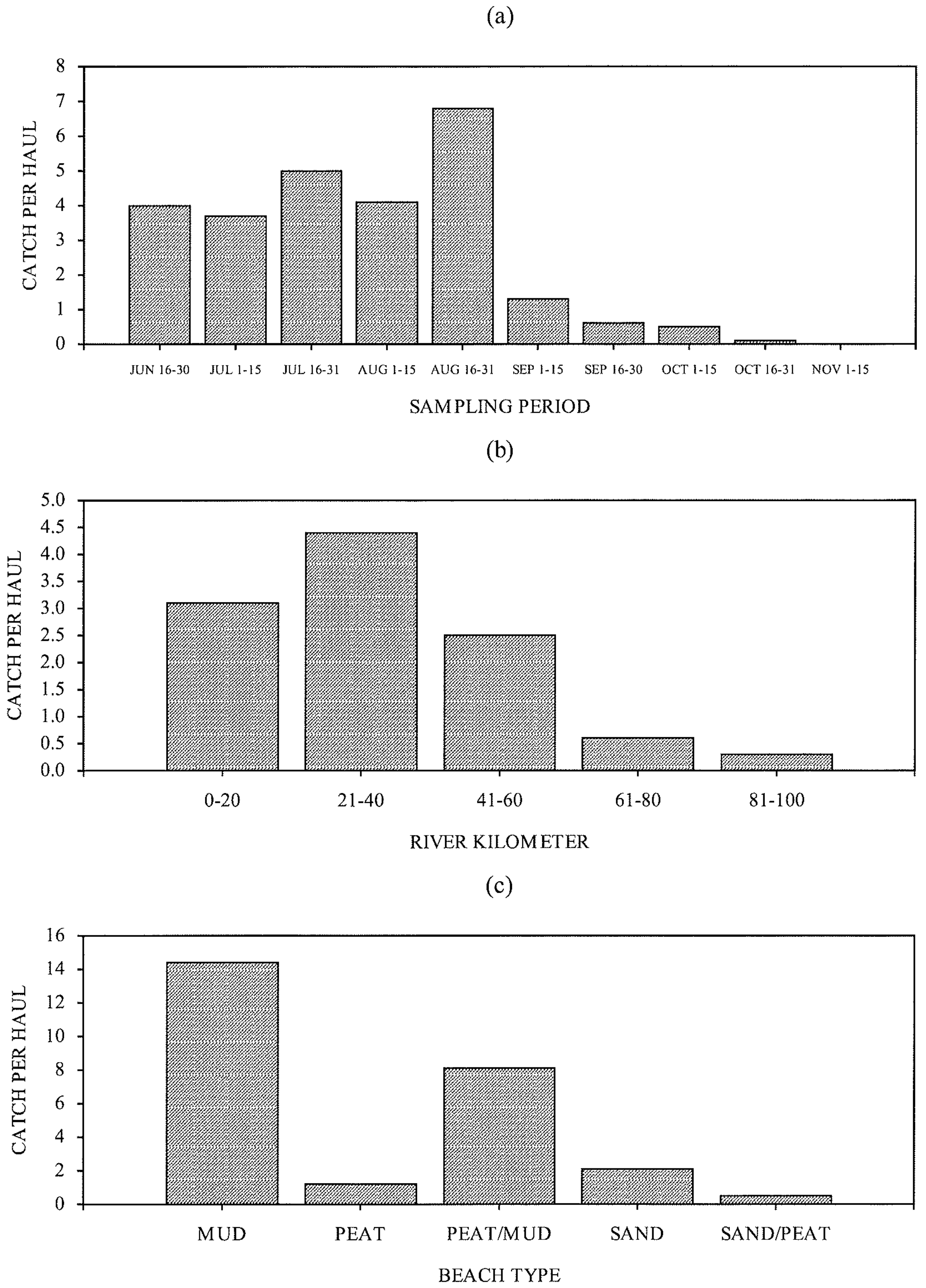


Figure 5-20 Mean catch per haul of spot by sampling period (a), river kilometer (b) and beach type (c), as observed during the 2008 baywide seine survey.

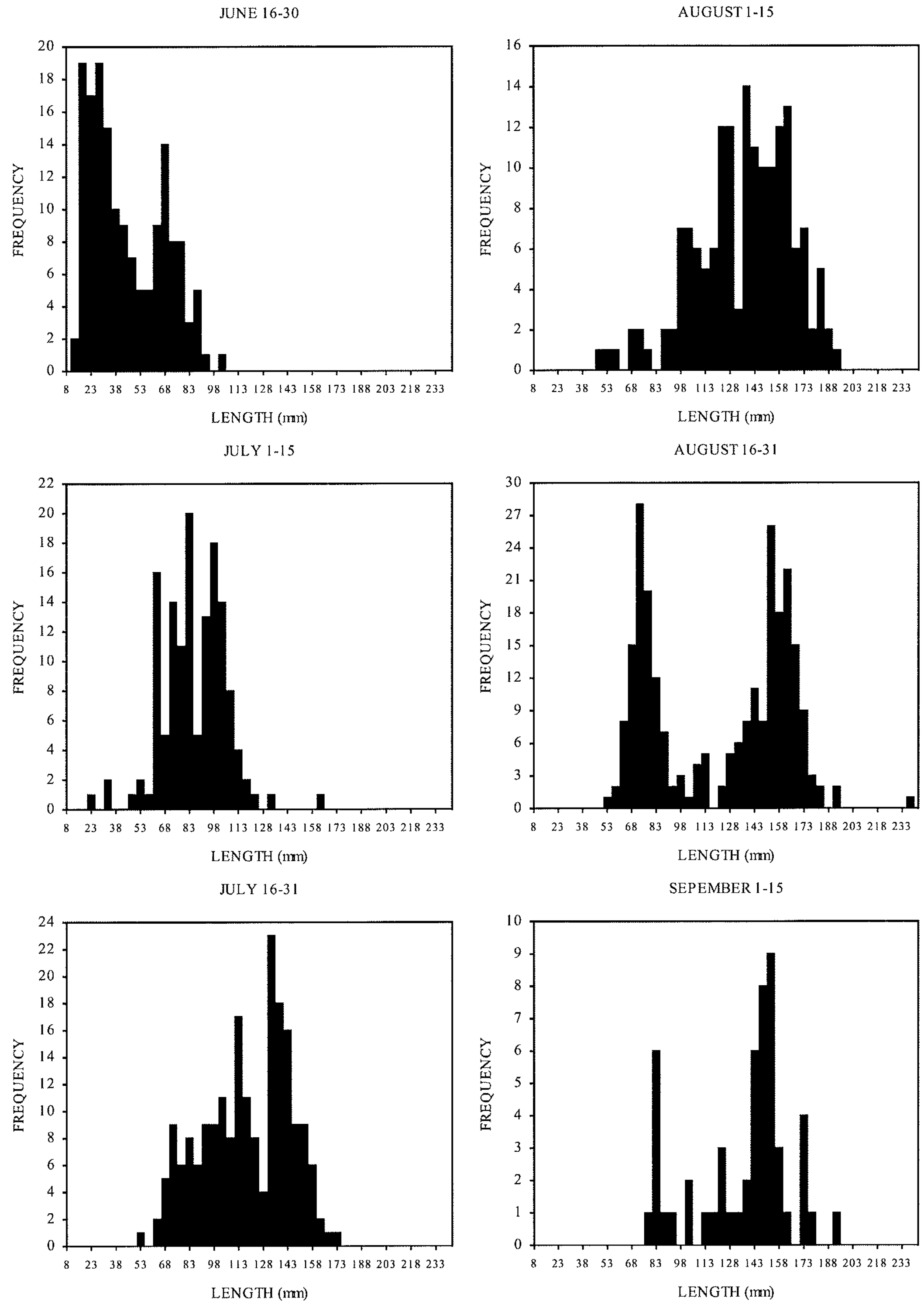
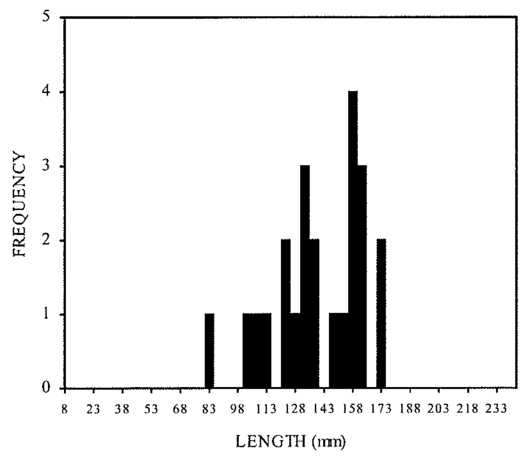


Figure 5-21 Length-frequency distribution by sampling period for spot taken during the 2008 baywide seine survey.

SEPEMBER 16-30



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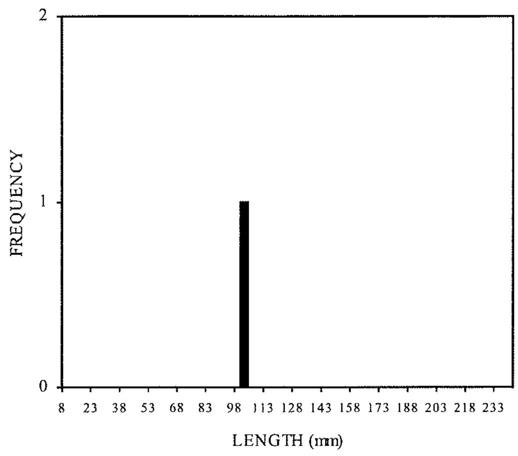
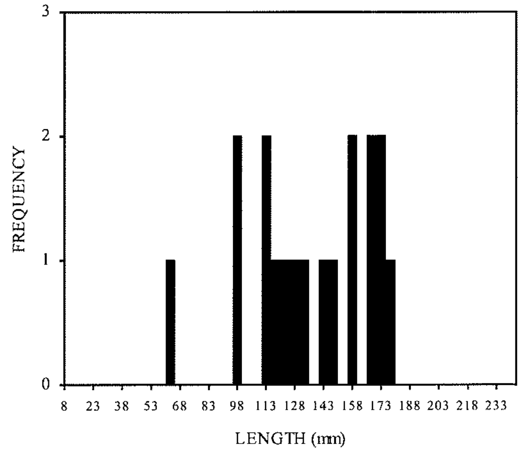
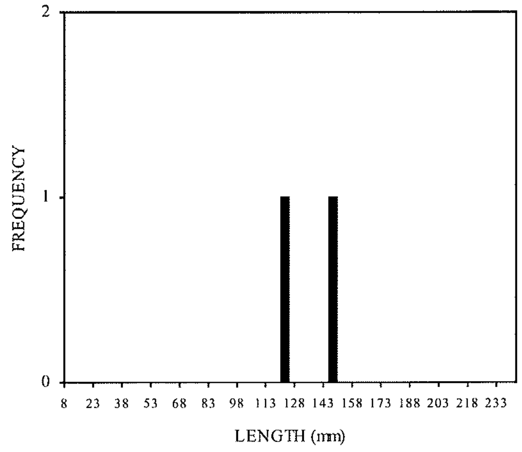


OCTOBER 1-15



OCTOBER 16-31



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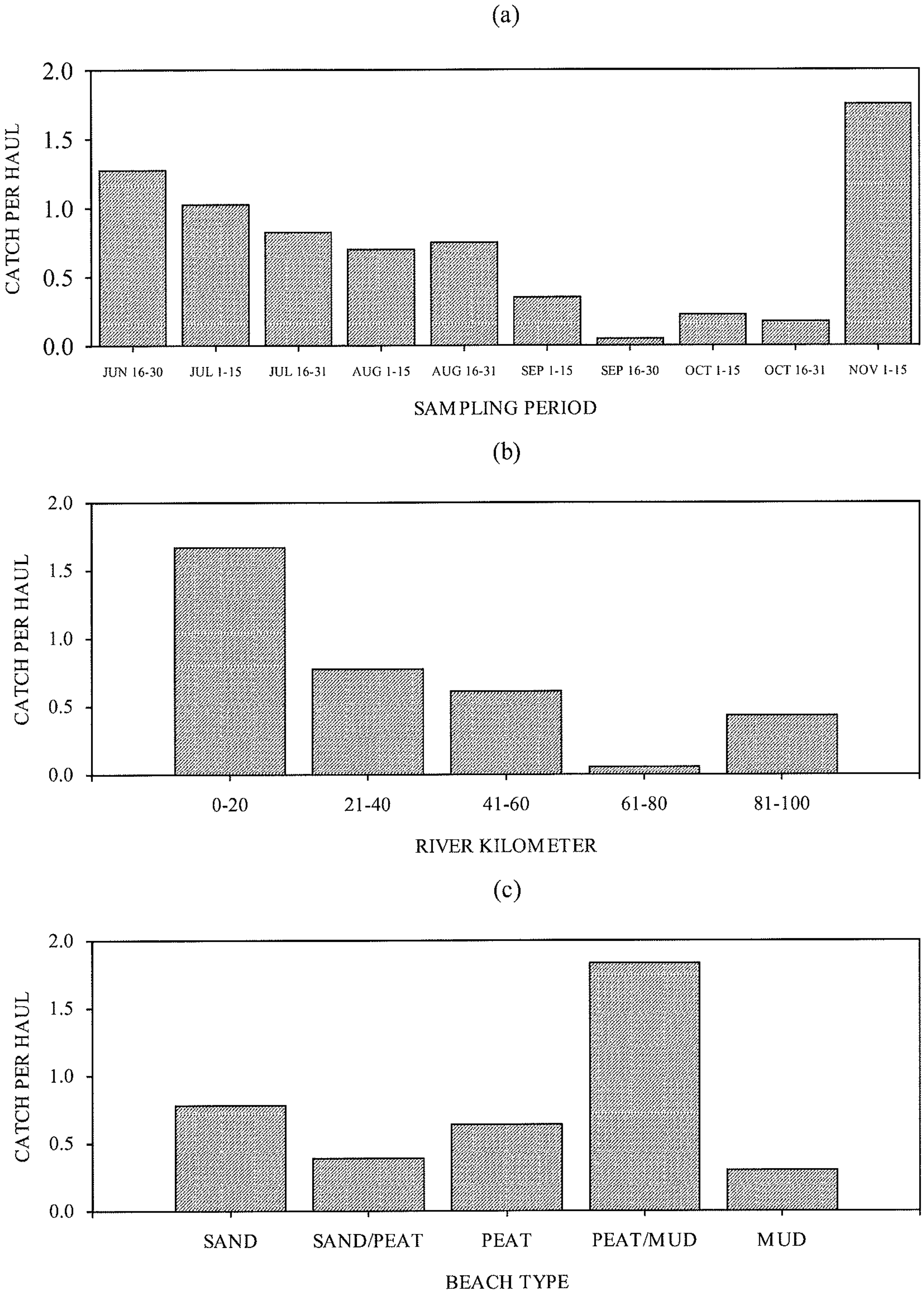

Figure 5-22 Mean catch per haul of Atlantic croaker by sampling period (a), river kilometer (b) and beach type (c) as observed during the 2008 baywide seine survey.

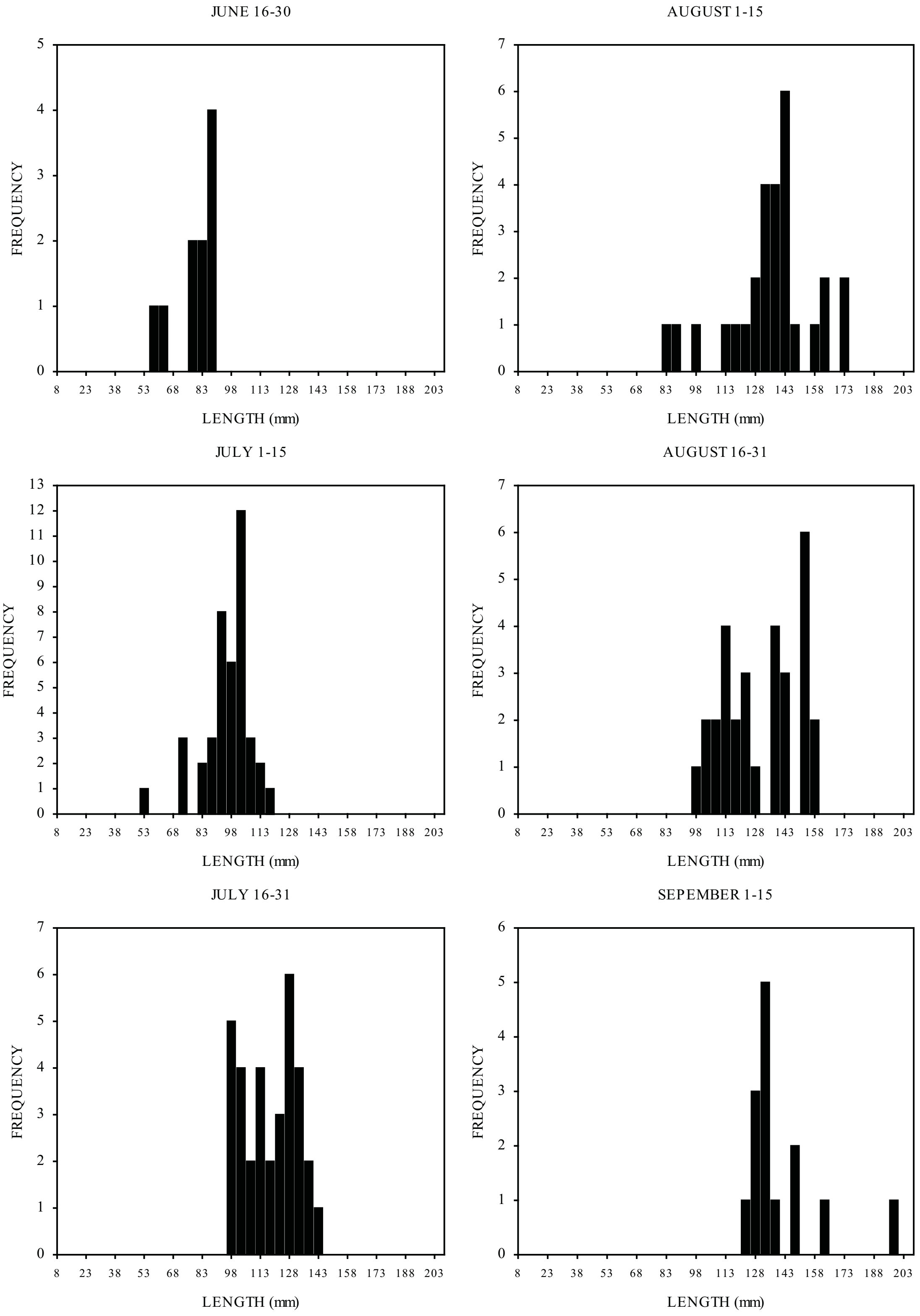

Figure 5-23 Length-frequency distribution by sampling period for Atlantic croaker taken during the 2008 baywide seine survey.

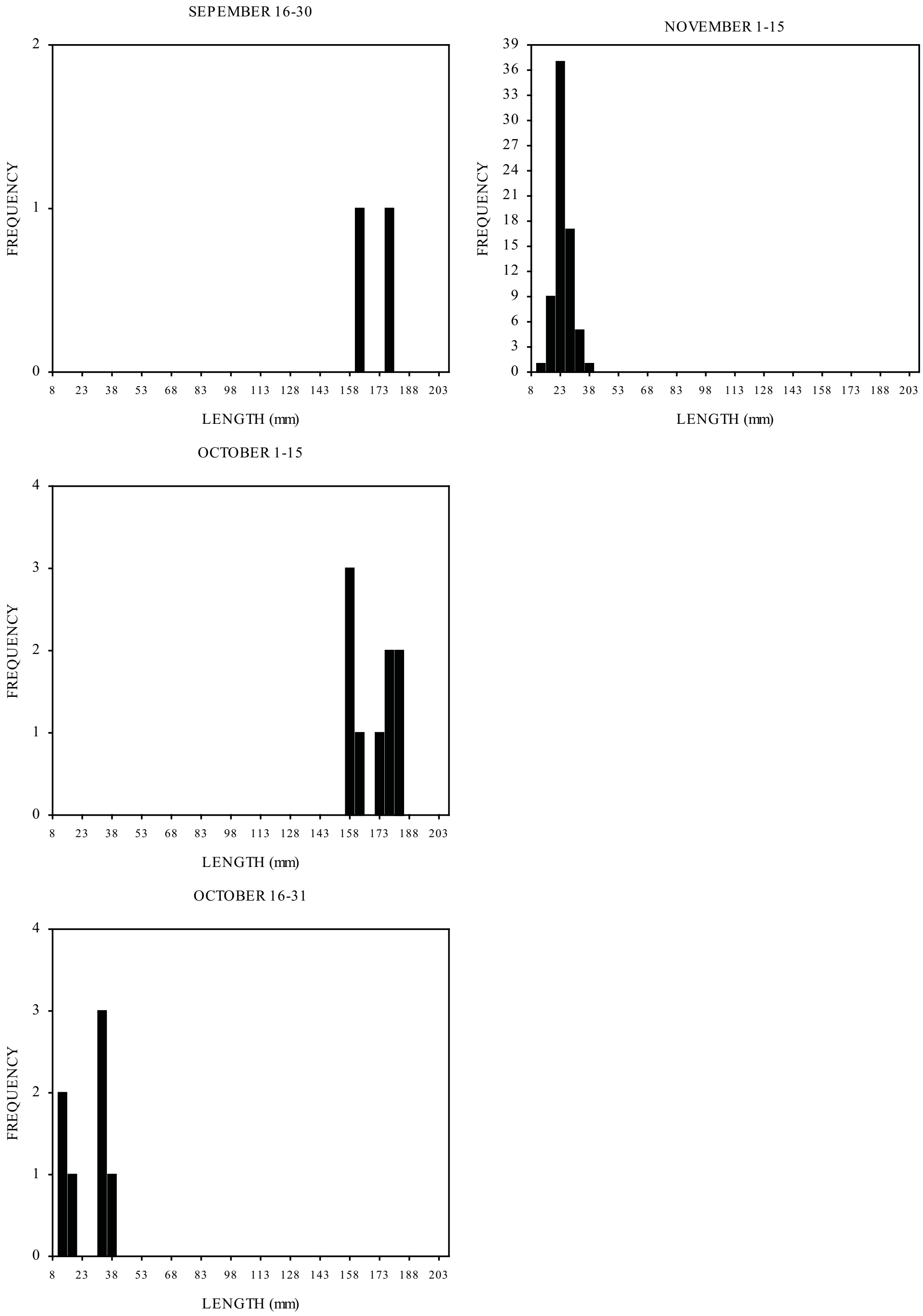

Figure 5-23 Continued.

Appendix 5-1. Region (rkm) and beach-type designations for the 40 beach seine stations.

Station #	Region (rkm)	Beach Type
1	0 - 20	Sand
2	0 – 20	Sand
3	0 - 20	Sand
4	21 - 40	Sand/Peat
5	21 – 40	Sand/Peat
6	21 – 40	Mud
7	21 – 40	Peat
8	41 – 60	Sand
9	41 – 60	Sand
10	41 – 60	Peat
11	41 – 60	Sand
12	61 – 80	Sand/Peat
13	61 – 80	Sand/Peat
14	61 – 80	Peat
15	61 – 80	Sand
16	81 - 100	Sand
17	81 - 100	Peat
18	61 – 80	Sand/Peat
19	61 – 80	Sand
20	61 – 80	Sand/Peat

Station #	Region (rkm)	Beach Type
21	61 – 80	Sand
22	41 – 60	Sand/Peat
23	41 – 60	Peat
24	41 – 60	Peat
25	21 - 40	Mud
26	21 – 40	Sand
27	21 – 40	Sand
28	21 - 40	Peat/Mud
29	0 – 20	Sand
30	0 – 20	Sand
31	0 – 20	Sand
32	0 - 20	Sand
33	21 - 40	Peat
34	21 – 40	Peat/Mud
35	21 – 40	Sand/Peat
36	21 – 40	Peat/Mud
37	21 - 40	Peat
38	41 – 60	Sand/Peat
39	61 – 80	Peat
40	81 - 100	Peat

CHAPTER 6: FISH LADDER MONITORING

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FISH LADDER MONITORING

6.1 INTRODUCTION

PSEG Nuclear LLC (PSEG), as a Special Condition of its NJPDES Permit (1995) (No. NJ0005622, Part IV-B/C Special Conditions, H.4), was required to construct and maintain five fish ladders on Delaware River estuary tributaries for spawning run restoration of the alewife (*Alosa pseudoharengus*) and the blueback herring (*Alosa aestivalis*), collectively known as river herring. Site evaluation studies conducted in 1994 and 1995 resulted in the initial selection of five impoundments for construction of fish ladders: Silver Lake, McGinnis Pond, McColley Pond, in Delaware and Cooper River Lake, and Sunset Lake in New Jersey. Silver Lake in Dover, McGinnis Pond near Frederica, and McColley Pond near Milford drain to the Delaware Bay (Figures 6-1, 6-4, 6-6, 6-8; Table 6-1). Construction of Alaska Steeppass fish ladders at these three locations was completed in 1996. Sunset Lake in Bridgeton, New Jersey (Figures 6-1, 6-13; Table 6-1); drains to the Delaware Bay. Construction of Alaska Steeppass fish ladder at Sunset Lake was completed in 1997. Cooper River Lake in Camden, New Jersey, drains into the Delaware River (Figures 6-1, 6-10; Table 6-1). Construction of an Alaska Steeppass fish ladder at this site was completed in 1998.

Even though these five initial sites satisfied the 1995 permit requirements, PSEG, using PSEG funds escrowed to DNREC as a result of a settlement agreement, subsequently installed fish ladders at three additional sites in Delaware. These sites are Coursey Pond, Garrisons Lake, and Moores Lake. Coursey Pond is near Frederica, Delaware and drains into Delaware Bay (Figures 6-1, 6-7; Table 6-1). Construction of the Alaska Steeppass fish ladder at Coursey Pond was completed in 1997. In early 1999, Alaska Steeppass fish ladders were installed at Garrisons and Moores lakes near Dover and Cheswold, Delaware, respectively (Figures 6-1, 6-3, 6-5; Table 6-1); both of these impoundments drain to the Delaware Bay. In 2004 additional fish ladders were added in Noxontown Pond near Odessa and Silver Lake in Milford, Delaware and Newton and Stewart lakes south of Camden, NJ (Figure 6-1, 6-2, 6-9, 6-11, and 6-12 and Table 6-1).

Components of PSEG's Improved Biological Monitoring Work Plan (IBMWP) require monitoring for adult and juvenile river herring use of the sites. Study objectives are to: 1) quantify the adult river herring use of the fish ladders and 2) to document year-class development by sampling for juveniles in the impoundments. To avoid impacting the reproductive success of migrating herring, monitoring of adult passage has been discontinued at sites where the target of 5 adult herring per impoundment acre was achieved by passage alone.

A supplemental stocking program was initiated in the spring 1998 to provide a target number of at least five spawning run adult fish per impoundment surface area. This stocking element is dependent on the availability of adult river herring and is conducted to augment the remnant herring runs at selected sites by promoting optimal adult spawning activity within these targeted impoundments, which should accelerate the rate of increase in spawning run size in subsequent years. The stocking program should yield additional juvenile production, which after a four-year maturation period at sea, would result in a greater number of adult herring returning to that fish ladder site in subsequent years. No stocking occurred during 2005 through 2007 due to the limited availability of adult herring for trap and transfer.

In 2008 sampling of adult passage was conducted at Moores Lake, Coursey Pond, and McColley Pond. These three fish ladders have consistently passed adult herring.

In 2008 sampling was not conducted at McGinnis Pond thus allowing the spawning run fish to freely enter the pond without holding in the fish traps or being pilfered from the traps would allow more spawning activity in the ponds.

Monthly electroshocking was not performed during 2008 as production has been documented in all twelve impoundments.

6.2 MATERIALS AND METHODS

SPILLPOOL MONITORING

Spillpool temperatures were monitored three days per week starting February 15, 2008 in advance of opening the fish ladders. This monitoring was conducted to ensure that when the temperature reached 7.0 °C that the fish ladders were opened and that at 8.0 °C the monitoring of the fish ladder passage commenced.

ADULT PASSAGE SAMPLING

Spawning of river herring in the tributaries to Delaware Bay and the lower River is reported to occur at water temperature ranges of 12.0-22.5°C for alewife and 15.0-24.0°C for blueback herring, (Smith, 1971; Wang and Kernehan, 1979). Jones (1999) reported alewives arriving at Wagamons at 9-11°C and blueback herring arriving at 13-20°C. Delaware fish ladders were opened on March 1. New Jersey fish ladders were opened on March 2. Adult passage sampling is scheduled to begin when water temperature in the spill pool reaches 8°C. In 2008, traps were set at Noxontown, Garrisons Lake, and Silver Lake (Dover) fish ladder sites on March 26. The traps were set at Moores Lake, Courseys Pond, and McColley Pond. Sunset Lake and Stewart Lake sampling commenced on March 31 when water temperatures reached and remained at or above 8ºC. Sampling at Cooper River Lake and Newton Pond commenced on April 20. Sampling at Silver Lake (Milford) began on April 22. During 2008, no adult sampling was conducted at McGinnis Pond in accordance with the IBMWP. Table 6-2 describes the fish ladder operation and maintenance activities for the twelve sites.

Although the study design required sampling at each site for a minimum of five days per week with a minimum of four hours of sampling per pond per day, sampling since 2002 has been continuous (24 hour) at most sites. This was achieved by leaving the exit trap in place and visiting each site one or more times each day to enumerate catch and release the herring into the impoundment. The six Delaware traps were modified in 2001 to minimize holding mortality by limiting confining areas within each trap and incorporating K-less® knotless netting (Figures 6-14 through 6-17). The stronger knotted mesh is replacing the K-less® knotless netting as traps are being repaired. The additional two traps added in Delaware are similarly constructed. A modified commercial trap net was employed at the upper end of the fish ladder extending into the lake (Figure 6-18).

Adult herring use of the fish ladders was monitored with a fish trap placed at the exit (upper end) of the fish ladder (Figures 6-14 through 6-17). The fish trap was secured to the trash bars at the exit of the fish ladder and positioned so that it extended into the pond. While no sampling was performed during 2008, at Coursey Pond and McColley Pond, during previous years a reducer was placed at the outlet of the fish ladder to standardize the exit opening and the fish trap was attached to the reducer. At Silver Lake, a fish diversion curtain constructed of weighted, clear vinyl strips, was suspended across the lower end of the spill pool at the start of the spawning run to guide adult herring to the entrance of the fish ladder (Figure 6-19). At Moores Lake a temporary aluminum fish diversion flume was employed to direct fish to the entrance of the fish ladder (Figure 6-20).

The adult passage sampling sequence commenced when the fish trap was secured to the face of the fish ladder. Upon subsequent arrival at the site, the fish trap was checked for fish. Any catch was identified to species, enumerated, and the herring released into the pond; other species taken (e.g., gizzard shad, white perch) were released back to the spill pool. Next, the spill pool and tail water areas below the dam were observed for the presence of adult herring and any indication of spawning activity; polarized glasses were used to facilitate these observations. Cast netting and/or dip netting was occasionally employed to confirm observations and species identification; this activity was limited to minimize disturbance to the adult herring.

Additionally, impoundment and spill pool water quality parameters were measured at a minimum of once per day. Water temperature, conductivity, and dissolved oxygen were measured using a Yellow Springs Instruments (YSI) Model 85; an Oaklon® Model pHTestr 2 was used to measure pH; both instruments were calibrated daily to ensure accuracy. Water clarity was measured with a standard 20 cm (8-in) secchi disk. Meteorological conditions (e.g., sky conditions, weather) were also noted.

Hourly temperature monitoring was initiated at some sites using "TidbiT" temperature loggers. Loggers were used in each of the spillpools and placed to minimize disturbance by the public.

Sampling at all sites was discontinued on June 11th, at which time water temperatures exceeded 26ºC (Figures 6-21 and 6-22) and no herring had been observed for a period of one week.

STOCKING

A goal of establishing at least five adult river herring per surface acre of impoundment, through the adult passage or by the stocking program, was based on recommendations from researchers in New England and Canada. Target stocking numbers were as follows:

Impoundment	Acreage	Target number of herring @ 5/acre
Noxontown Pond	162	810
Garrisons Lake	86	430
Silver Lake (Dover)	171	855
Moores Lake	27	135
McGinnis Pond	31	155
Coursey Pond	58	290
McColley Pond	49	245
Silver Lake (Milford)	27	135
Cooper River Lake	190	950
Newton Lake	41	205
Stewart Lake	38	190
Sunset Lake	94	470

The supplemental stocking is dependent on the availability of adult river herring in the spillpool of impoundments with installed fish ladders or from other nearby sources. Adult herring are not trapped in the spillpools when low numbers are present. Adult herring are typically taken from local tributaries and spillpools using cast nets. Fish are transferred from the point of capture to the release site in a specially outfitted transport tank. Only vigorous adults are counted as stocked; the few fish that loose equilibrium are stocked but not counted. For the eight Delaware sites, an effort is made to utilize adults from the site-specific spill pool. Adult herring for supplemental stocking in the New Jersey impoundments were originally trapped at the Union Lake dam on the Maurice River; however, the NJDEP Bureau of Fresh Water Fisheries stipulated in 2004, that fish to be stocked should be obtained from the spillpools immediately below the water control structures of the targeted impoundment. That condition removed Union Lake as a source for spawning run herring to stock.

Due to the low numbers of river herring present in the impoundment spillpools during 2008, no fish were trapped and transferred

JUVENILE SAMPLING

Juvenile monitoring is no longer performed as production has been documented in all twelve impoundments.

Historically, monthly electroshocker sampling during September through November was used to assess juvenile river herring occurrence at each of the twelve impoundments. The primary goal of this sampling was to provide evidence of successful post-larval herring development. A Smith-Root Model 2.5-GPP portable electro-fisher unit with two UAA-4 umbrella anode arrays was used for electroshocking. The electroshocker unit was operated in pulsed DC at 120 pulses per second and typically at 6-8 amps. The standard sampling duration was 1200 sec (20 min) of electroshocker operation at each impoundment. Effort was directed to the open water of the impoundments where experience has shown the highest probability of encountering juvenile herring. Fish are counted each time the foot switch is pressed. The count of small numbers of fish is exact. Estimates of larger numbers of fish are made in 10, 25, 50, 100, 150, and 200 fish increments. When herring were encountered in considerable numbers, electroshocking was briefly interrupted to limit the stress on the fish.

With each collection, a subsample of specimens of each herring species was measured for fork length, to the nearest millimeter. Several specimens of each species from each impoundment were retained for QA/QC of the speciation.

6.3 RESULTS

SPILLPOOL MONITORING

Spillpools were observed and spillpool temperatures were monitored manually. Spillpool temperatures were also collected using a "TidbiT" temperature logger at some spillpools. Representative water temperature data for Delaware and New Jersey pond spillpools is presented in Figures 6-21 and 6-22.

ADULT PASSAGE MONITORING AND STOCKING

Adult passage monitoring during 2008 spanned the period March 26th to June 11th, during which time a total of 17,986.61 hours of fish ladder trap net sampling was conducted. The following table lists the sampling hours specific to each site:

Fish Ladder Site	Hours Sampled
Noxontown Pond	1846.17
Garrisons Lake	1751.92
Silver Lake (Dover)	1845.08
Moores Lake	1703.67
McGinnis Pond	0
Coursey Pond	1823.92
McColley Pond	1840.50
Silver Lake (Milford)	1155.75
Cooper River Lake	1728.32
Newton Lake	740.10
Stewart Lake	1774.63
Sunset Lake	1776.55
Total	17,986.61

The daily catches of adult herring at each of the eight fish ladder sites monitored during 2007 are listed in Table 6-3. The range and peak periods of occurrence of each herring species, along with corresponding spill pool water temperatures at each site are described in Table 6-4. The number of pre-spawn herring passed into each of the impoundments is presented in Table 6-5. The following briefly summarizes the trap net catch and stocking effort at each site:

- Trap net sampling at Noxontown Pond yielded no alewife and one live blueback herring. The blueback herring was taken on April 11. 2008. Trap tampering was very common. No alewife or blueback herring were stocked into Noxontown Pond from the spillpool.

- Trap net sampling at Garrisons Lake yielded no alewife and no blueback herring. Trap tampering was very common with numerous people dipping fish out of the trap. No alewife or blueback herring were stocked into Garrisons Lake from the spillpool.

- Trap net sampling at Silver Lake (Dover) yielded one live alewife and seven live and one dead blueback herring. The alewife was taken on April 3, 2008. The blueback herring were taken April 14 through April 25. Trap tampering was also common with several people trying to fowl hook fish from the trap. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at Moores Lake yielded four alewife and 635 live and 14 dead blueback herring. The alewife were taken from April 3, 2008 to April 22, 2008. The blueback herring were taken April 7 through June 2, 2008. Trap tampering and vandalism was common. No alewife or blueback herring were stocked from the spillpool.

- No trap net sampling was conducted at McGinnis Pond. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at Courseys Pond yielded 39 live and 2 dead alewife and 1,057 live and 49 dead blueback herring. The alewife were taken from March 28, 2008 to April 16, 2008. The blueback herring were taken April 7 through May 30, 2008. Trap tampering and vandalism was common. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at McColley Pond yielded one live alewife and 651 live and 30 dead blueback herring. The alewife was taken on April 24, the blueback herring were taken from April 7 through May 30, 2008. Trap tampering and vandalism was common. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at Silver Lake (Milford) yielded no alewife and no blueback herring. Trap tampering and vandalism was common. Trap tampering and vandalism was common. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at Cooper River Lake yielded one live alewife and one dead blueback herring. The alewife was taken on April 21 and the blueback herring was taken on May 18, 2008. No herring were obtained from the spillpool for stocking into the lake.

- Trap net sampling at Newton Lake yielded no alewife and 3 blueback herring. The blueback herring were taken April 25. Occasional tampering with the trap was observed. Debris in the net was very common. No alewife or blueback herring were stocked from the spillpool.

- Trap net sampling at Stewart Lake yielded two live alewife and 1 dead blueback herring. The alewife were taken from April 2 and April 8, 2008. The blueback was taken on May 8, 2008. Debris in the trash bars was a common occurrence. No alewife or blueback herring were stocked from the spillpool.

- Sampling at Sunset Lake yielded 134 live and 2 dead alewife and 34 live blueback herring. The alewife were taken March 30 through May 1, 2008. The blueback herring were taken from April 22 through May 31, 2008. Trap tampering was common individuals collecting herring for bait or other fish for food. Seining in the second spillpool yielded no herring for stocking into Sunset Lake.

No trap net sampling was conducted in 2008 at the McGinnis Pond fish ladder. Physical chemistries were collected and the ladders were checked and cleaned on the days when sampling occurred at other PSEG fish ladder sites.

JUVENILE SAMPLING

No juvenile sampling was conducted in 2008.

6.4 DISCUSSION

ADULT USE OF THE FISH LADDERS

In 2008, adult river herring migrated into freshwater to spawn in the creeks, spillpools, and ponds beginning in early March continuing through early June. As expected, the adult herring movement appeared to be associated with rising creek water temperature and sunny days. As evidenced in Table 6-4 the occurrence of adult herring at the fish ladder sites generally coincides with reported spawning temperatures of between 12.0-22.5°C for alewife (Wang and Kernehan, 1979) and 15.0-24.0°C for blueback herring (Smith, 1971). However, in sampling since 1996 pre-spawning blueback herring were observed at temperatures as high as 26.7°C. Most herring movement was observed during the middle part of the day, on sunny days, with warming temperatures, which is consistent with observations by Leim and Scott (1966). Very little herring movement was observed on overcast days or at night. A summary of monitoring results at each of the fish ladder sites over the period of study (1996-2008) is presented in Table 6-6 and Figures 6-25 through 6-31. A summary of all of the species utilizing the fish ladders is presented in Tables 6-7 and 6-8.

Short duration sampling was conducted in 2001, 2002, 2003, 2004 and 2008 to determine the temporal distribution of herring passage through the fish ladders. Results from sampling, on days when few or no herring moved through the ladder, were removed. A lack of 2002, 2003, and 2004 data is due to very few herring utilizing the ladder during the days when short duration sampling was conducted. Hourly sampling in 2008 at Coursey and McColley Ponds was productive. The resulting distribution shown in Table 6-9 is similar to the results found by Jones (1999) at Wagamons Pond. Herring generally began to move up the fish ladder about 09:00 hours and continued to use the ladder through approximately 21:00 hours.

Noxontown Pond

The Noxontown Pond fish ladder, installed early in 2004 appears to be functioning properly. The pond has a heavy algae and organic debris load which fouls the net. One live blueback herring was taken in the trap in 1846 hours of sampling in 2008. The bridge where the water control structure and ladder are located is a favorite fishing spot and the ladder and trap are very easily accessible and are often subject to pilfering and occasional vandalism.

Garrisons Lake

The Garrisons Lake fish ladder, installed early in 1999 appears to be functioning properly. The trap at Garrisons Lake also suffers from a high debris loading of vegetation and trash which requires daily cleaning to ensure that the flow through the ladder is sufficient to pass herring. The State of Delaware dredging operations near the spillway have ended. No herring were collected was passing during 1752 hours of sampling in 2008.

Silver Lake (Dover)

Entrance modifications initiated in 1996 appear to have directed the flow from the ladder into the stream channel. The fish diversion curtain also appears to be effective, as the number of herring passed through the ladder has increased since its use began in 1998 (Table 6-6). The 9 adult herring counted passing the fish ladder yields 1.0% of the target goal of 855. In the 2001, 2002, and 2003, sampling seasons, stocked fish were released in mid-pond, west of the causeway, in an effort to provide immediate access to spawning habitat (Figure 6-4). In 2006 through 2008 no herring were stocked into Silver Lake in Dover.

Moores Lake

The fish ladder at Moores Lake, installed in 1999, appears to be functioning properly. A wooden weir at the exit of the spill pool apron renders the fish ladder inaccessible at the lower portions of the tide. Substantial spawning was observed in 1999 and 2000 throughout the spill pool area. In 2001 a temporary concrete diversion flume was installed by PSEG on the dam apron to guide the spawning run fish from the gap in the wooden weir to the entrance of the fish ladder. In 2002 the concrete diversion flume was replaced by a temporary aluminum flume. The flumes appear to have been successful passing 690, 682, 652, 697 herring in 2001, 2002, 2003, and 2004 as compared to 95 and 78 in 1999 and 2000 (Table 6-6). No Adult Sampling was conducted at

Moores Lake in 2005 through 2007. Sampling in 2008 yielded 653 herring. The dam where the water control structure and ladder are located is a favorite fishing spot and the ladder is easily accessible and is subject to occasional vandalism.

McGinnis Pond

Velocities within the structure and the entrance configuration allowed some fish to pass in 1996 and 1997. In early 1998, modifications were made to the fish ladder to lower velocities. While no herring passed earlier in that season, after the modifications to the ladder, 25 adult blueback herring were observed exiting the fish ladder. Permanent modifications to this fish ladder were completed in early 1999. No adult sampling was conducted in 2006 and 2007. The situation of herring not being able to reach the McGinnis spillpool has been addressed by annual stream cleaning which was conducted again in 2008 to remove woody debris that routinely blocks and diverts the stream. In 2006 through 2008, spawning run herring were seldom observed in the spillpool and the stream below McGinnis Pond which is similar to 2003 and 2004, a marked contrast to many of the previous years. In 2008 no adult sampling was conducted, however, during the collection of water quality data and cleaning of the fish ladder large numbers of blueback herring were occasionally observed in the spillpool.

Coursey Pond

River herring approaching the Coursey Pond fish ladder appeared to follow the bridge abutment to the entrance of the fish ladder. If they did not encounter the fish ladder or chose not to use it they moved in a counter clockwise direction around the spillpool. Herring appeared to have the opportunity to pass the fish ladder entrance each time they circled. Some herring were observed spawning among the rocks (rip rap) in the spillpool. Sampling collected 39 alewife and 1,057 blueback herring in 1824 hours of sampling for 377.93% of the target goal of 290.

McColley Pond

Appropriate velocities continue within the structure and the entrance was accessible to fish throughout the tidal cycle. River herring approaching the McColley Pond fish ladder appeared to follow the bridge abutment to the entrance of the fish ladder. If they did not encounter the fish ladder or chose not to use it they moved in a counter clockwise direction around the spillpool. Herring appeared to have the opportunity to pass the fish ladder entrance each time they circled. Sampling collected one alewife and 651 blueback herring in 1841 hours of sampling for 266.12% of the target goal of 245.

Silver Lake (Milford)

The Silver Lake (Milford) fish ladders, installed early in 2004 appear to be functioning properly. The lower ladder in a small concrete dam is generally inaccessible by the public during the herring season. Debris obstructing this ladder was common and required routine removal. The upper ladder and trap are easily accessible and are subject to continual vandalism with the trap damaged on several occasions. Pilfering from the trap is common. No herring were collected in 1156 hours of sampling.

Cooper River Lake

The fish ladder was installed in 1998. In 1728 hours of trap sampling one adult alewife and no adult blueback herring were taken at the Cooper River Lake fish ladder in 2008. At higher tidal elevations, spawning run herring are able and known to pass through the water control structure tide gates. The trap was damaged on one occasion when lines were cut. Stocking of fish into Cooper River Lake was limited by NJDEP's request that fish stocked into a pond come only from the stream and spillpool below the impoundment and that fish should not be moved in from another stream. No adult herring were able to be collected from below the water control structure for stocking into the impoundment.

Newton Lake

The Newton Lake fish ladder, installed late spring in 2004, appears to be functioning properly. The fish ladder is located in a generally inaccessible area beneath the roadway. High tides and flows limited access to allow for net planning and deployment. Sampling in 2007 and 2008 utilized a net similar to the Cooper River net to allow accessibility at high tide and to limit the accessibility to the public. Three blueback herring were taken in 740 hours of sampling. Newton Lake has a heavy debris load which routinely obstructed and occasionally destroyed the net. A small amount of tampering with the net was observed.

Stewart Lake

The Stewart Lake fish ladder, installed late spring in 2004, appears to be functioning properly. The ladder and trap are easily accessible to the public. Large heavy debris in the form of tree limbs, firewood and heavy wooden dunnage left in the pond and under the bridge routinely plugged the entrance to the fish ladder. In 2008 during 1775 hours of sampling 2 live alewives were taken. A small amount of tampering with the trap was observed.

Sunset Lake

Engineering changes were initiated in 1998 to reduce fish ladder velocities. Permanent engineering changes were completed for the 1999 spawning season. The lower end of the fish ladder is now 18 to 24 inches above the bottom due to erosion of the sediment due to flows from the fish ladder and the bypass flow. The thirty-four blueback herring and 134 alewife that were counted passing through the fish ladder during 1777 hours of sampling during 2008. Some pilferage from the trap was observed and reported. The trap was commonly found tipped up in a condition where herring could bypass the trap and enter the pond uncounted.

6.5 LITERATURE CITED

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Table 6-1. Characterization of the twelve fish ladders sites.

	Noxontown Pond	**Garrisons Lake**	**Silver Lake (Dover)**
Size (acres)	162	86	171
Length (miles)	1.99	0.76	1.71
Perimeter (miles)	7.03	2.19	4.52
Maximum Depth (feet)	8.0	4.0	9.0
Mean Depth (feet)	4.0	1.3	4.0
Receiving Waters	Appoquinimink River, drains to the Delaware Bay	Leipsic River, drains into the Delaware Bay	Saint Jones River, drains into Delaware Bay
Distance from Delaware Bay (miles)	9.65	12.57	13.33
Impoundment Watershed Size (acres)	6,110	10,752	20,480
Tributaries of the Impoundment	The main stem of the impounded creek flows from Wiggins Pond	Willis Branch, Leipsic River from Massey's Mill Pond, and two small unnamed branches	Forked Branch McKee Run and an unnamed branch
Combined Tributary Length (miles)	7.93	8.03	29.25
Shoreline	Natural, bulkhead, wooded, and turf	Natural, wooded	Natural, bulkhead, small beach
Bottom Types	Sand and mud	Mud	Sand and mud
Surrounding Land Use	Residential, forested and farm lands	Residential, forested and farm lands	Urban and agricultural
Predominant Vegetation	Spatterdock	Spatterdock	Swamp Loosestrife, Water Willow, and Spatterdock
Water Quality	Eutrophic, tannins	Eutrophic, tannins	Eutrophic, tannins
Notes	St Andrew’s had the pond sprayed with herbicide starting about mid April 2007.	DNREC dredging occurred in 2006 and occasionally in 2007	

Table 6-1. Continued.

	Moores Lake	**McGinnis Pond**	**Coursey Pond**
Size (acres)	27	31	58
Length (miles)	0.76	0.76	0.72
Perimeter (miles)	1.87	2.16	2.48
Maximum Depth (feet)	5.0	9.0	4.0
Mean Depth (feet)	2.6	4.4	2.0
Receiving waters	Isaac Branch drains into Saint Jones River, drains into Delaware Bay	Hudson Branch, drains into Spring Creek, drains into the Murderkill River, drains into the Delaware Bay	Murderkill River, drains into the Delaware Bay
Distance from Delaware Bay (miles)	11.30	11.66	12.06
Impoundment Watershed Size (acres)	11,776	7,040	14,579
Tributaries of the Impoundment	Drainage from Wyoming Lake	Hudson Branch and two unnamed branches	Murderkill River from Killen Pond and Spring Branch
Combined Tributary Length (miles)	1.52	2.75	11.81
Shoreline	Natural, bulkhead, small beach	Natural, heavily wooded	Natural, heavily wooded
Bottom Types	Sand and mud	Sand and Mud	Sand and Mud
Surrounding Land Use	Urban and agricultural	Rural, forested and farm lands	Rural, forested and farm lands
Predominant Vegetation	Spatterdock	Swamp Loosestrife and Spatterdock Elodea, and Lyngbya (algae)	Swamp Loosestrife, Spatterdock,
Water Quality	Eutrophic, tannins	Eutrophic, tannins	Eutrophic, tannins
Notes			

Table 6-1. Continued.

	McColley Pond	**Silver Lake (Milford)**
Size (acres)	49	27
Length (miles)	1.14	0.49
Perimeter (miles)	3.34	1.56
Maximum Depth (feet)	6.0	10.0
Mean Depth (feet)	2.9	4.2
Receiving Waters	Brown's Branch, drains into the Murderkill River, drains into the Delaware Bay	Mispillion River, drains into the Delaware Bay
Distance from Delaware Bay (miles)	11.68	12.80
Impoundment Watershed Size (acres)	6,080	17,326
Tributaries of the Impoundment	Browns Branch and an unnamed branch	Mispillion River from Haven Lake
Combined Tributary Length (miles)	21.15	34.56
Shoreline	Natural, heavily wooded	Natural, bulkhead, riprap, turf, and wooded
Bottom Types	Sand and Mud	Sand and Mud
Surrounding Land Use	Rural, forested and farm lands	Urban and residential
Predominant Vegetation	Swamp Loosestrife and Spatterdock	Spatterdock
Water Quality	Eutrophic, tannins	Eutrophic, tannins
Notes		

Table 6-1. Continued.

	Cooper River Lake	**Newton Lake**	**Stewart Lake**
Size (acres)	190	41	38
Length (miles)	4.53	2.87 (two branches)	1.17 (two branches)
Perimeter (miles)	9.57	6.03	4.39
Maximum Depth (feet)	10.0	5.0	6.5
Mean Depth (feet)	3.5	1.8	4.8
Receiving waters	Cooper River, drains into the Delaware River	Newton Creek drains into the Delaware River	Woodbury Creek drains into the Delaware River
Distance from Delaware Bay (miles)	2.95	2.31	3.4
Impoundment Watershed Size (acres)	23,680	2,332	2,897
Tributaries of the Impoundment	No tributaries within the lake, Wallworth Lake and Evans Pond drain into Cooper River Lake	Newton Creek and Peter Creek	Hester's Branch and Woodbury Creek
Combined Tributary Length (miles)	8.94	1.91	4.23
Shoreline	Urban and parkland	Urban and parkland	Urban and parkland
Bottom Types	Mud, sand, and rubble	Mud	Mud and sand
Surrounding Land Use	Urban and parkland	Urban, parkland, and residential	Urban, parkland, and residential
Predominant Vegetation	Spatterdock	Spatterdock	Spatterdock
Water Quality	Eutrophic	Eutrophic	Eutrophic
Notes		Several sewage plant spills into Newton Lake were reported to have occurred in the summer of 2007 with locals reporting fish kills.	

Table 6-1. Continued.

	Sunset Lake
Size (acres)	94
Length (miles)	0.67
Perimeter (miles)	2.10
Maximum Depth (feet)	9.0
Mean Depth (feet)	3.5
Receiving waters	Cohansey River, drains into the Delaware Bay
Distance from Delaware Bay (miles)	20.38
Impoundment Watershed Size (acres)	29,248
Tributaries of the Impoundment	A spring fed tributary from Mary Elmer Lake and the Cohansey River
Combined Tributary Length (miles)	34.15
Shoreline	Natural, wooded, some bulkhead and hard shore, small beaches
Bottom Types	Sand and mud stumps in upper reaches
Surrounding Land Use	Parkland and residential
Predominant Vegetation	Spatterdock
Water Quality	Eutrophic, tannins
Notes	

Table 6-2. Operations and Maintenance Log for the twelve fish ladder sites during 2008.

Date		Action
1/15/2008		Delaware juvenile bypasses closed, ladders inspected
2/15/2008		Spillpool monitoring started and ladders inspected
2/22/2008		Cooper River Lake trash removal
2/26/2008		Trash removed from Noxontown and Garrisons Lake ladders
3/1/2008		Delaware and New Jersey Fish ladders inspected and opened
3/26/2008		Noxontown, Garrisons, and Silver Lake (Dover) traps installed
3/27/2008		Moores, Coursey, and McColley traps installed
3/27/2008		Stewart Lake trap installed
3/28/2008		Sunset Lake trap installed
3/31/2008		Cooper River Lake trap installed
4/3/2008		Newton Net fabrication
4/4/2008		Attempt to install Newton Net
4/8/2008		Newton Pond Trap installed
4/9/2008		Silver Lake (Dover) curtain installed
4/10/2008		Debris removed from lower Silver Lake (Milford) ladder
4/22/2008		Silver Lake (Milford) trap installed
4/23/2008		Silver Lake (Milford) trap adjustment and Debris removed from lower ladder
4/30/2008		Silver Lake (Milford) trap adjustment and remove debris
5/12/2008		Newton trap damaged by a storm and out of service
5/21/2008		Repair Newton trap
5/23/2008		Repair Newton trap
5/27/2008		Newton trap returned to service
6/10/2008		Stewart Lake ladder closed
6/11/2008		Noxontown, Garrisons, Silver Lake (Dover), Moores Lake, Coursey, McColley, and Silver Lake (Milford) ladders closed
6/11/2008		Cooper River, Newton, and Sunset Lake ladders closed
6/25/2008		Newton and Cooper traps removed and ladders inspected
7/ 16 /2008		Removed Fish Curtain from Silver Lake (Dover)
7/17/2008		Removed disconnected trap from Garrisons Lake
7/23/2008		Removed disconnected trap from Silver Lake Milford
8/8/2008		Large log removed from Cooper River Lake ladder
9/11/2008		Upper four Delaware ladders inspected
9/17/2008		New Jersey ladders inspected
9/24/2008		Lower four Delaware ladders inspected
10/6/2008		Debris removed from Silver Lake (Dover) ladder
11/13/2008		New Jersey Fish ladders inspected
11/28/2008		Delaware Fish ladders inspected, low and no flow conditions
12/4/2008		Delaware Fish ladders inspected, low and no flow conditions

12/11/2008		Silver Lake (Dover) and Moores Lake juvenile bypass opened low water at other ponds
12/12/2008		Noxontown, Garrisons Lake, and McGinnis juvenile bypass opened
12/12/2008		Coursey and McColley juvenile bypass opened. Only two logs below the surface were removed due to low flows.
12/17/2008		Silver Lake (Milford) juvenile bypass opened
12/24/2008		Delaware juvenile bypasses closed, ladders inspected, all but Coursey had low flows at closure.
Note		The Delaware and New Jersey fish ladders and bypass facilities (closed for the season) are checked occasionally over the winter.
Note		Cooper River Lake fish ladder will be inspected weekly throughout the year as part of the Camden County Parks inspection of the water control structure.

Table 6-3. Number of adult herring collected in fish ladder trap sampling at eleven of the twelve fish ladder sites in 2008 with number alive and (number dead).

Date	Noxontown Pond		Garrisons Lake		Silver Lake (Dover)		Moores Lake		McGinnis Pond		Coursey Pond		McColley Pond		Silver Lake (Milford)	
	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring
3/26/2008									No Sampling							
3/27/2008																
3/28/2008											6					
3/29/2008																
3/30/2008											11					
3/31/2008																
4/1/2008											2					
4/2/2008											11					
4/3/2008					1		1									
4/4/2008											3					
4/5/2008											4					
4/6/2008																
4/7/2008							2	4			1 (2)	1 (1)				
4/8/2008																
4/9/2008																
4/10/2008																
4/11/2008		1						1				4				
4/12/2008								1				6		2		
4/13/2008																
4/14/2008						1		2				1 (2)		4		
4/15/2008								2 (4)				23 (2)		38		
4/16/2008								4			1	16		5		
4/17/2008								(1)				3		3		
4/18/2008								1				14				
4/19/2008																
4/20/2008						1 (1)		8 (1)				198		11(1)		
4/21/2008								108				163		49		
4/22/2008							1	50				29 (12)		33(2)		
4/23/2008						1		10				10		12(2)		
4/24/2008						3		4				178	1	219		
4/25/2008						1		39				44		63		
4/26/2008																
4/27/2008								58 (6)				67(17)		74(11)		
4/28/2008								73				48(7)		43(5)		
4/29/2008								15				6		8		
4/30/2008								2								

Table 6-3. Continued.

	Noxontown Pond		**Garrisons Lake**		**Silver Lake (Dover)**		**Moores Lake**		**McGinnis Pond**		**Coursey Pond**		**McColley Pond**		**Silver Lake (Milford)**	
Date	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**
5/1/2008								1	No Sampling			36				
5/2/2008								4				23				
5/3/2008								10				19(4)		2		
5/4/2008																
5/5/2008								70				34		40(8)		
5/6/2008								62				21		9		
5/7/2008																
5/8/2008								11				36		2		
5/9/2008								22 (1)				39		29		
5/10/2008																
5/11/2008								8				3		1		
5/12/2008																
5/13/2008												4				
5/14/2008								6								
5/15/2008								11								
5/16/2008												1		1(1)		
5/17/2008								4				2				
5/18/2008																
5/19/2008								6						1		
5/20/2008								2								
5/21/2008																
5/22/2008								2								
5/23/2008																
5/24/2008																
5/25/2008								2				4				
5/26/2008																
5/27/2008								6				2(4)		1		
5/28/2008								23				18		1		
5/29/2008								3				2				
5/30/2008												2				
5/31/2008																
6/1/2008																
6/2/2008								(1)								
6/3/2008																
6/4/2008																
6/5/2008																
6/6/2008																
6/7/2008																

Table 6-3. Continued.

	Noxontown Pond		**Garrisons Lake**		**Silver Lake (Dover)**		**Moores Lake**		**McGinnis Pond**		**Coursey Pond**		**McColley Pond**		**Silver Lake (Milford)**	
Date	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**
6/8/2008									No Sampling							
6/9/2008																
6/10/2008																
6/11/2008																
Alive	0	1	0	0	1	7	4	635			39	1,057	1	651	0	0
Removed	0	0	0	0	0	0	0	0			0	0	0	0	0	0
Dead	0	0	0	0	0	1	0	14			2	49	0	30	0	0
Total	0	1	0	0	1	8	4	649			41	1,106	1	681	0	0

number dead = ( )

Table 6-3. Continued.

	Cooper River Lake		Newton Lake		Stewart Lake		Sunset Lake	
Date	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring	Alewife	Blueback Herring
3/27/2008								
3/28/2008								
3/29/2008								
3/30/2008							3	
3/31/2008								
4/1/2008							1	
4/2/2008							3	
4/3/2008					1		19	
4/4/2008								
4/5/2008							10	
4/6/2008								
4/7/2008					1		19	
4/8/2008							9	
4/9/2008							8	
4/10/2008								
4/11/2008							4	
4/12/2008								
4/13/2008							3	
4/14/2008							19(2)	
4/15/2008								
4/16/2008							9	
4/17/2008							4	
4/18/2008								
4/19/2008							4	
4/20/2008								
4/21/2008	1							
4/22/2008							18	21
4/23/2008								
4/24/2008								
4/25/2008				3				
4/26/2008								
4/27/2008								
4/28/2008								
4/29/2008								1
4/30/2008								
5/1/2008							1	2
5/2/2008								

Table 6-3. Continued.

	Cooper River Lake		**Newton Lake**		**Stewart Lake**		**Sunset Lake**	
Date	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**
5/3/2008								
5/4/2008								
5/5/2008								
5/6/2008								3
5/7/2008						(1)		1
5/8/2008								
5/9/2008								2
5/10/2008								
5/11/2008								
5/12/2008								
5/13/2008								1
5/14/2008								
5/15/2008								
5/16/2008								
5/17/2008								
5/18/2008		(1)						
5/19/2008								
5/20/2008								
5/21/2008								
5/22/2008								
5/23/2008								
5/24/2008								
5/25/2008								
5/26/2008								
5/27/2008								
5/28/2008								2
5/29/2008								
5/30/2008								1
5/31/2008								
6/1/2008								
6/2/2008								
6/3/2008								
6/4/2008								
6/5/2008								
6/6/2008								
6/7/2008								

Table 6-3. Continued.

	Cooper River Lake		Newton Lake		Stewart Lake		Sunset Lake	
Date	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**	**Alewife**	**Blueback Herring**
6/8/2008								
6/9/2008								
6/10/2008								
6/11/2008								
Alive	1	0	0	3	2	0	134	34
Removed	0	0	0	0	0	0	0	0
Dead	0	1	0	0	0	1	2	0
Total	1	1	0	3	2	1	136	34

Table 6-4. Range and peak periods of occurrence for alewife and blueback herring as observed in trap net sampling, with corresponding spill pool water temperatures (°C), at the eleven fish ladder sites monitored in 2008.

Species	**Noxontown Pond**	**Garrisons Lake**	**Silver Lake (Dover)**	**Moores Lake**	**Coursey Pond**	**McColley Pond**	**Silver Lake (Milford)**
Alewife							
Period of occurrence			April 3	April 3- 22	March 28 - April 16	April 24	
Temperature range (°C)			12.6	11.4 - 19.5	11.3 - 18.7	19.5	
Peak occurrence			April 3	April 7	March 30 - April 2	April 24	
Temperature (°C)			12.6	12.2	12.3-15.7	19.5	
Blueback Herring							
Period of occurrence	April 11		April 14 - 25	April 7 - June 2	April 7 - May 30	April 12 - May 28	
Temperature range (°C)	15		15.5 - 21.6	12.2 - 24	12.3 - 23.1	13.5 -24.2	
Peak occurrence	April 11		April 24	April 21 April 28 May 5 May 28	April 15 April 20 - May 9	April 15 April 21-28 May 5 May 9	
Temperature (°C)	15		21.6	19.3 17 19.6 21.7	17.2 16.9 - 23.1	17.1 18.6 - 20.8 19.4 19.8	

Species	**Cooper River Lake**	**Newton Lake**	**Stewart Lake**	**Sunset Lake**
Alewife				
Period of occurrence	April 21		April 3 - 8	March 30 - May 1
Temperature range (°C)	19.6		11.4 - 13.1	10.3 - 18.8
Peak occurrence	April 21		April 3 - 8	April 3 - April 22
Temperature (°C)	19.6		11.4 - 13.1	11.2 - 18.8
Blueback Herring				
Period of occurrence	May 18	April 25	May 8	April 22 - May 30
Temperature range (°C)	17.7	20	21.4	14.1 - 23.2
Peak occurrence	May 18	April 25	May 8	April 22
Temperature (°C)	17.7	20	21.4	17.5

Table 6-5. Number of spawning run adult herring counted passing in the eleven impoundments monitored in 2008.

	Noxontown Pond		**Garrisons Lake**		**Silver Lake (Dover)**		**Moores Lake**		**Coursey Pond**		**McColley Pond**		**Silver Lake (Milford)**	
Date	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**
March 23-29									6					
March 30-April 5					1		1		31					
April 6-12		1					2	6	1	11				
April 13-19						1		9	1	57		50		
April 20-26						6	1	199		593	1	387		
April 27-May 3								163		193		127		
May 4-10								165		130		80		
May 11-17								29		10		2		
May 18-24								10				1		
May 25-31								34		28		2		
June 1-7														
June 8-14														
Total Spawners	0	1	0	0	1	7	4	635	39	1,057	1	651	0	0
Total Herring	1		0		8		639		1,096		652		0	
Target Number	810		430		855		135		290		245		135	
Percent	0.12		0		0.94		513.33		377.93		266.12		0	

Table 6-5. Continued.

	Cooper River Lake		**Newton Lake**		**Stewart Lake**		**Sunset Lake**	
Date	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**	**Alewife**	**Blueback**
March 23-29								
March 30-April 5					1		36	
April 6-12					1		40	
April 13-19							39	
April 20-26	1			3			18	21
April 27-May 3							1	3
May 4-10								6
May 11-17								1
May 18-24								
May 25-31								3
June 1-7								
June 8-14								
Total Spawners	1	0	0	3	2	0	134	34
Total Herring	1		3		2		168	
Target Number	950		205		190		470	
Percent	0.11		1.46		1.05		35.74	

Table 6-6. Summary of annual herring monitoring results at the twelve fish ladder sites during 1996-2008.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Noxontown Pond									0	5	1	1	1
									0	7			
Garrisons Lake				39	70	4	3	31	23	1	22	1	0
				67	0	0	0	0	0	0			
Silver Lake Dover	4	7	113	163	65	151	139	31	183	76	117	95	9
	0	0	0	0	0	25	3	2	0	4			
Moores Lake				95	78	690	682	678	712				653
				78	71	1	0	0	8	0			
McGinnis Pond	1	2	25	48	33	99	774	25	226	216			
	20	114	398	9	718	244	899	0	2,221	19			
Courseys Pond		30	488	1,102	784	1,966	1,531	346	284				1,147
		13	144	89	39	72	129	7	20	81			
McColley Pond	115	177	559	1,122	1,250	918	931	228	679				682
	24	133	1,061	489	715	92	688	1	928	649			
Silver Lake Milford									0	62	4	0	0
									0	29			
Cooper River Lake			3	1	4	2	11	13	0	7	3	4	2
			15,000	12,394	7,848	24,327	438	6,606	0	2,209			
Newton Lake									NS	1	0	5	3
									833	399			
Stewart Lake									NS	20	7	13	3
									7	1,134			
Sunset Lake		0	7	60	32	195	366	64	1	2	63	396	170
		0	1.301	212	335	0	1,638	173	189	256			

Adult Passage
Electrofishing Juveniles

Table 6-7. Summary of species and numbers collected in adult passage monitoring at seven Delaware fish ladder sites during 2008.

Species	**Noxontown Pond***	**Garrisons Lake***	**Silver Lake (Dover)***	**Moores Lake**	**Courseys Pond**	**McColley Pond**	**Silver Lake (Milford) ***
Alewife	1		1	4	39 (2)	1	
Black Crappie	1	38	5		30	3	
Blueback Herring			7 (1)	635 (14)	1,057 (49)	651 (30)	
Bluegill	61	38	98	32	20	9	8
Brown Bullhead	241	95			2	13	
Carp		11		1	50	2	1
Chain Pickeral	1			1			
Channel Catfish	4	21			3		
Gizzard Shad	683 (7)	236 (6)	608	1,239 (9)	831 (4)	589 (3)	28
Golden Shiner	14	24				10	
Goldfish	1						
Largemouth Bass	4			4	1		1
Pumpkinseed	117	5	1				
Silvery Minnow		1					
White Catfish	8	373			2		1
White Perch	366	1859 (18)		3	22 (1)	7	4
Total	1,502	2,725	896	1,947	2,113	1,318	43

( ) number dead

* Sampling net frequently vandalized.

Table 6-8. Summary of species and numbers collected in adult passage monitoring at four New Jersey fish ladder sites during 2008.

Species	**Cooper River Lake**	**Newton Lake**	**Stewart Lake**	**Sunset Lake***
Alewife			2	134 (2)
American Eel		1		
Black Crappie	11 (98)	24	33	
Blueback Herring	1 (1)	3	(1)	34
Bluegill	7 (82)	45 (1)	482 (3)	24 (1)
Brown Bullhead	2 (4)	2	93 (1)	
Carp			6	3
Chain Pickeral				4
Channel Catfish	3 (4)	4 (2)		
Gizzard Shad	15 (75)	2 (9)	95 (34)	1,455 (9)
Golden Shiner		2	86 (14)	1
Goldfish			1	
Hickory Shad	(1)			
Largemouth Bass	(3)	1	16 (5)	
Pumpkinseed	3 (7)	14	96	3
Silvery Minnow	5			
White Catfish	(1)			4
White Perch	7 (1,474)	8 (6)	50 (1)	3 (1)
White Sucker				5
Yellow Perch	1 (93)		5	2
Total	1,898	124	1,024	1,685

( ) number dead

*sampling net frequently vandalized.

Table 6-9. Temporal sampling of spawning run herring at three fish ladders, during 2001.

	Moores Lake			Coursey Pond			McColley Pond				
Time	4/24/01	4/25/01	5/7/01	4/23/01	4/24/01	4/25/01	4/23/01	4/24/01	4/25/01	5/7/01	Average
7:30											
8:00											
8:30											
9:00											
9:30											
10:00								0.33			0.33
10:30	10.33	4.75			19.00	1.50		0.33			7.18
11:00	10.33	4.75			19.00	1.50		0.33			7.18
11:30	10.33	4.75			19.00	1.50		21.45		2.04	9.51
12:00	10.33	4.75			6.40	1.50		21.45		2.04	7.41
12:30	10.33	2.09	3.40		6.40	13.00		21.45	3.47	2.04	7.52
13:00	10.33	2.09	3.40		6.40	13.00		21.45	3.47	2.04	7.52
13:30	11.00	2.09	3.40		6.40	13.00		21.45	3.47	2.04	7.60
14:00	11.00	2.09	3.40		6.40	13.00		21.45	3.47	2.04	7.60
14:30	11.00	2.09	3.40		6.40	13.00	3.63	21.45	3.47	2.04	7.16
15:00	11.00	2.09	3.40		6.40	13.00	3.63	21.45	3.47	2.04	7.16
15:30	11.00	2.09	3.40	3.57	6.40	13.00	3.63	21.45	3.47	2.04	6.80
16:00	11.00	2.09	3.40	3.57	6.40	13.00	3.63	21.45	3.47		7.56
16:30	11.00	2.09	3.40	3.57			3.63	21.45	3.47		6.94
17:00		2.09		3.57			3.63				3.10
17:30		2.09		3.57			3.63				3.10
18:00				3.57			3.63				3.60
18:30				3.57			3.50				3.54
19:00				16.50			3.50				10.00
19:30				16.50			5.50				11.00
20:00				1.50			5.50				3.50
20:30				1.50			3.00				2.25
21:00							3.00				3.00
22:00											
22:30											
23:00											
23:30											
0:00											

Table 6-10. Temporal sampling of spawning run herring at two fish ladders, during 2008.

	Coursey Pond	**McColley Pond**	
Time	4/24/2008	4/24/2008	Average
7:30	0.18	0.54	0.36
8:00	0.18	0.54	0.36
8:30	0.18	0.54	0.36
9:00	4.5	8.5	6.5
9:30	4.5	8.5	6.5
10:00	4	0.5	2.25
10:30	4	0.5	2.25
11:00	7.5	1.0	4.25
11:30	7.5	1.0	4.25
12:00	5.5	14.5	10
12:30	5.5	14.5	10
13:00	10.5	16	13.25
13:30	10.5	16	13.25
14:00	14.5	13	13.75
14:30	14.5	13	13.75
15:00	8.5	14	11.25
15:30	8.5	14	11.25
16:00	21	23	22
16:30	21	23	22
17:00	6	5.5	5.75
17:30	6	5.5	5.75
18:00	3.5	3	3.25
18:30	3.5	3	3.25
19:00	0	0	0
19:30	0	0	0
20:00	0	0	0
20:30	0	0	0
21:00	0	0	0
22:00	0	0	0
22:30			
23:00			
23:30			
0:00			

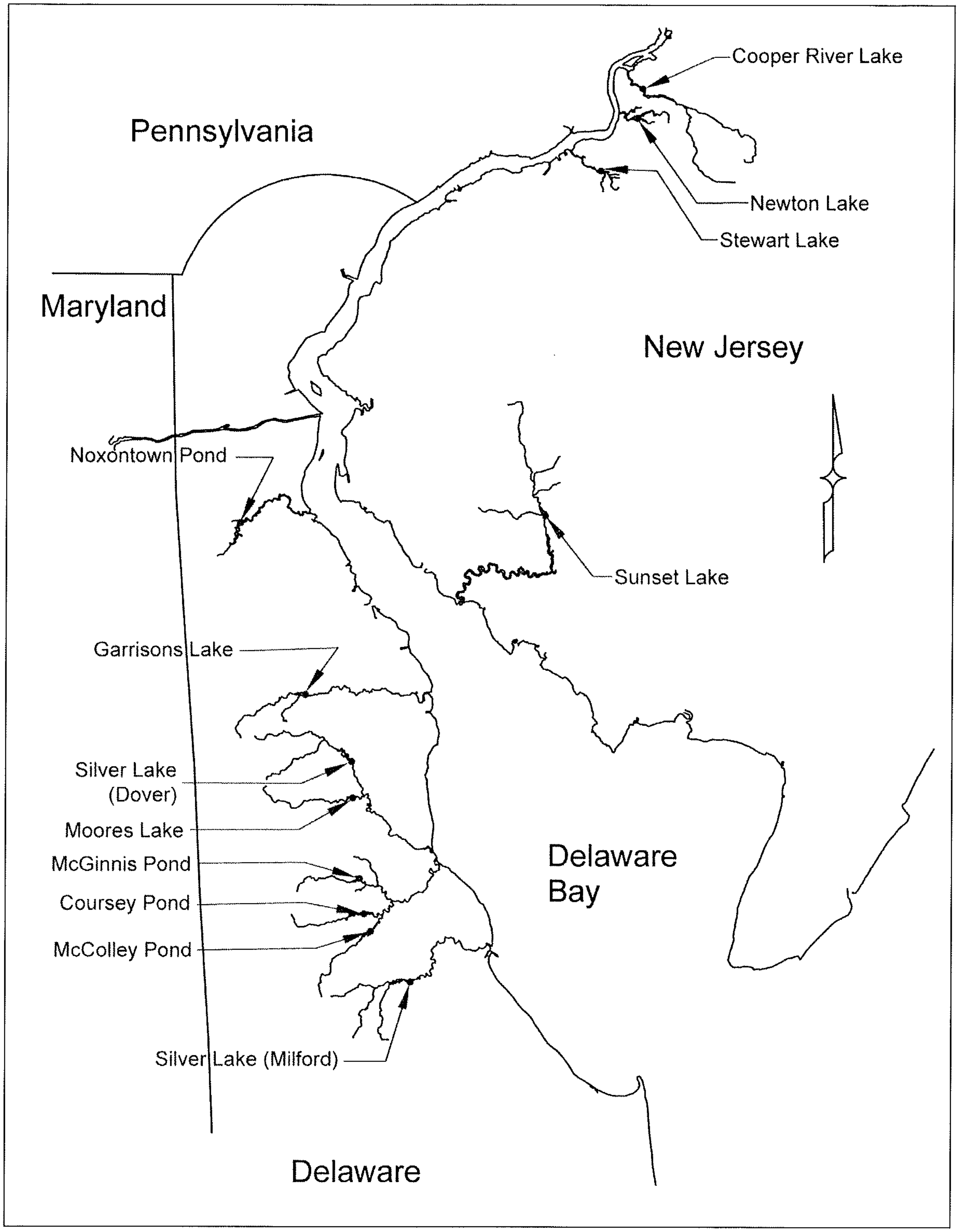


Figure 6-1. Map depicting the locations of the twelve PSEG fish ladders within the Delaware River estuary.

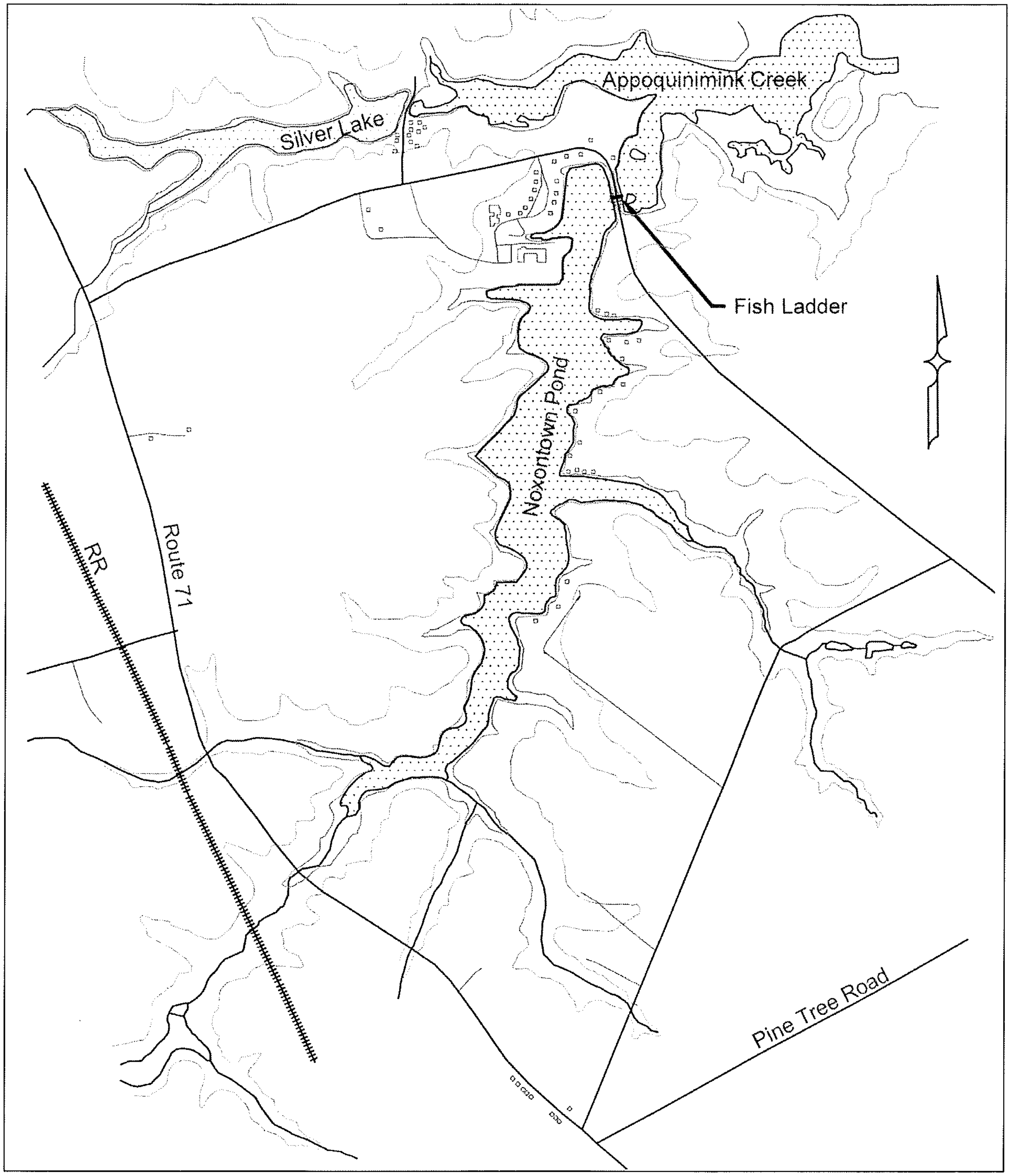


Figure 6-2. Noxontown Pond on the Appoquinimink River, in Odessa, DE.

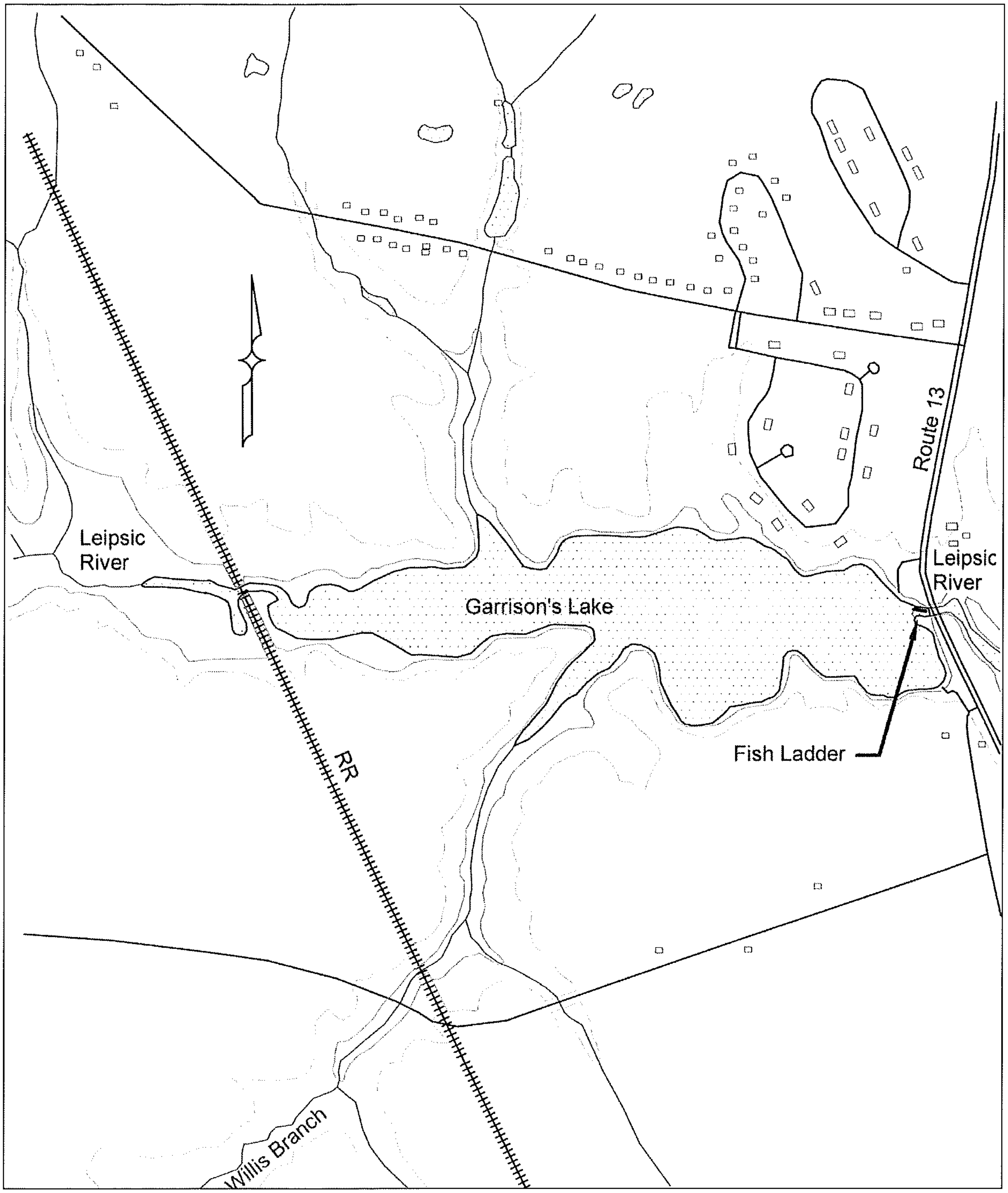


Figure 6-3. Garrisons Lake on the Leipsic River, near Cheswold, DE showing fish ladder.

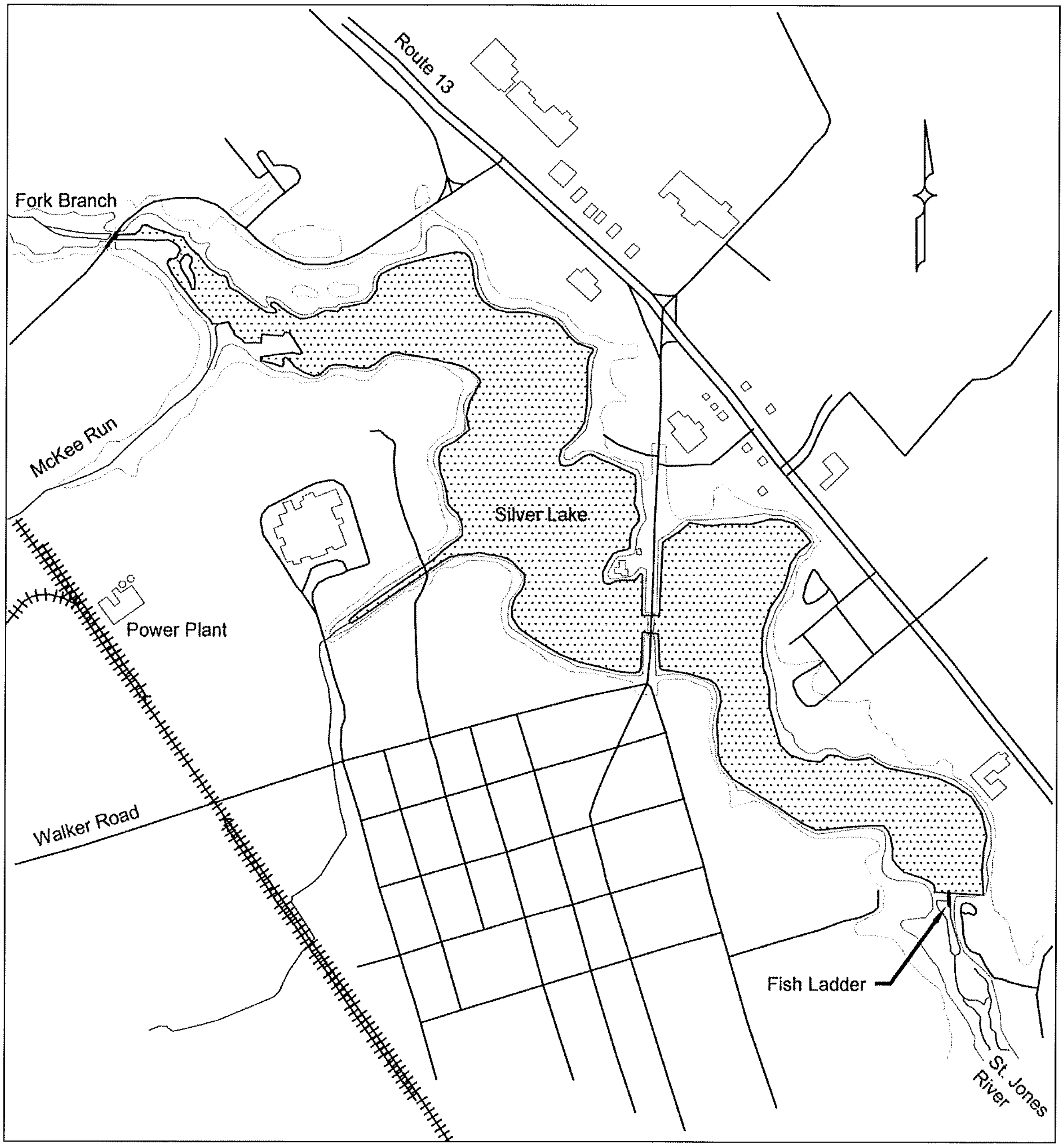


Figure 6-4. Silver Lake on the St Jones River, in Dover, DE.

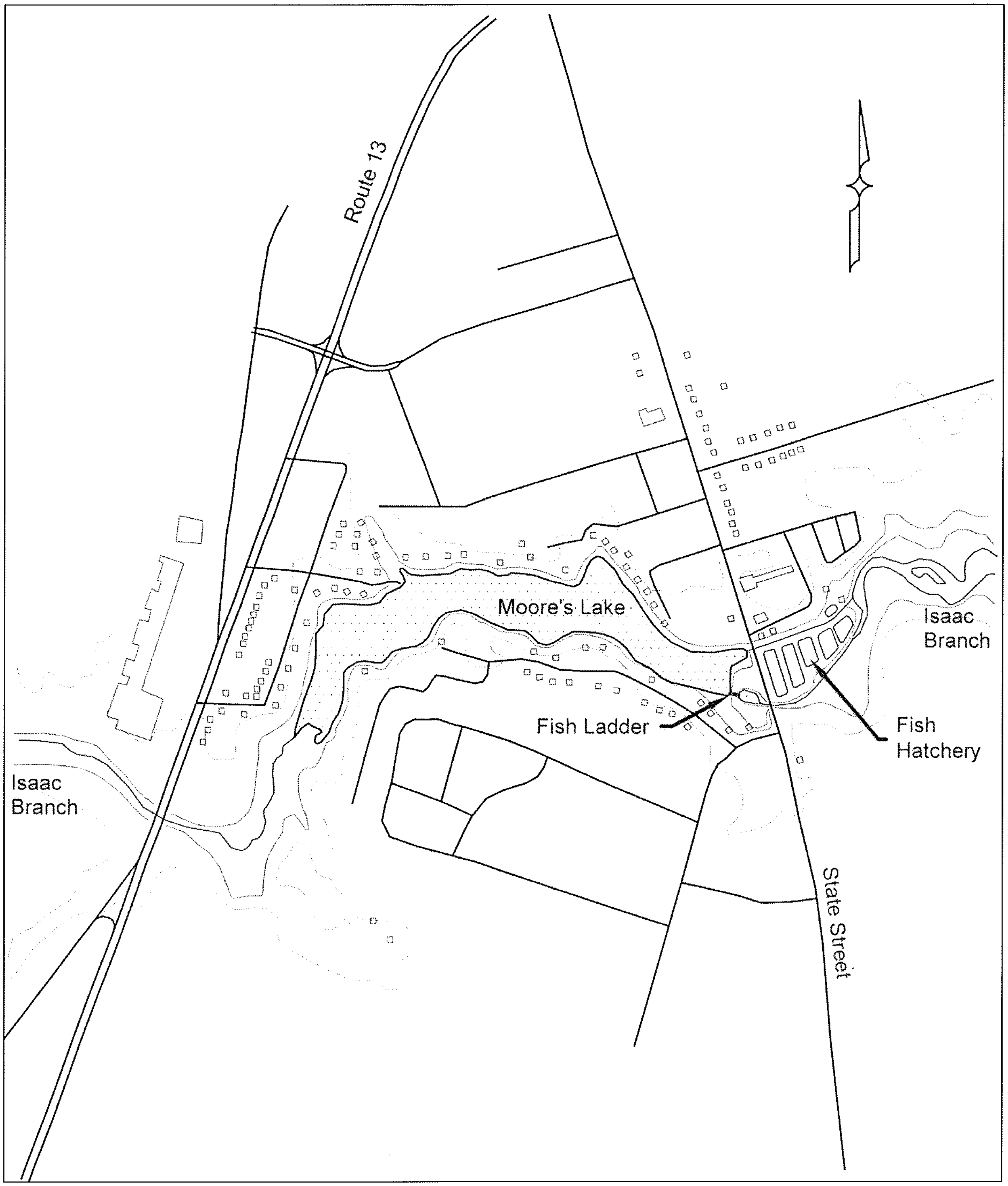


Figure 6-5. Moores Lake on Isaacs Branch, a tributary to the St. Jones River, near Dover, DE.

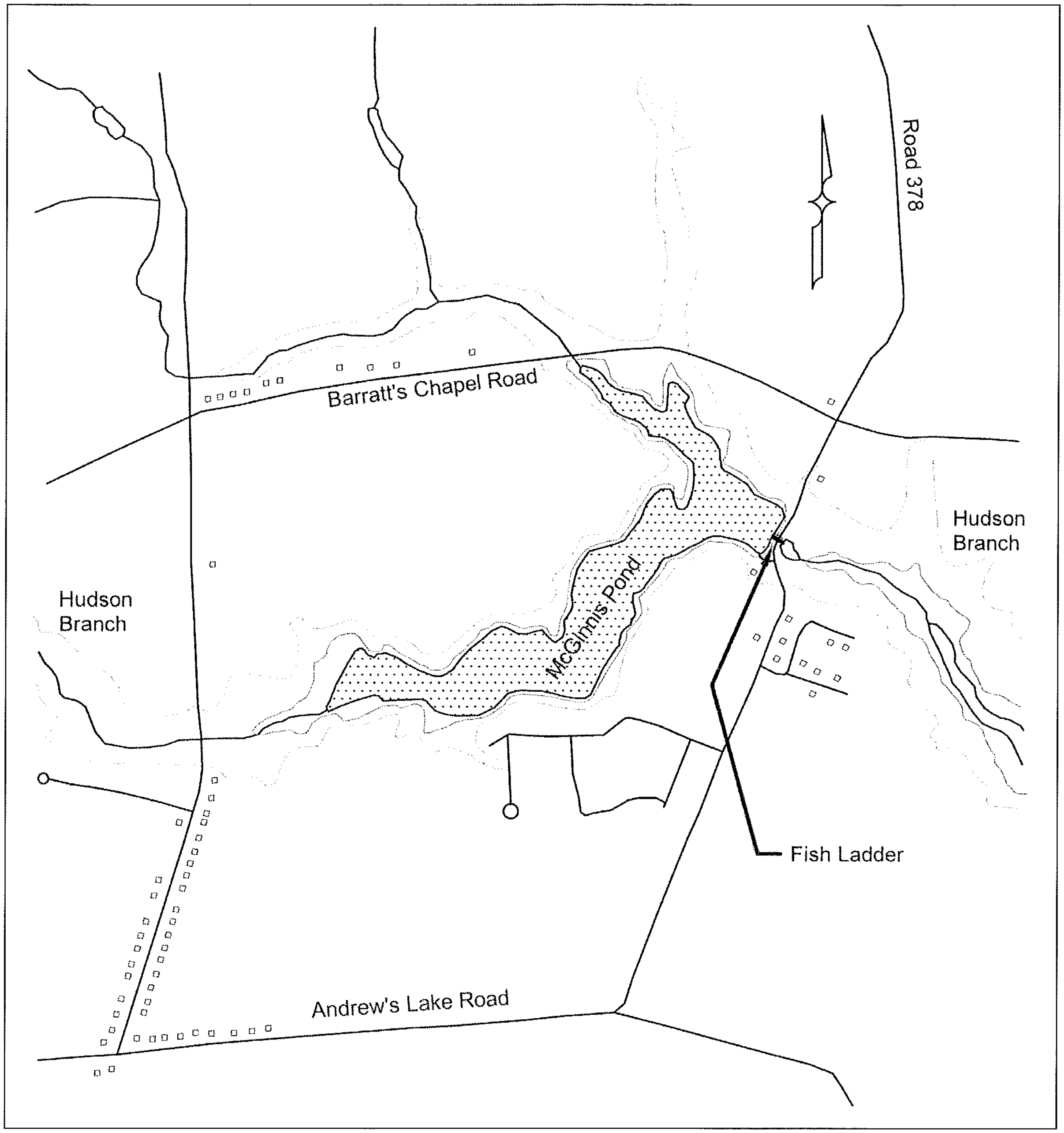


Figure 6-6. McGinnis Pond on Hudson Branch, a tributary of the Murderkill River, near Frederica, DE.

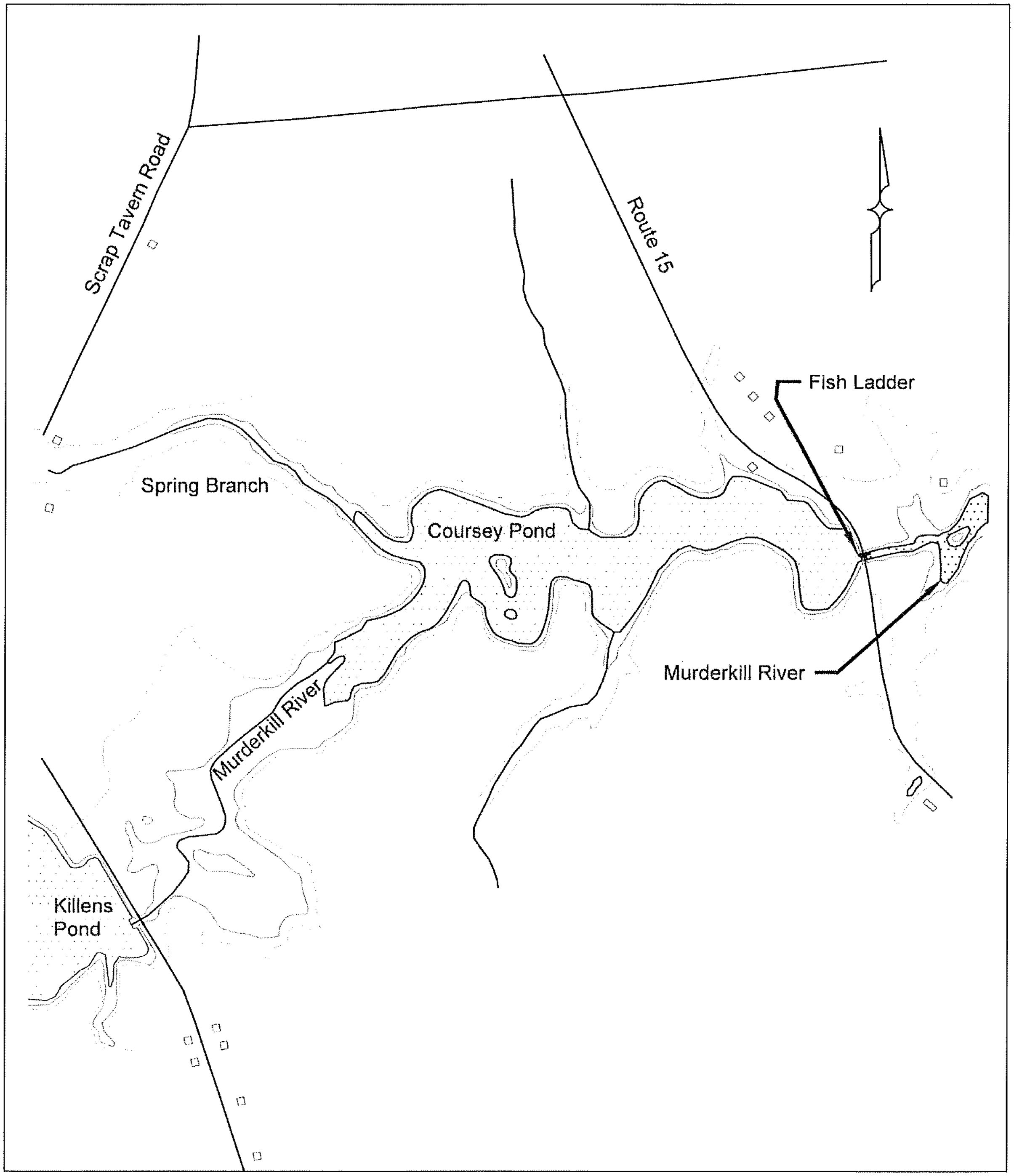


Figure 6-7. Coursey Pond on the Murderkill River, near Frederica, DE.

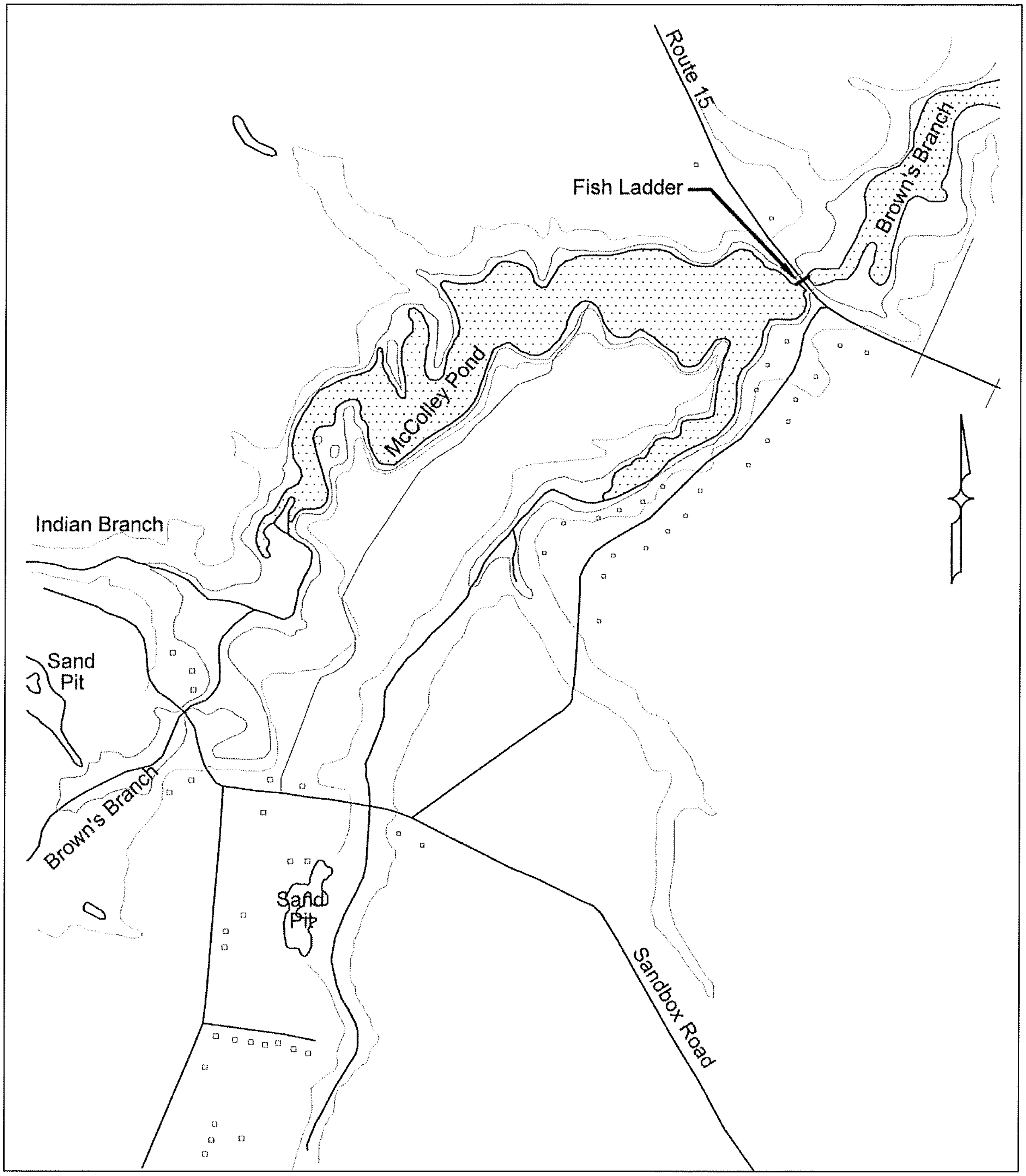


Figure 6-8. McColley Pond on Brown's Branch, a tributary to the Murderkill River, near Milford, DE.

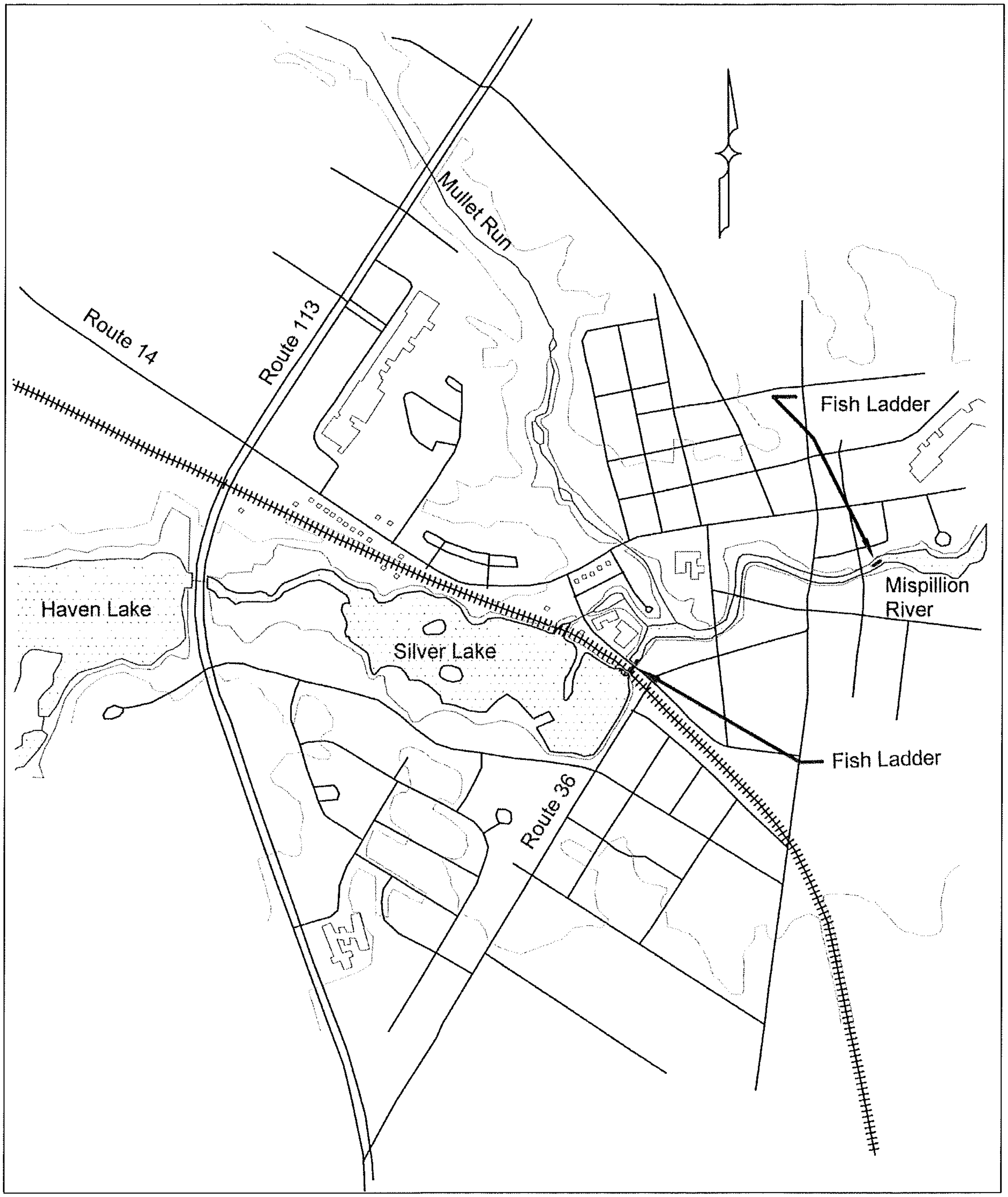


Figure 6-9. Silver Lake on the Mispillion River, in Milford, DE, showing the two fish ladders.

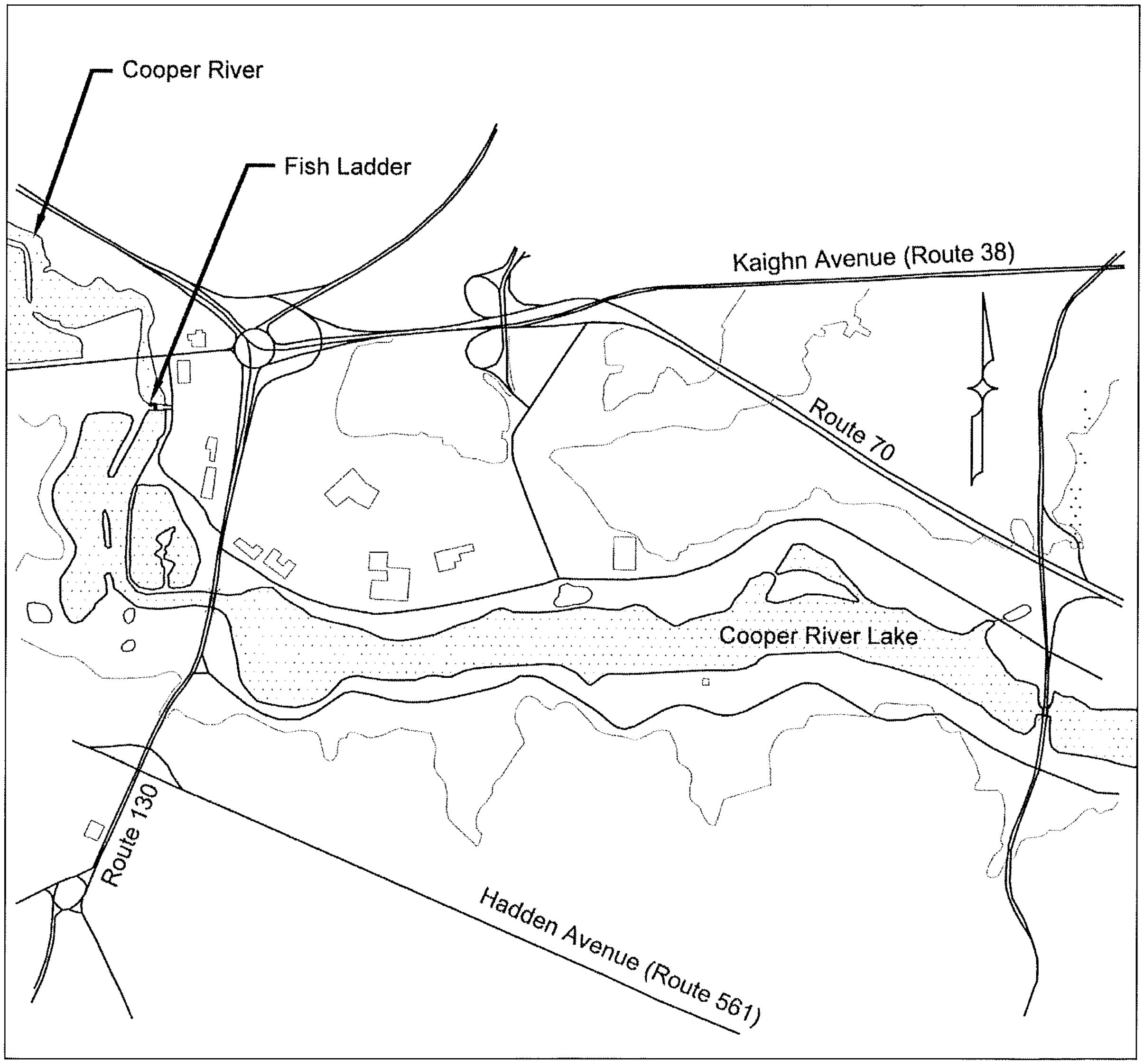


Figure 6-10. Cooper River Lake, an impoundment of the Cooper River, in Camden, NJ.

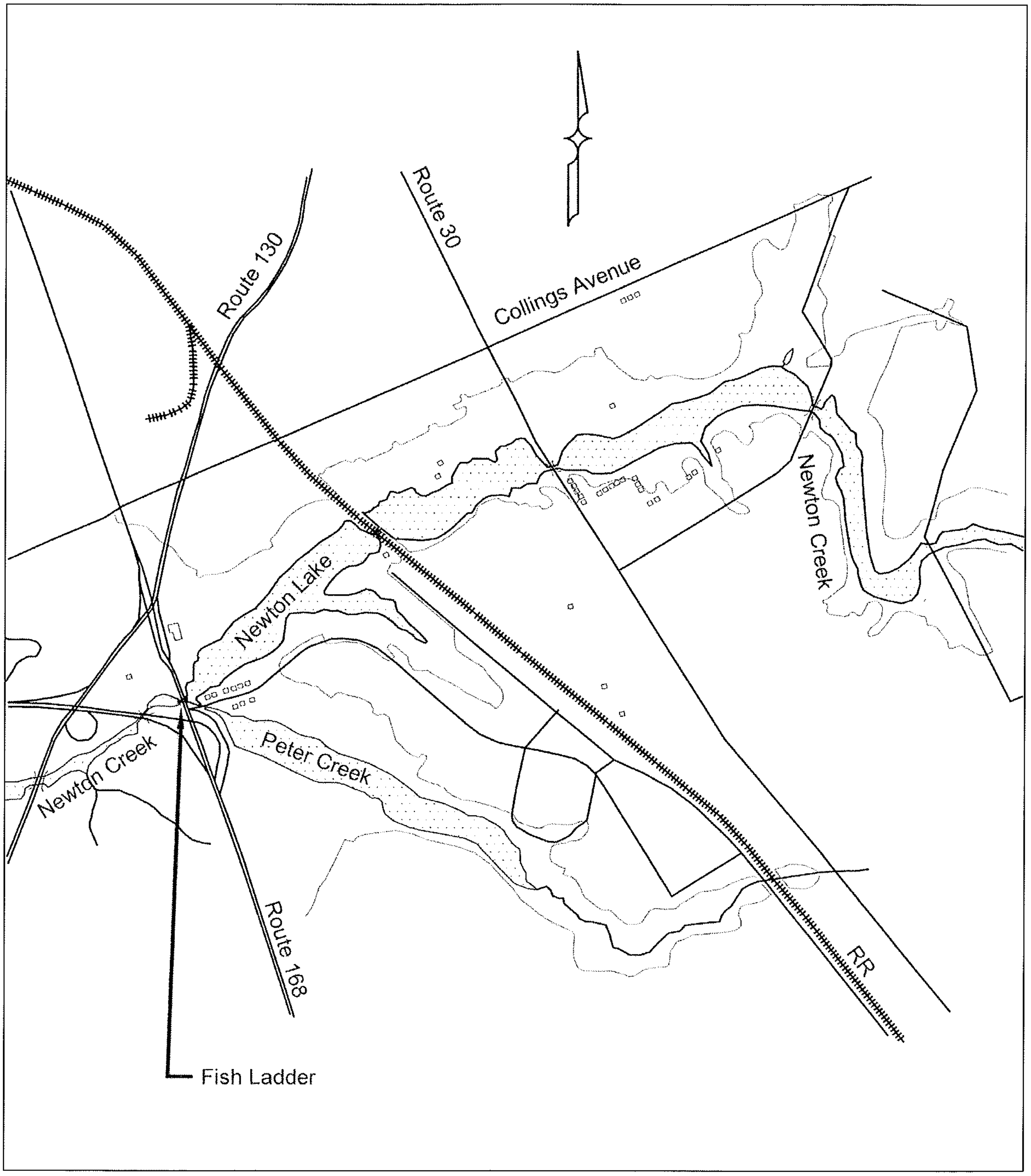


Figure 6-11. Newton Lake, an impoundment of Newton Creek, in Oaklyn, NJ.

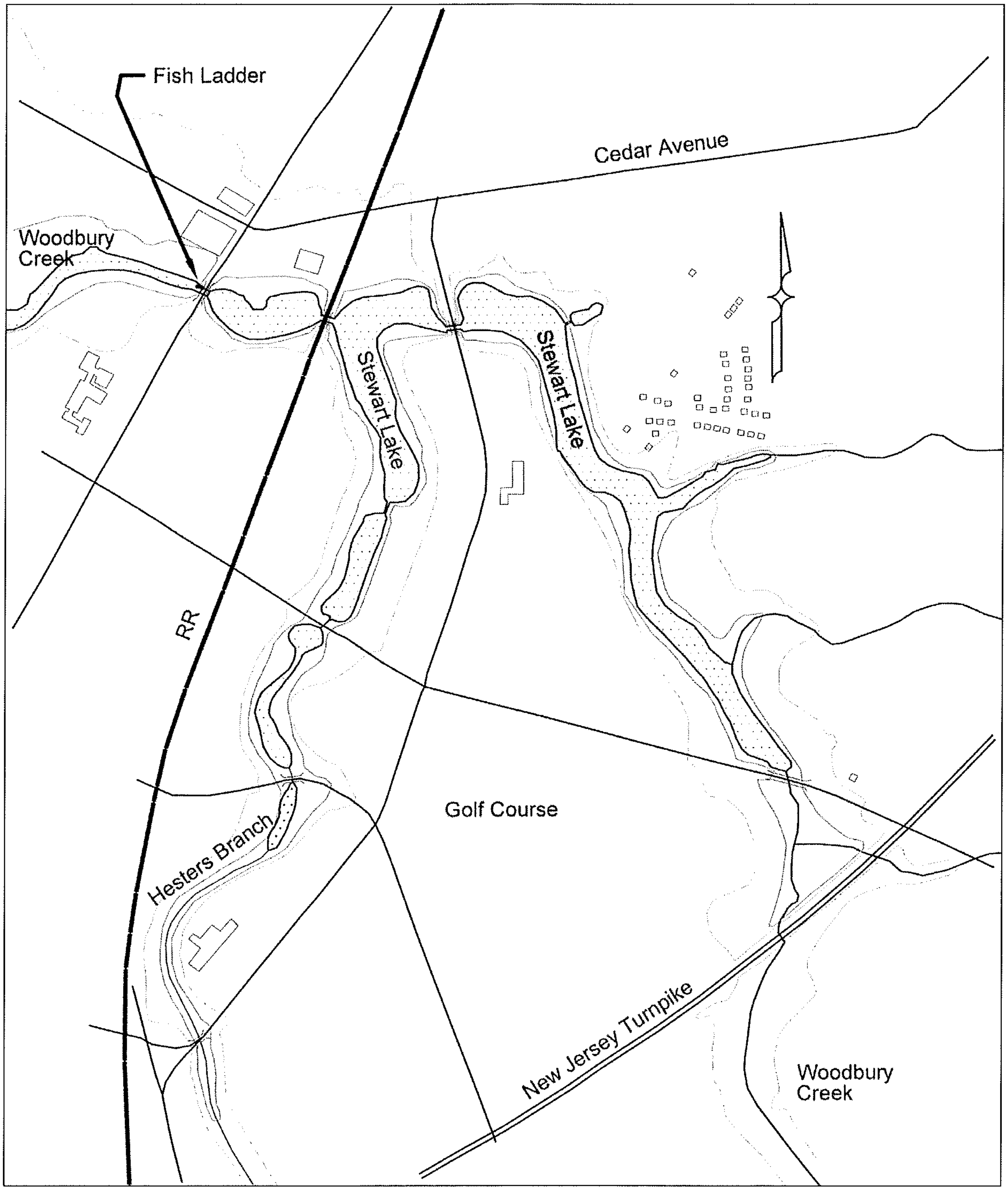


Figure 6-12. Stewart Lake, and impoundment of Woodbury Creek, in Woodbury, NJ.

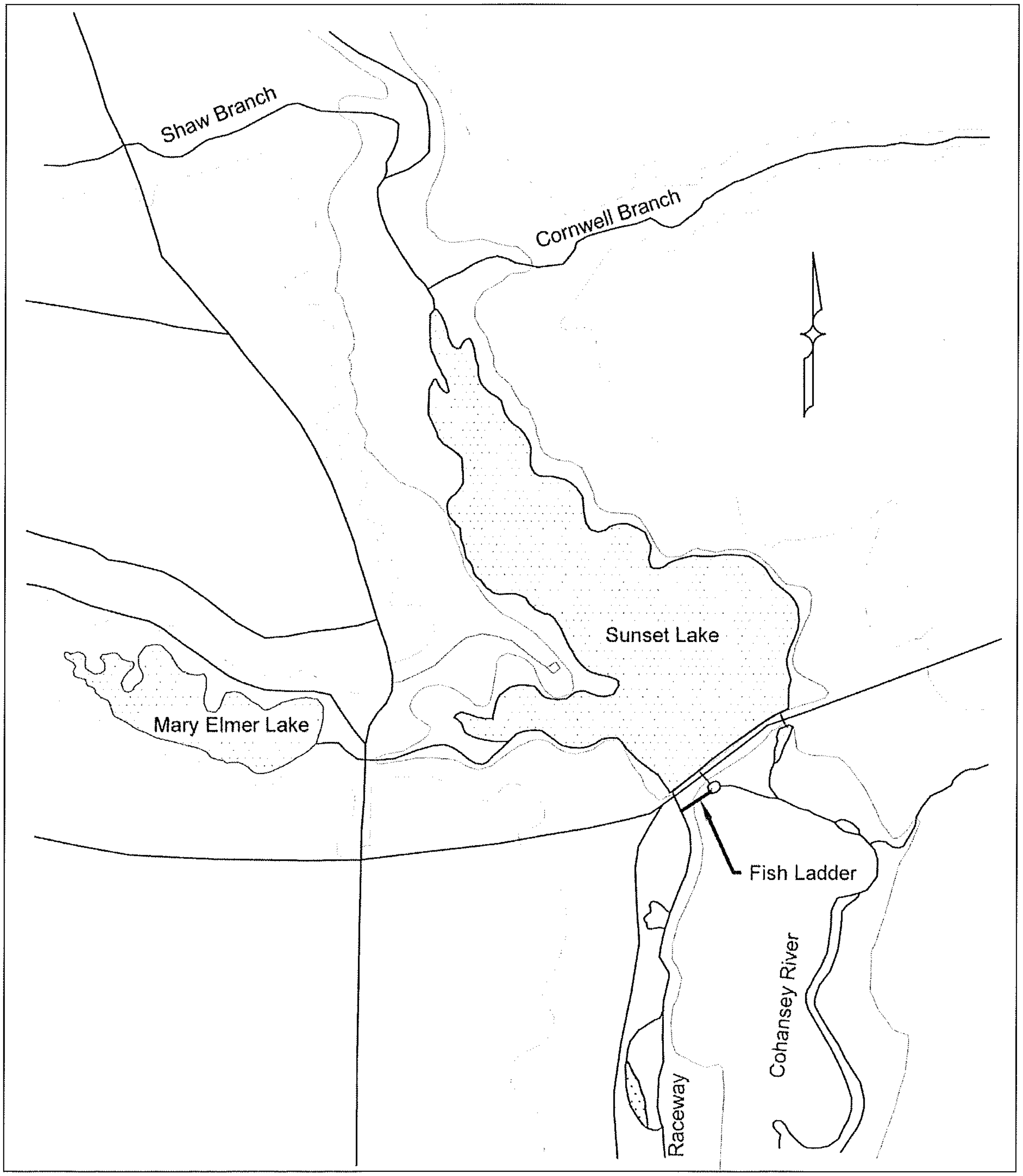
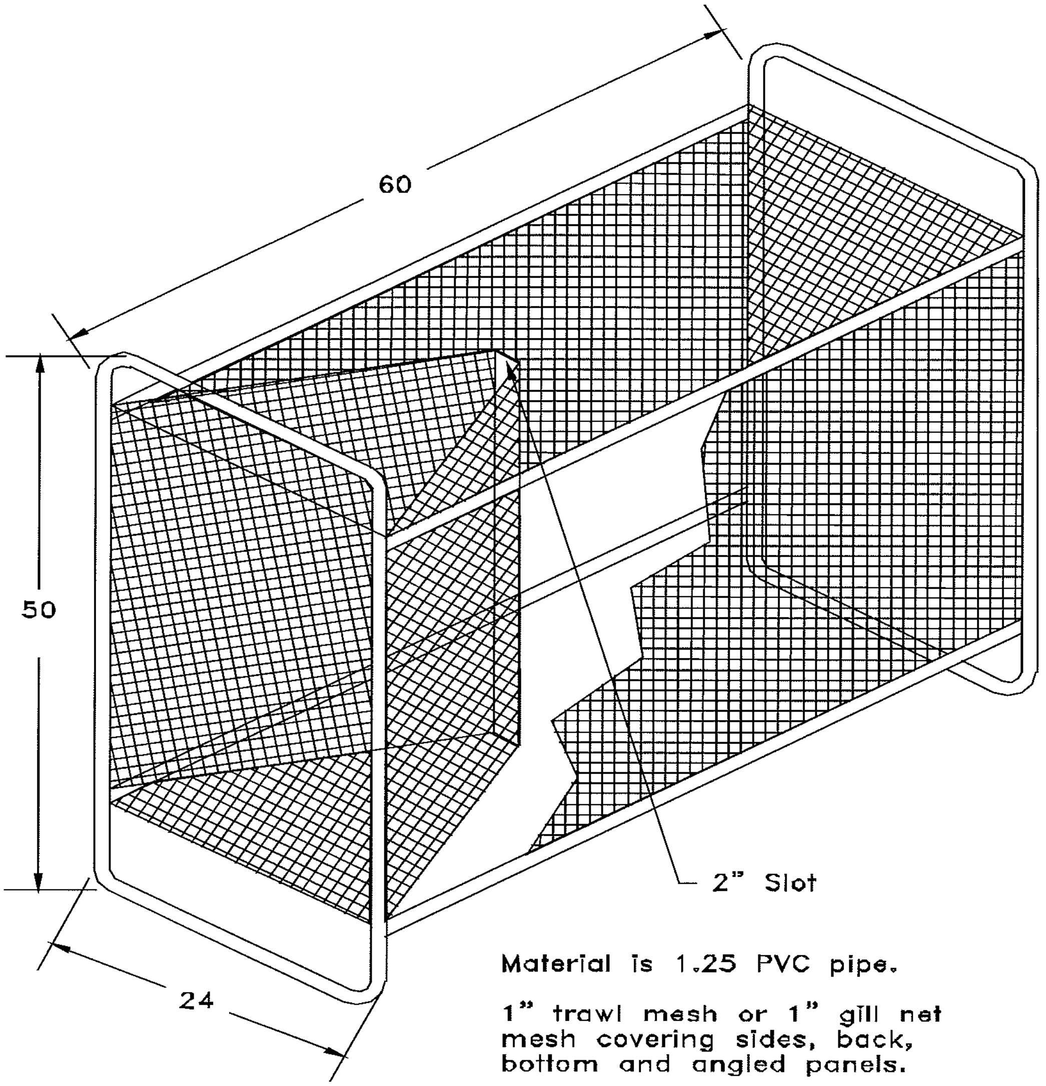


Figure 6-13. Sunset Lake on the Cohansey River, in Bridgeton, NJ.



Material is 1.25 PVC pipe.

1" trawl mesh or 1" gill net mesh covering sides, back, bottom and angled panels.

Figure 6-14. Generalized fish trap used to collect fish at the exit (upper end) of the fish ladders.

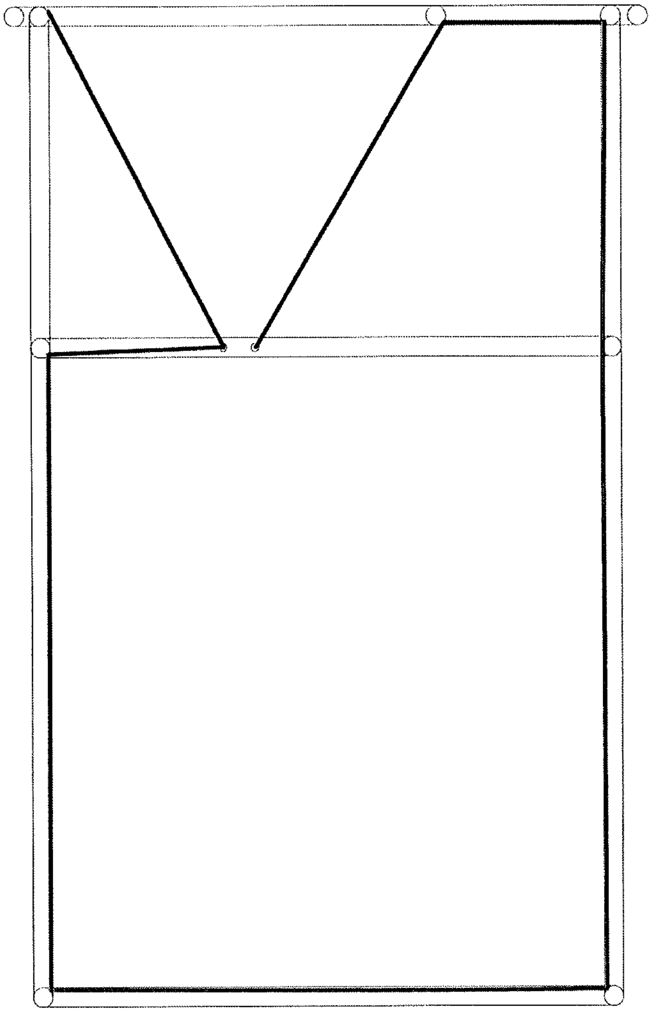


Figure 6-15. Plan view of Noxontown fish trap used to collect fish at the exit (upper end) of the fish ladder.

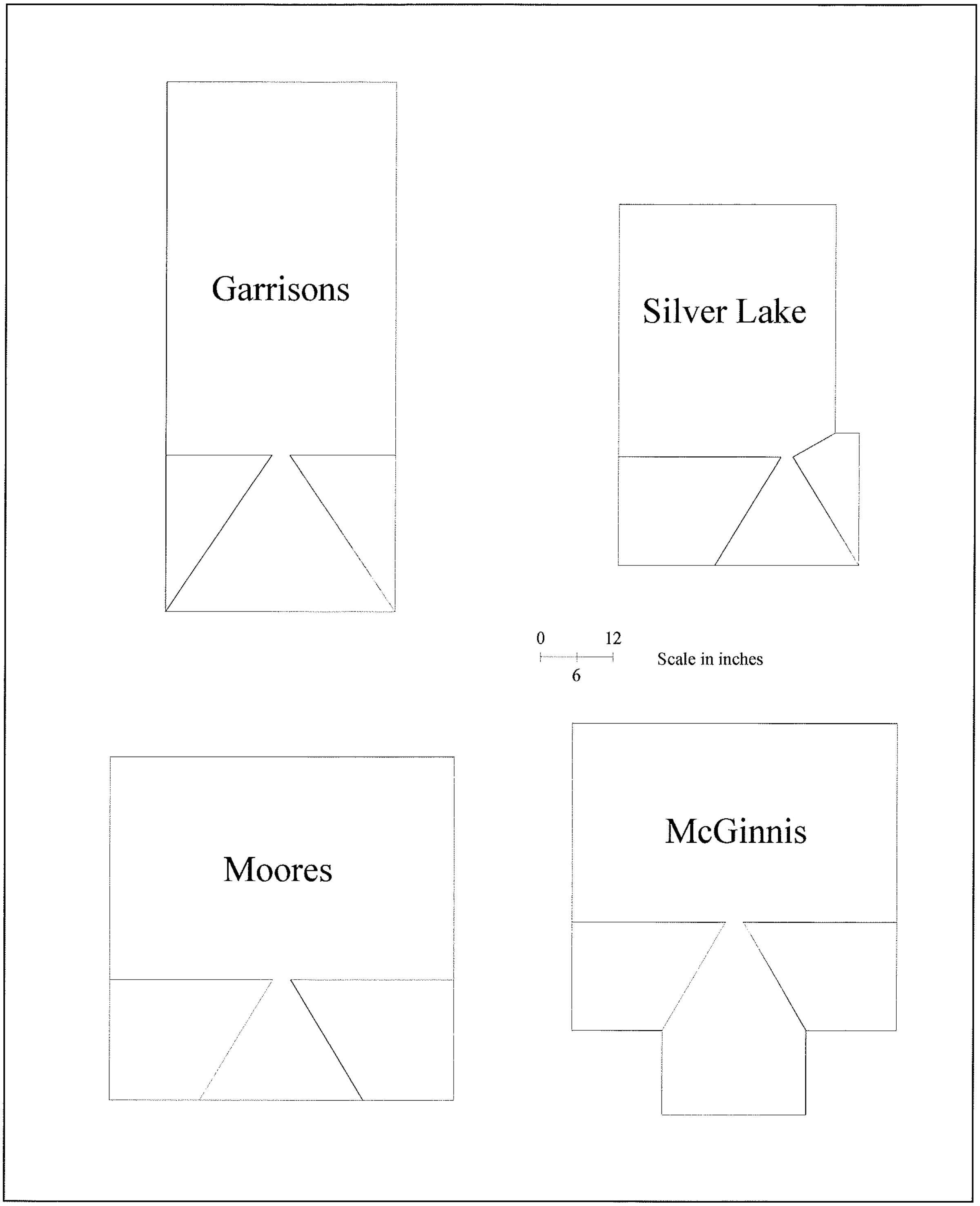


Figure 6-16. Plan views of four fish traps used to collect fish at the exit (upper end) of the fish ladders.

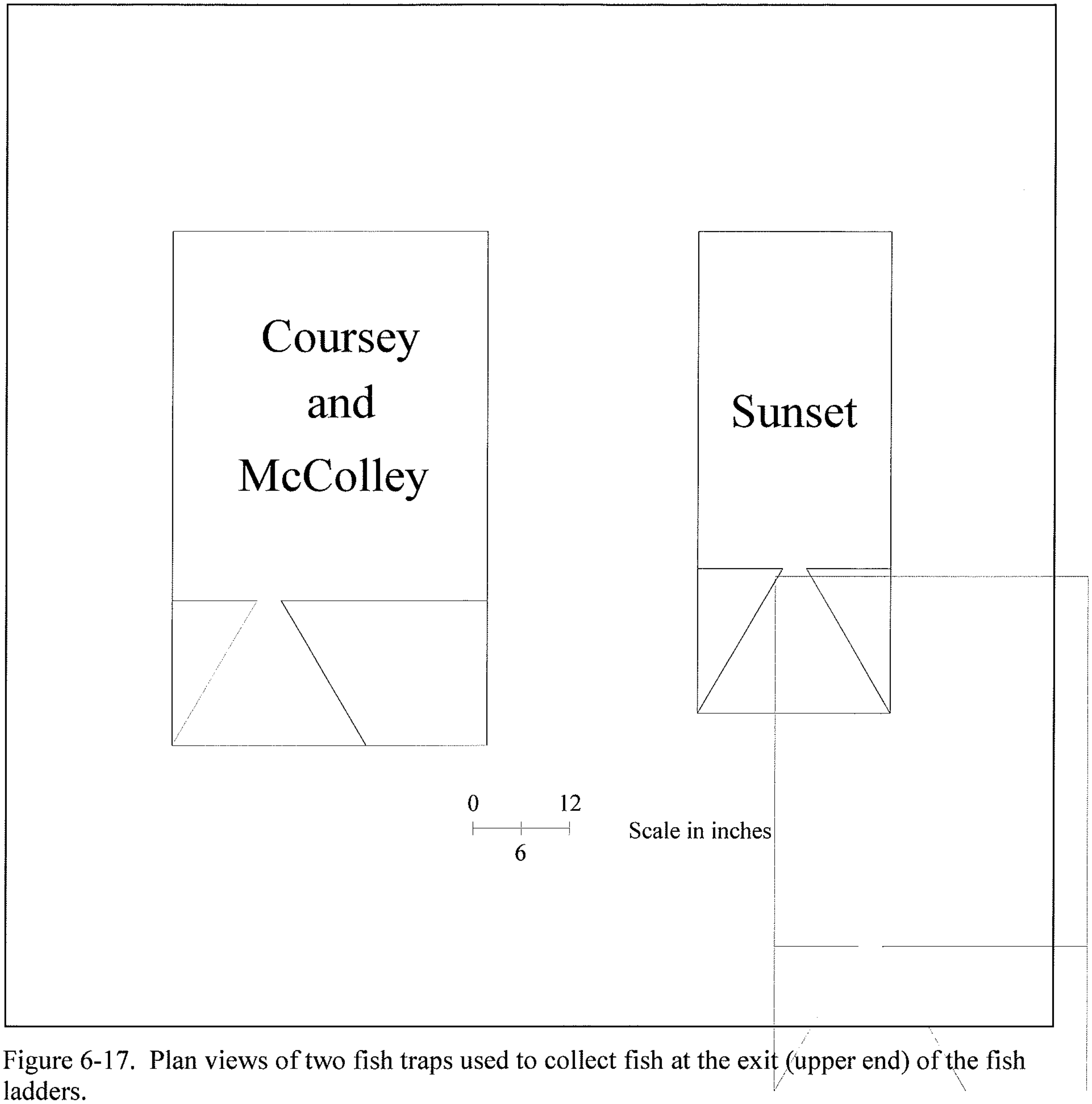


Figure 6-17. Plan views of two fish traps used to collect fish at the exit (upper end) of the fish ladders.

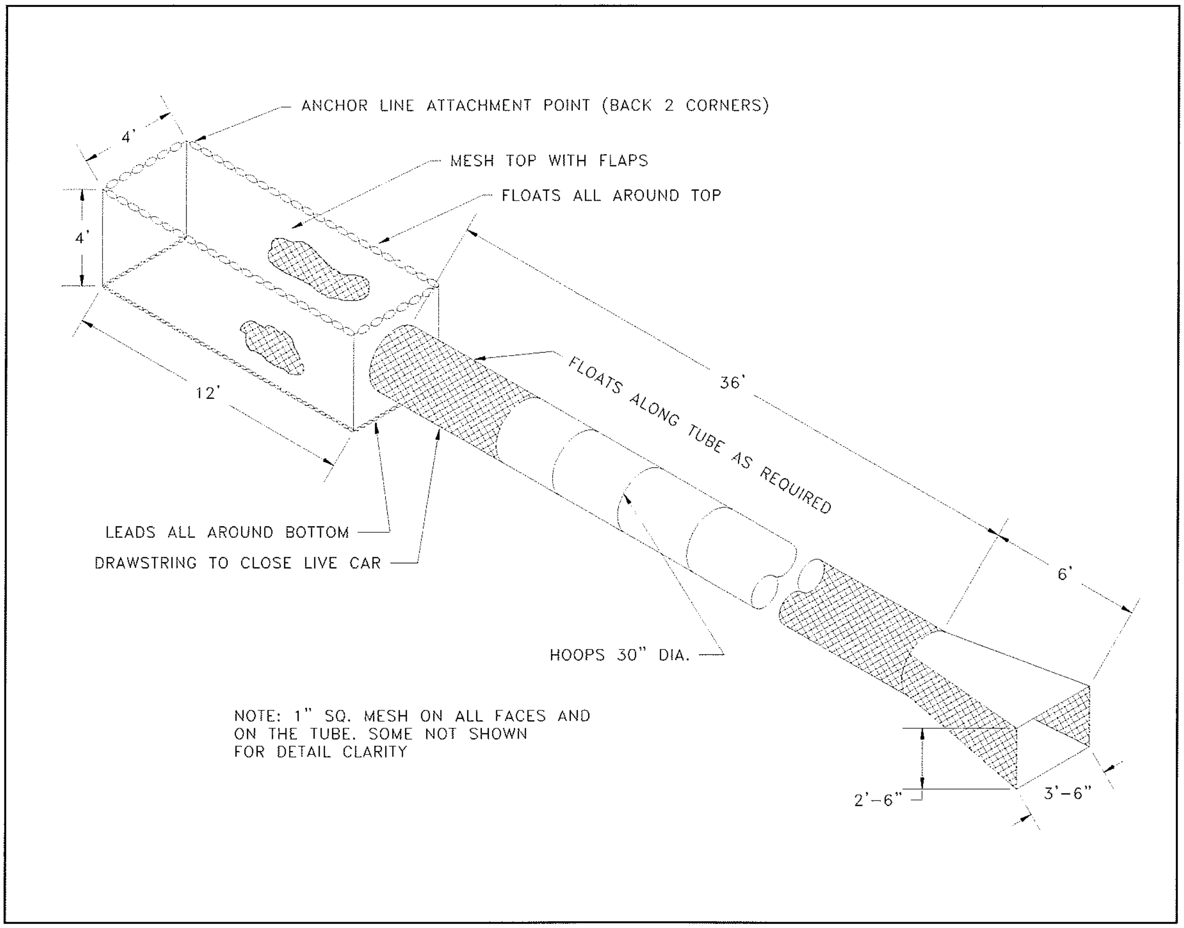


Figure 6-18. Modified commercial fish trap used to collect fish at the exit (upper end) of the Cooper River Lake fish ladder.

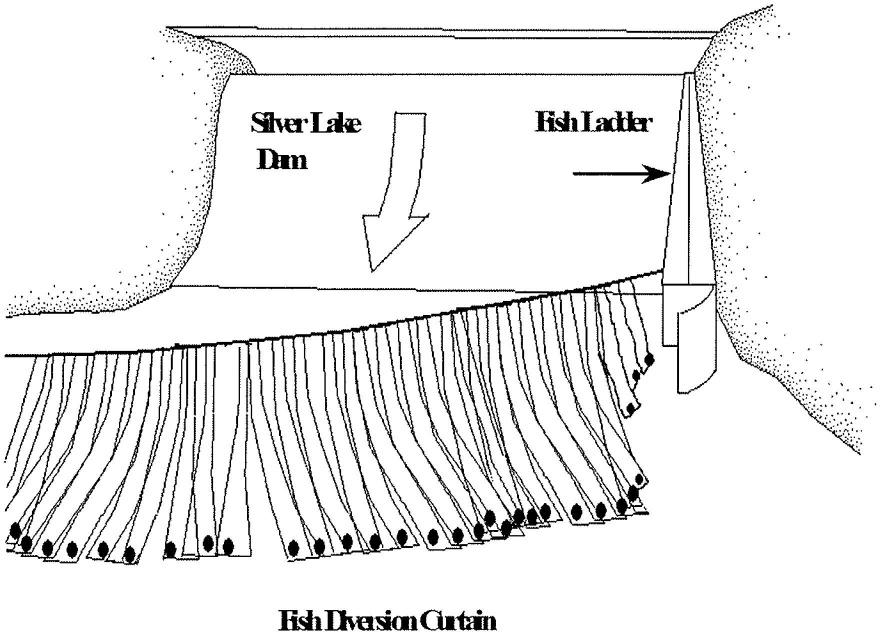


Figure 6-19. Fish diversion curtain at the Silver Lake fish ladder.

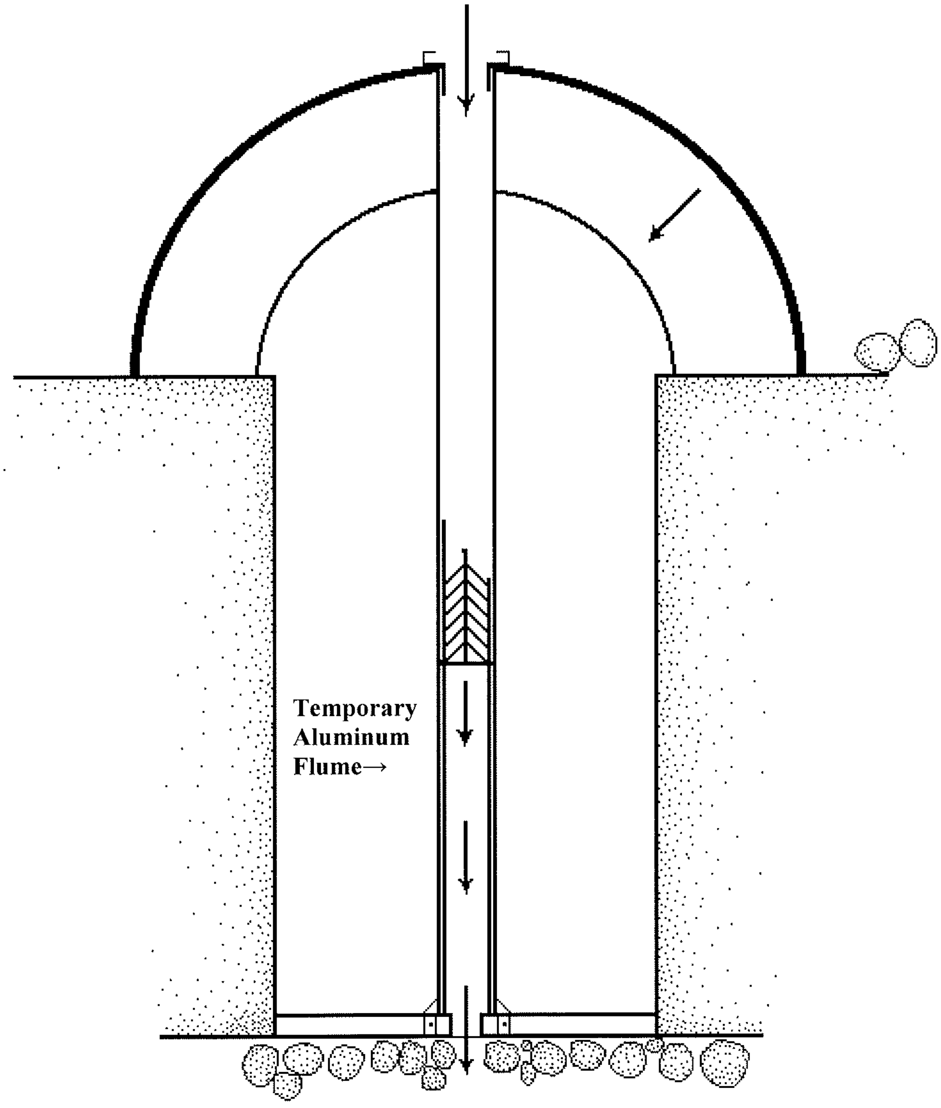
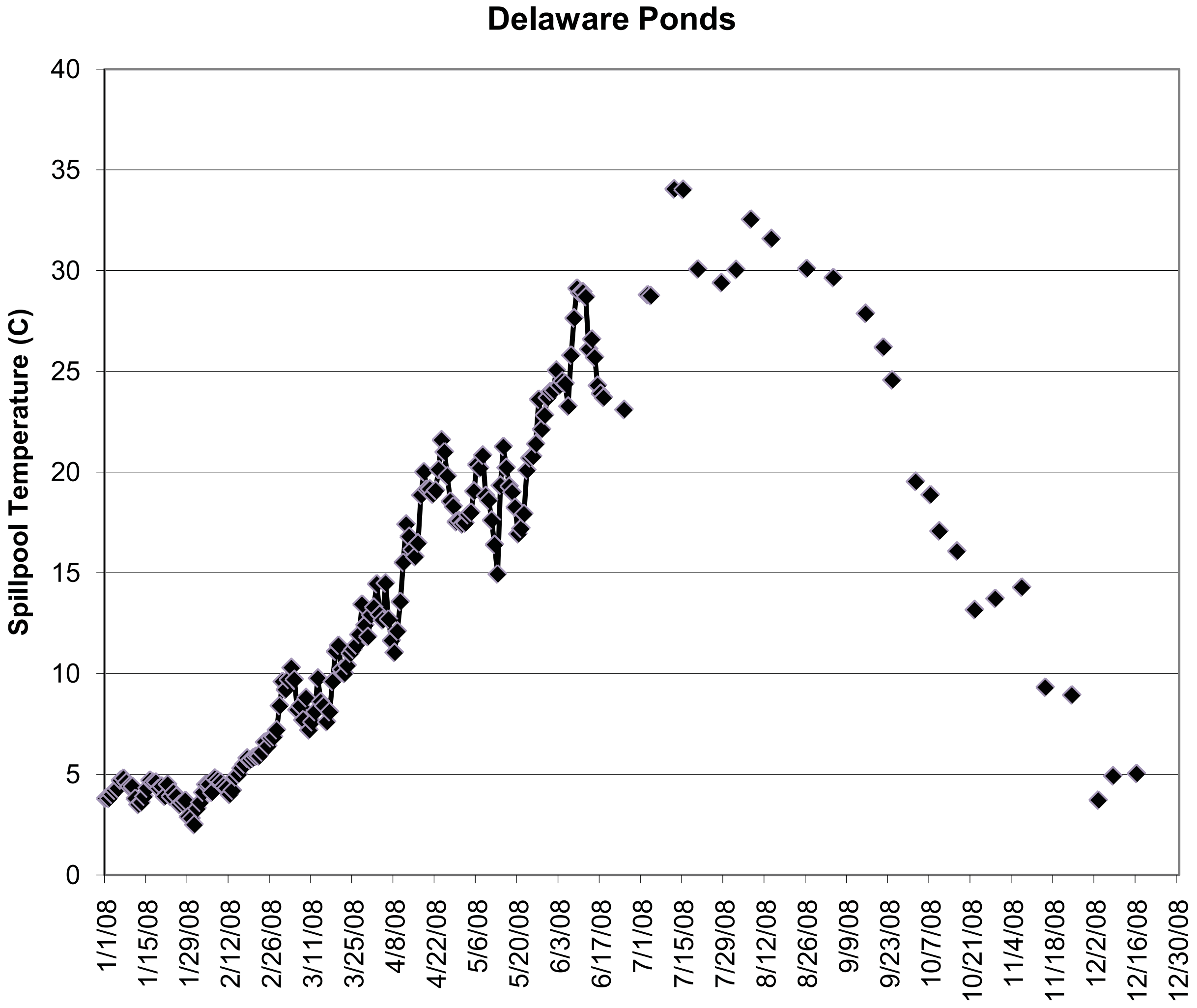


Figure 6-20. Fish diversion flume at Moores Lake fish ladder.



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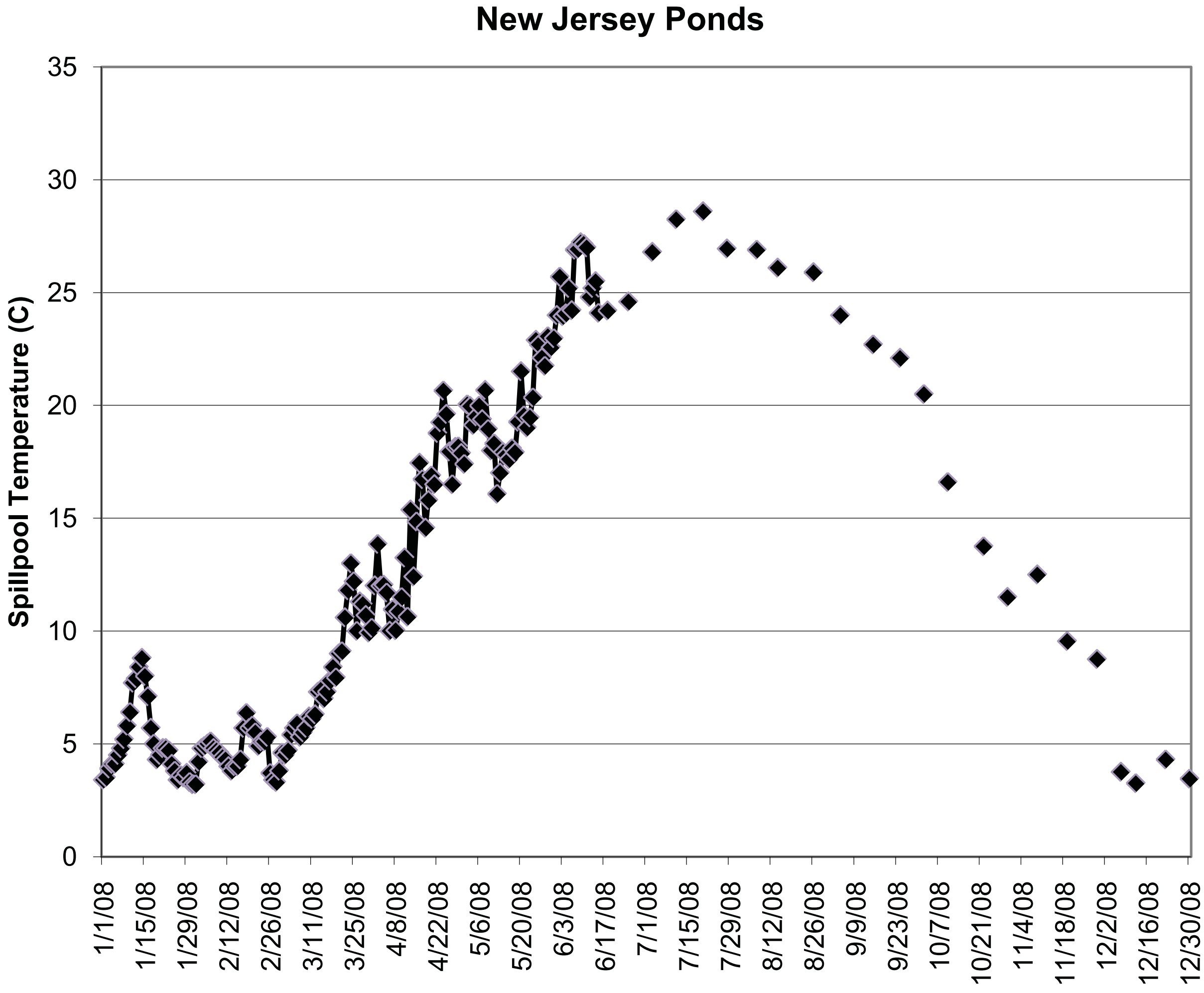

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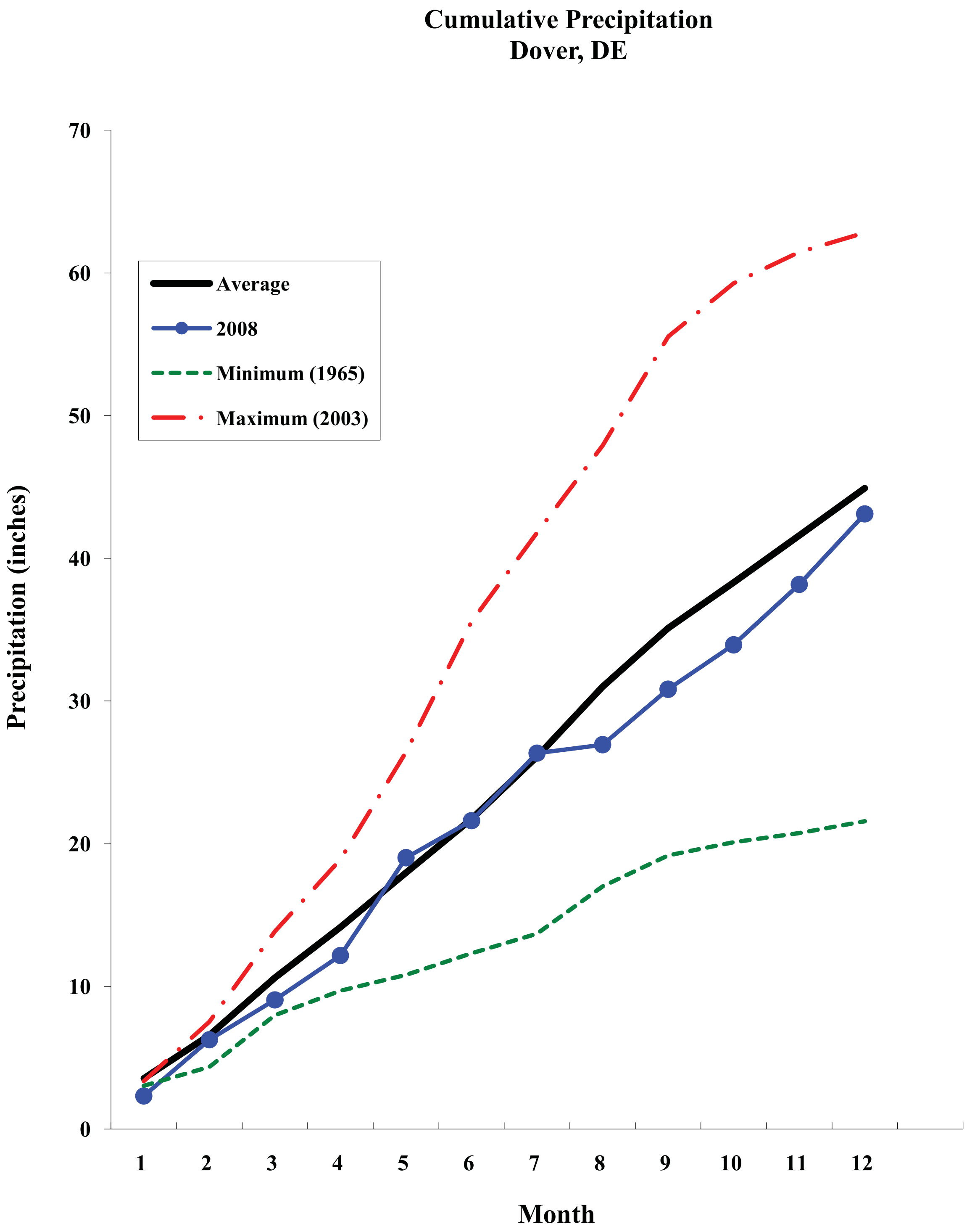

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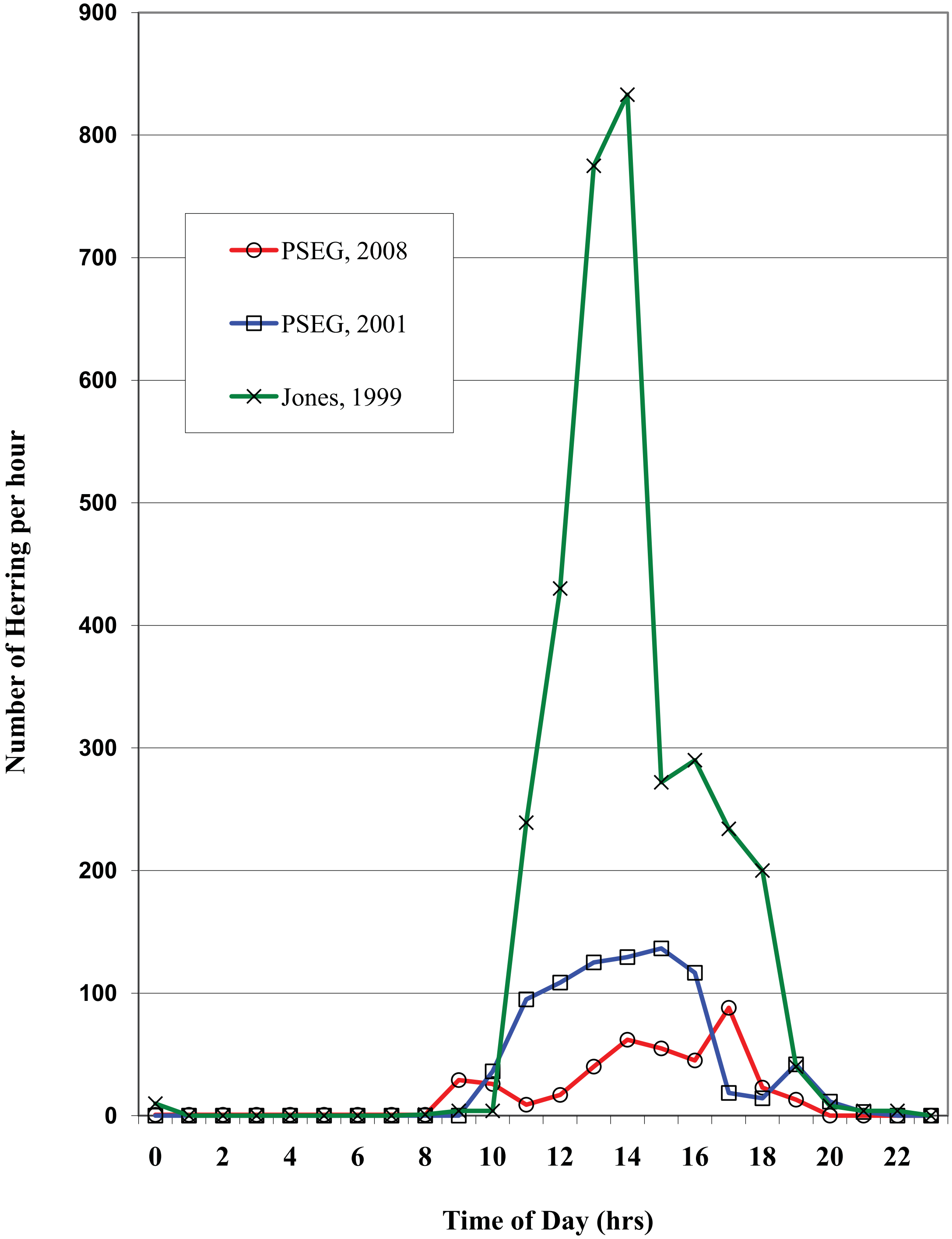

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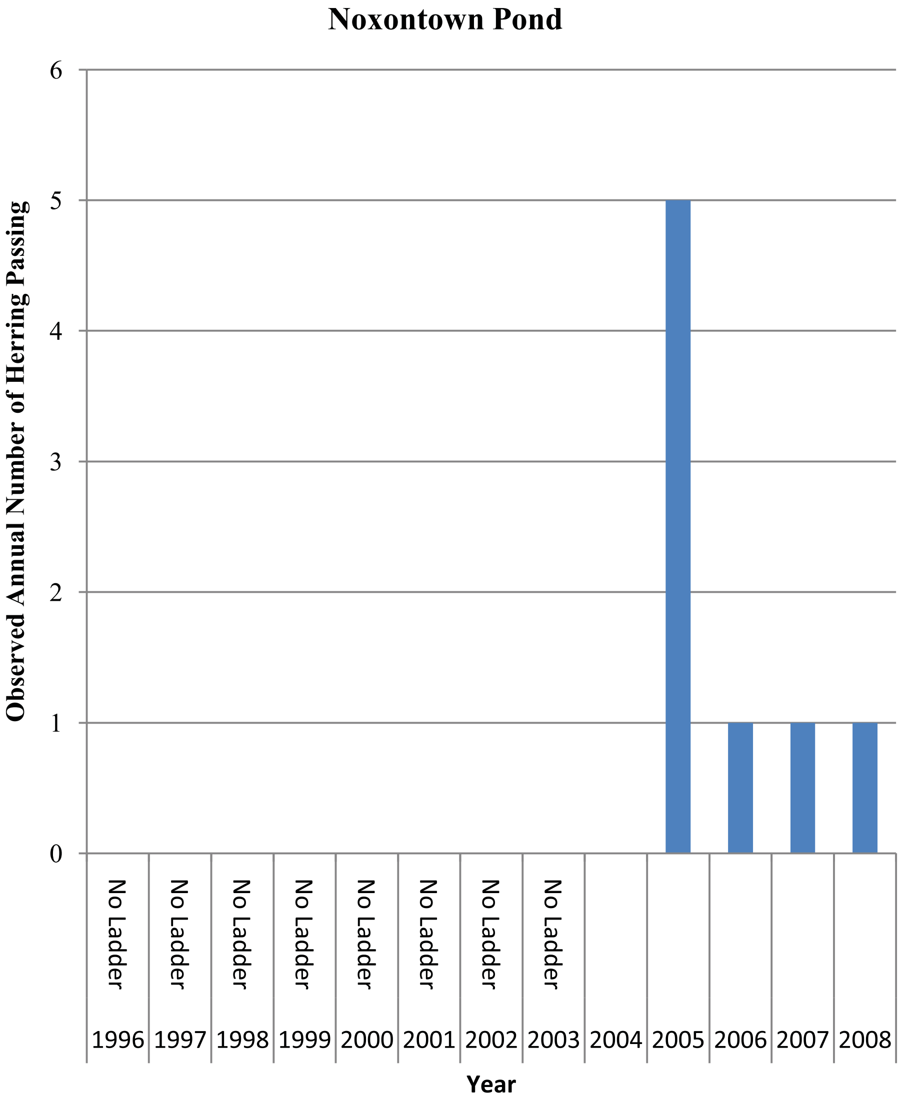

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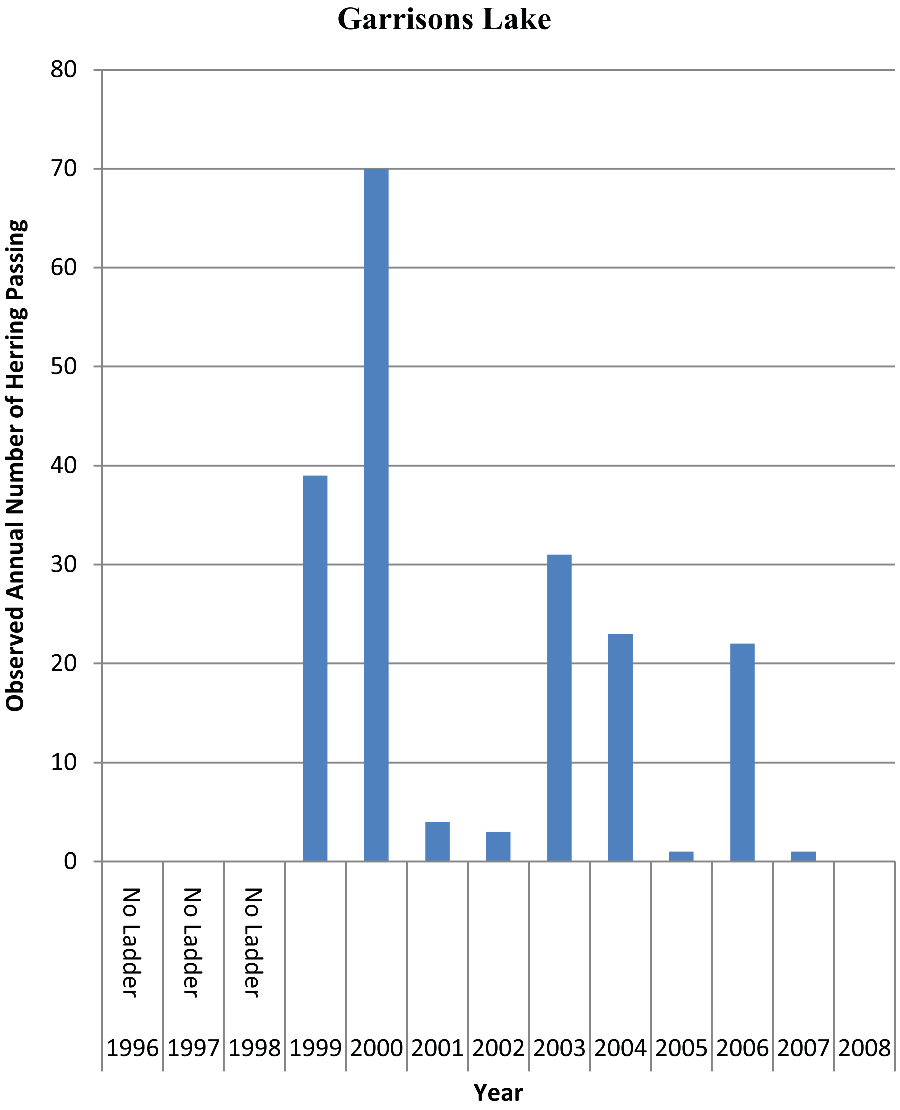

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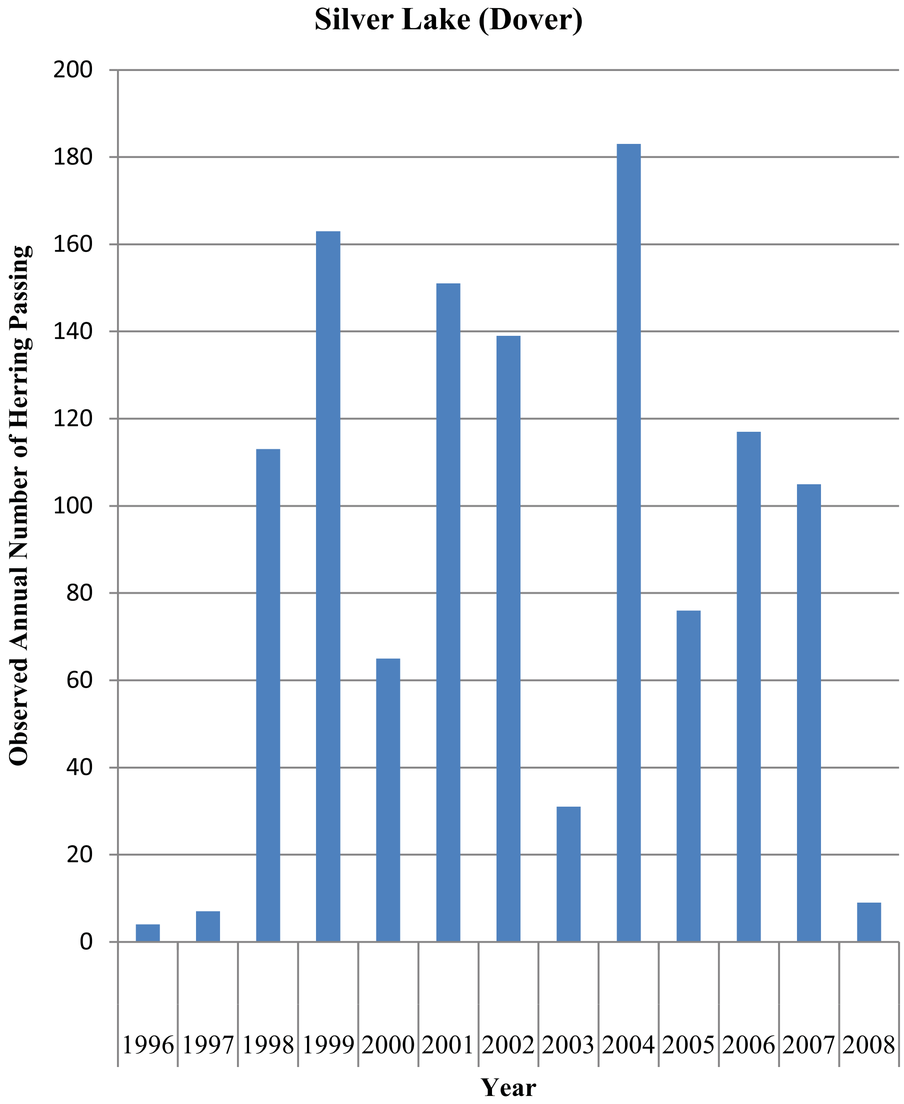

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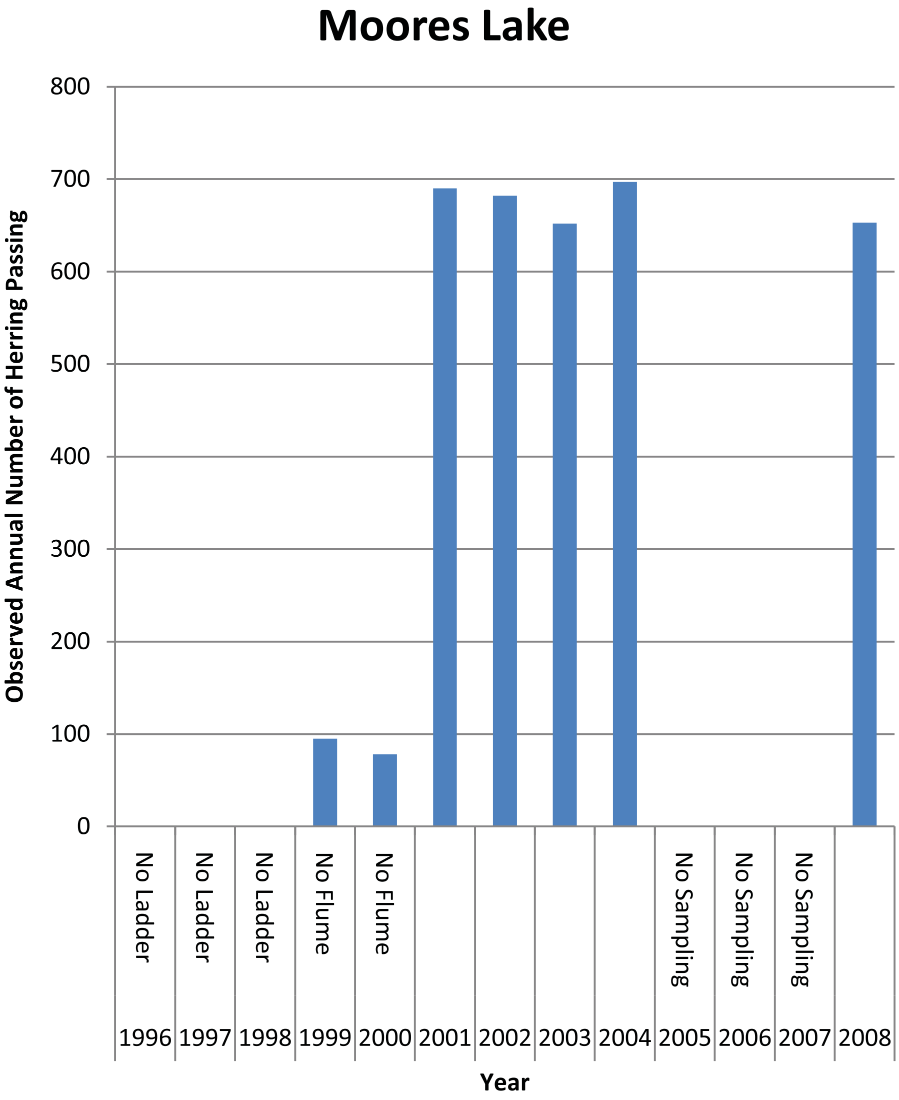

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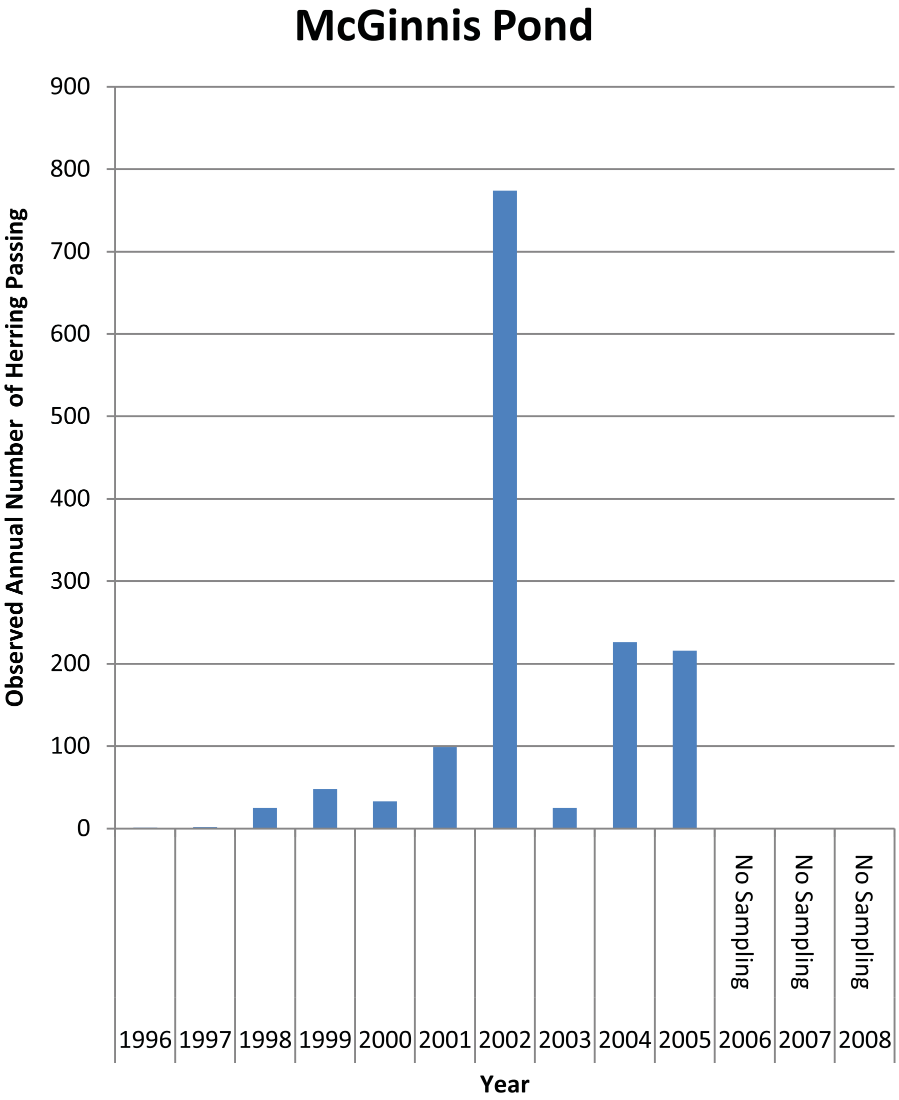

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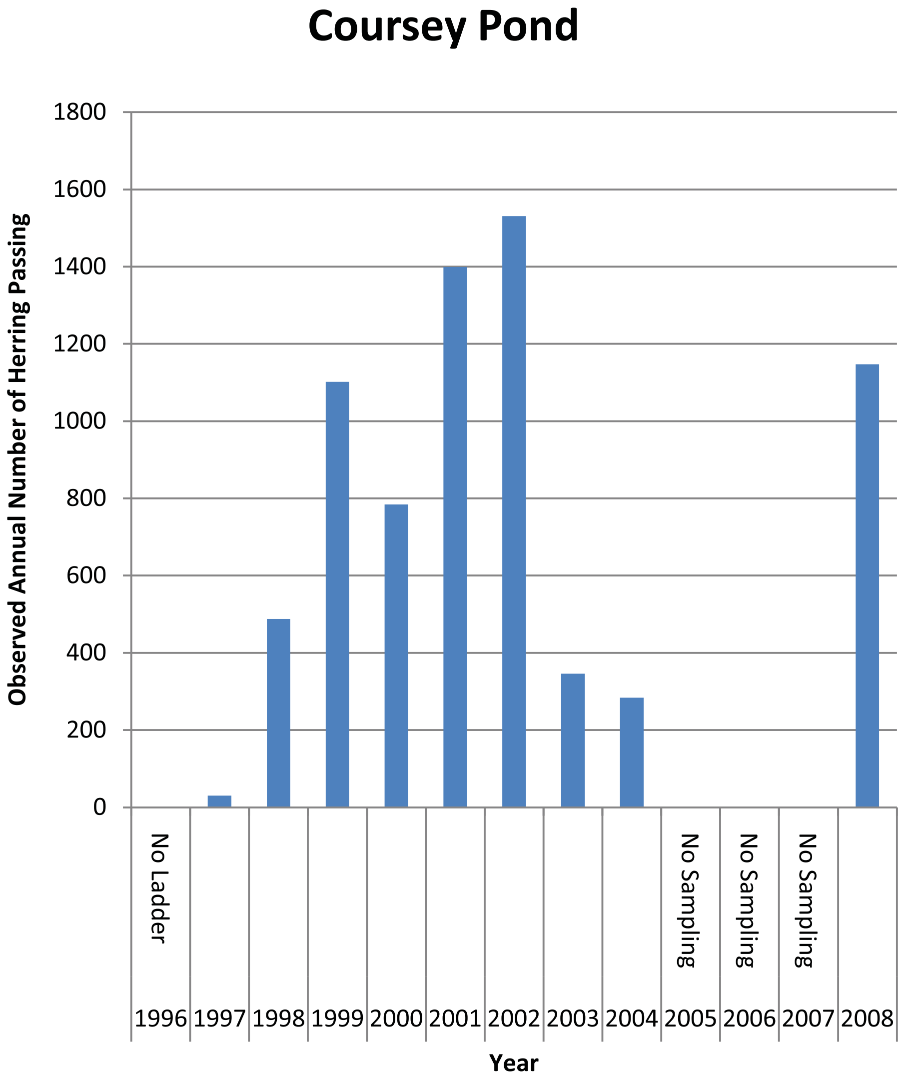

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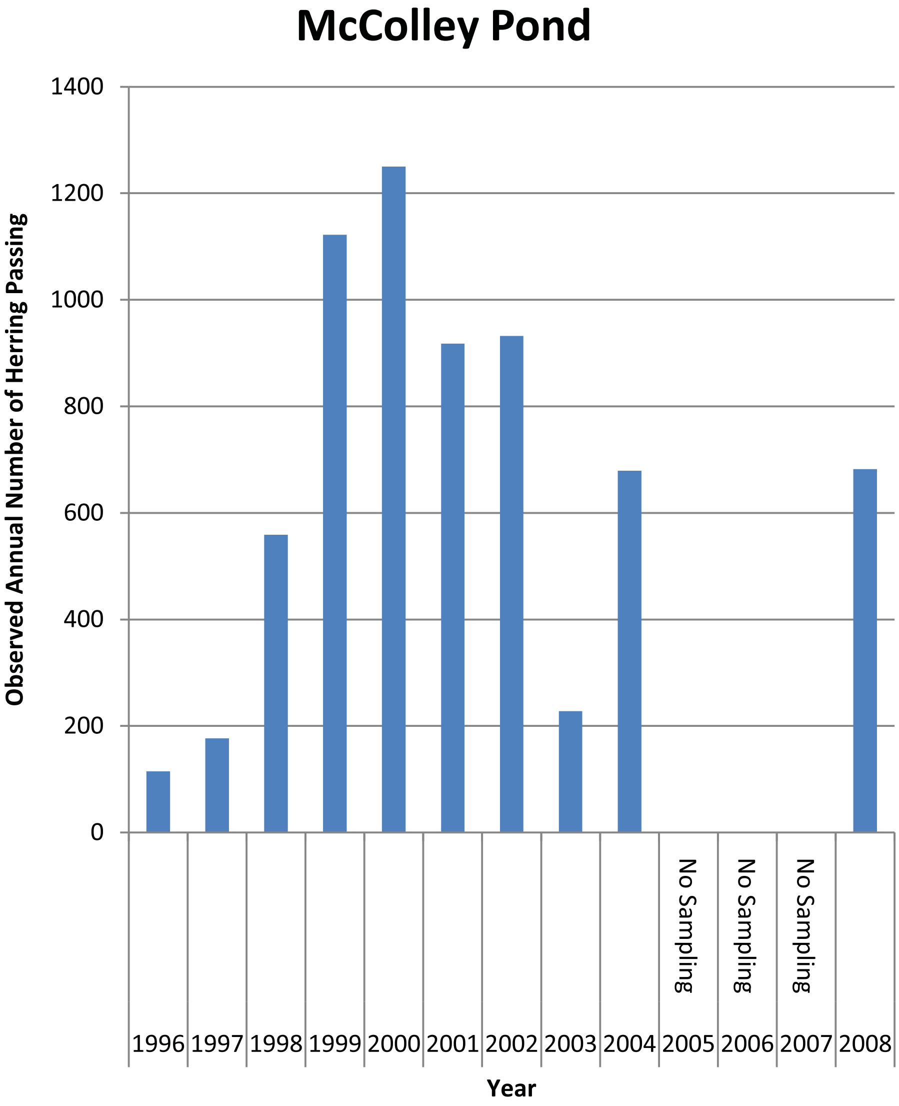

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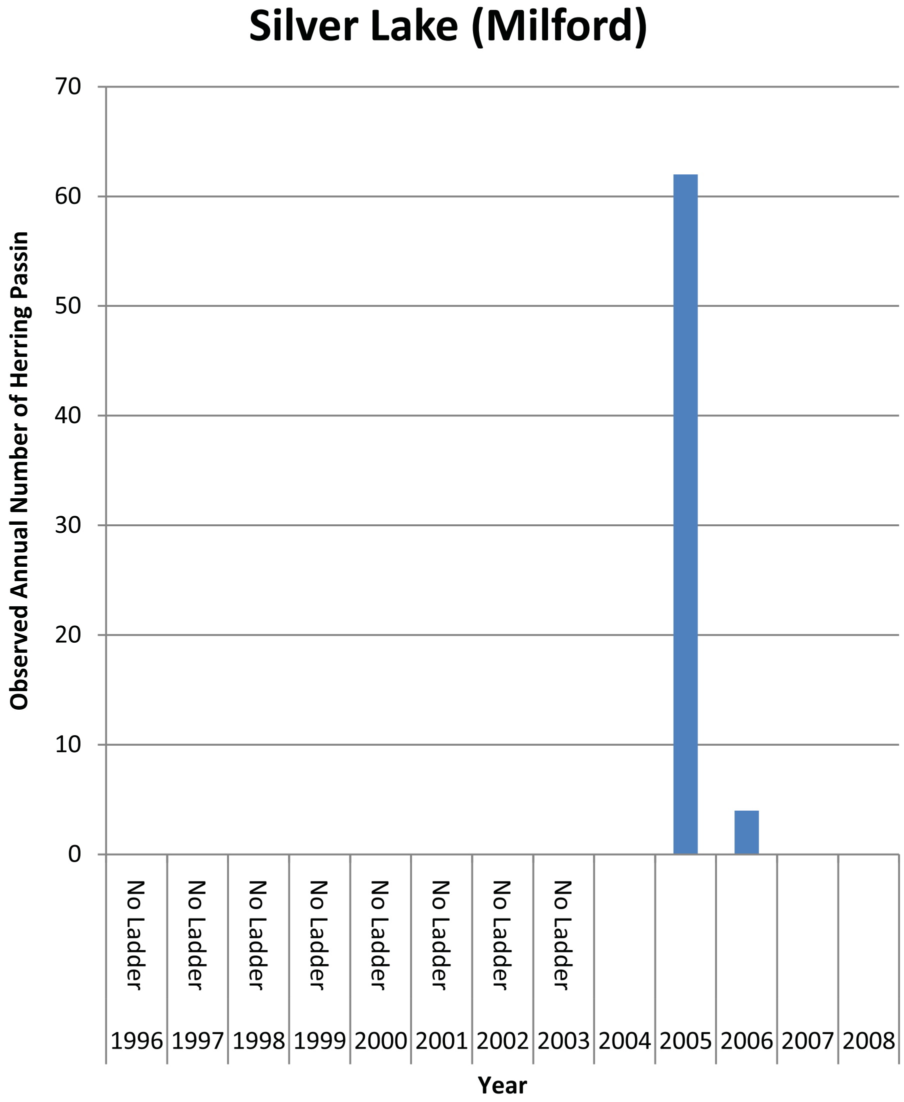

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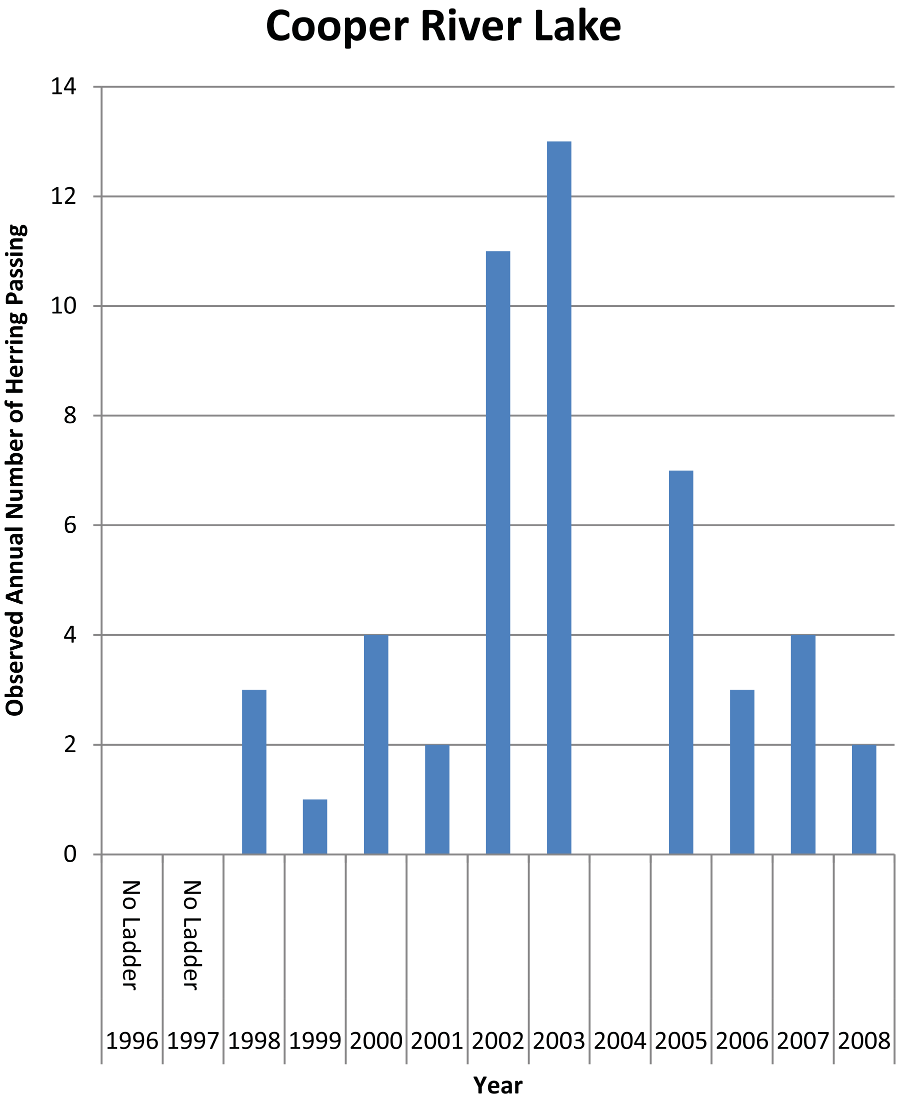

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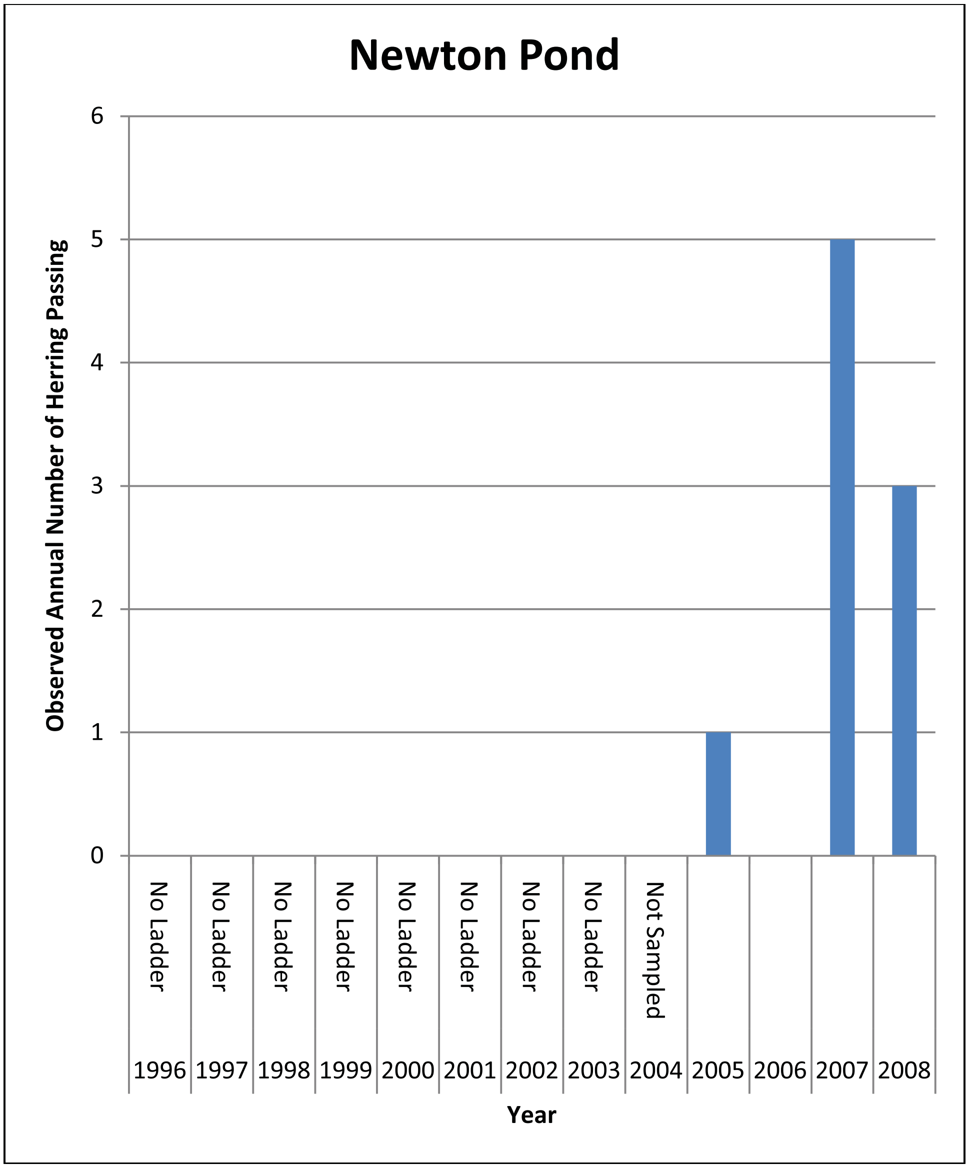

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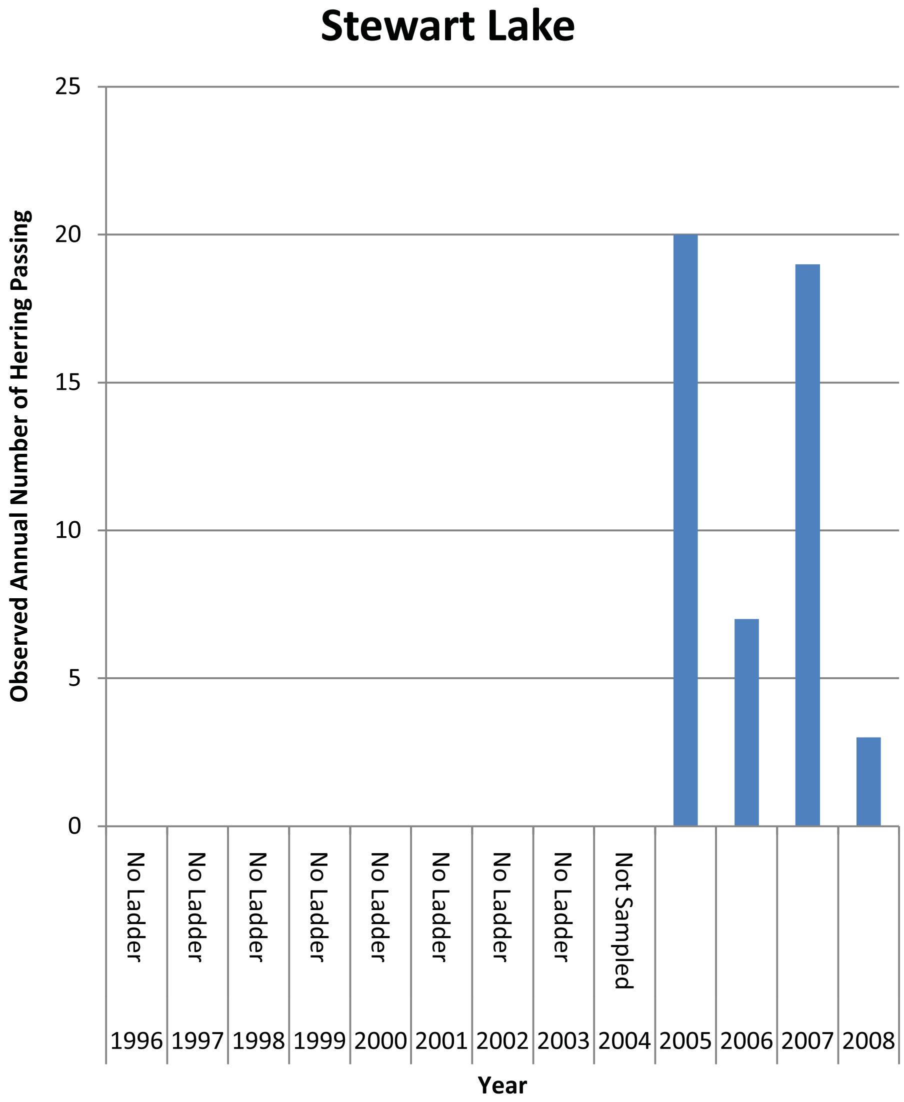

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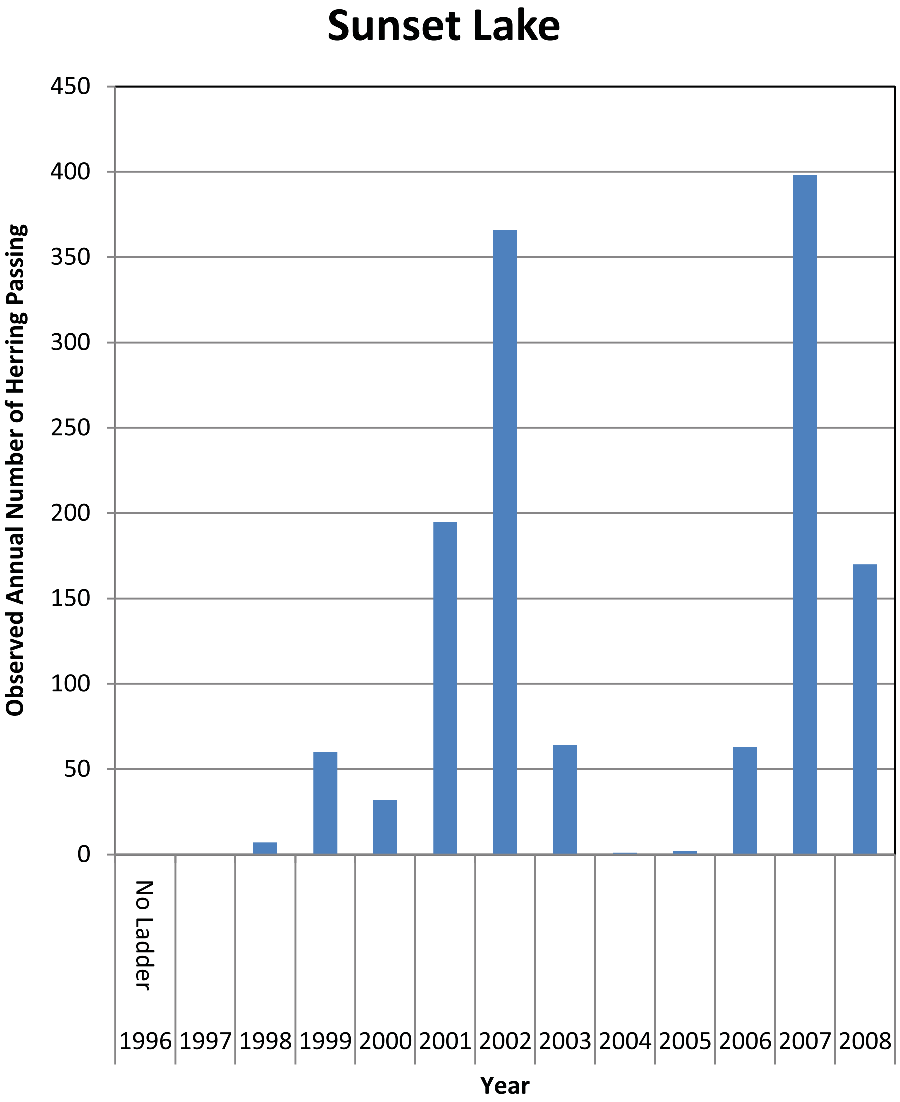

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CHAPTER 7: MARSH RESTORATION PROJECT: FISH ASSEMBLAGE STRUCTURE

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MARSH RESTORATION PROJECT: FISH ASSEMBLAGE STRUCTURE

INTRODUCTION

In July 1994, the New Jersey Department of Environmental Protection (NJDEP) issued the Final NJPDES Permit No. NJ0005622 ("Permit") for the Salem Station. In August 2001, the NJDEP renewed PSEG's Permit; with several Custom Requirements that advanced the restoration and monitoring measures required by the 1994 permit. Specific to marsh fish assemblage monitoring, the 2001 Permit required PSEG to develop and implement an Improved Biological Monitoring Work Plan (IBMWP). The IBMWP requires, among other things, the following studies:

> *Studies of habitat utilization by finfish will be conducted in restored wetlands and the results will be compared to those from reference wetlands. Four representative wetland restoration sites and two reference sites will be sampled from late spring through mid-fall in all years of the permit cycle.*
>
> *Two sampling methods will be employed, trawls and block nets. Trawl samples will be collected monthly at three stations within each marsh/adjacent study area: lower tidal creek, bay/marsh fringe (shoal), and deeper bay (>10 ft). At each of the three stations, three 2-minute tows will be conducted. Fish sampling in upper tidal creeks will employ block nets fished during daylight ebb tides on a monthly basis. All finfish will be identified to the lowest practical taxon and counted. The length of the target species will be measured in a subsample taken from each collection. Data on water temperature, dissolved oxygen, salinity, and turbidity also will be recorded at each sampling location.*

In addition to the IBMWP required monitoring, PSEG has continued weir monitoring of three habitat types within the Alloway Creek watershed to document changes in fish assemblage resulting from the restoration of *Phragmites*-dominated marsh.

The overall long-term objective of this research is to evaluate the effectiveness of restoration activities on faunal response with emphasis on the patterns and processes that control fish utilization and production for restored wetlands in Delaware Bay. More specifically, fish species composition, life history stage, and size are compared across habitat types (large and small marsh creeks) in restored and reference marshes. The target species are weakfish (*Cynoscion regalis*), white perch (*Morone americana*), spot (*Leiostomus xanthurus*), and bay anchovy (*Anchoa mitchilli*), although all fish species, as well as blue crabs (*Callinectes sapidus*), horseshoe crabs (*Limulus polyphemus*), painted turtles (*Chrysemys picta*), and diamondback terrapin turtles (*Malaclemys terrapin*) were included in sampling for a more complete understanding of restoration effects.

These studies of habitat utilization began in 1996 with the initiation of physical marsh restoration efforts, and this is the twelfth annual report in a long term monitoring project (PSE&G 1997-1999b; PSEG 2000-2008). The outline of this report was re-organized in 2007 to present results with a regional perspective. With this perspective, the fish assemblages, sampled in the restoration and reference sites monitored, can be more clearly described as part of respective ecological communities within the estuary. Accordingly, results from the Moores Beach

Reference Marsh and Commercial Township Restoration Site are summarized in the Lower Bay Region section of this report, reflecting the polyhaline (18-35 ppt) portion of the Delaware Estuary. The Mad Horse Creek Reference Marsh and Alloway Creek Restoration Site are summarized in the Upper Region section of this report, reflective of the oligohaline (0.5-5 ppt) portion of the Estuary. Sub-sections within site-specific summaries are as they have been in the previous annual reports.

MATERIALS AND METHODS

STUDY SITES AND SAMPLING FREQUENCY

The monitoring area encompasses two restoration and two reference tidal marsh sites arrayed along the New Jersey shore of Delaware Bay (Figure 7-1). These sites were sampled intensively once a month, from May through November, in daylight, and in coincident to the spring tides (Table 7-1). The intensively sampled sites included the Moores Beach Reference Marsh (Fig. 7-2a and b), the Commercial Township Restoration Site (Fig. 7-3a and b), the Mad Horse Creek Reference Marsh (Fig. 7-4), and the ACW Site, which includes the Alloway Creek (Fig. 7-5), and Mill Creek (Fig. 7-6) Sampling Areas. As previously described, based on their generalized salinity profiles and reference/restoration site characteristics the Moores Beach and Commercial Township sites were grouped into the Lower Bay Region; the Mad Horse Creek, Alloway Creek, and Mill Creek areas were grouped into the Upper Bay Region (Table 7-1). The restoration sites can also be divided broadly into two groups based on the nature of alteration: former salt hay farms adjacent to the lower bay and *Phragmites*-dominated sites adjacent to the upper bay. The Commercial Township Restoration Site, as a former salt hay farm, entailed the creation of higher order marsh creeks and the breaching of earthen dikes to allow a natural tidal inundation cycle to re-establish tidal exchange within the site. Moores Beach, located four miles southeast of the Commercial Township site, was designated as a reference site for the salt hay restoration site. The *Phragmites*-dominated restoration site included the Mill Creek and Alloway Creek areas. At these areas of the ACW site, restoration efforts are ongoing and include a range of measures to remove *Phragmites* and encourage the natural re-vegetation of *S. alterniflora* and other types of vegetation. Mad Horse Creek, located approximately 10 miles south of the ACW site, is the designated reference site for the *Phragmites*-dominated restoration sites. Mad Horse Creek has a minimal disturbance history, and probably represents the more natural marsh condition among the reference sites. Additionally, sampling of the two areas of the ACW site encompassed (within a single salinity/temperature and distance regime) stages of restoration including those dominated by *Phagmites*, areas undergoing restoration that were treated with herbicide, and reference areas dominated by *S. alterniflora.*

SAMPLING TECHNIQUES

Physical and chemical parameters were measured at the beginning of each sample, for all otter trawl and weir samples. From May to November 2008, temperature, dissolved oxygen concentration and salinity were measured with a calibrated hand-held salinity, temperature and oxygen meter (YSI Model 85), by lowering the probe into the water and recording near-surface values. Water transparency was measured by lowering a Secchi disc in the water column until it was no longer visible and recording the corresponding depth in 1.0 inch increments.

Large marsh creeks were sampled using a 4.9 m (16 ft.) semi-balloon otter trawl with 6.0 mm (0.25 inch) cod end mesh. At each site, two large marsh creeks were sampled at three locations: upper, lower, and mouth (e.g., Figure 7-2 a). Sampling took place around high tide, with three two-minute tows per station. The mouth of a creek was defined as its intersection with the next higher order creek. In general, the creek mouth trawling stations are subtidal and the lower and upper stations are shallow subtidal to intertidal. Start and end points for each trawl were recorded using Global Positioning System (GPS) co-ordinates to ensure that identical areas were sampled each month. Tow speed was 1.4 m/s (6 ft/s) and was measured using a Marsh-McBirney, Inc. model 201 flowmeter. All tows were against the current at a constant engine RPM of 1800 (90 hp Honda outboard on 24ft. Carolina Skiff) or 2500 (50 hp Honda outboard on 21ft. Carolina Skiff). Depth was measured at each site using a Hummingbird® Piranha Max 10 depth recorder. The ratio of towline to water depth was maintained at 5:1 with minor adjustments to compensate for current speed and tidal flow. A total of 504 otter trawls were made during the 2008 sampling season (Table 7-1).

The first 20 of each fish species, blue crabs, diamondback terrapins, horseshoe crabs, and painted turtles in each replicate tow were identified, enumerated, and measured separately to the nearest millimeter. Fork length (FL) was recorded for fish species with forked tails; total lengths (TL) were recorded for all other fish. Carapace width (CW) was measured for blue crabs and horseshoe crabs, and carapace length (CL) was recorded for diamondback terrapins and painted turtles. Tentative identifications were finalized and fish ages were determined using Wang and Kernehan (1979), Able and Fahay (1998) and PSE&G (1999a). Individual fishes not identifiable to species were preserved in 95% ethanol or 10% formalin and processed in the laboratory. All fish not preserved for laboratory identification and all turtles were returned to the water at the end of all sampling within a creek reach.

Small intertidal marsh creeks were sampled using weirs 1.8 m x 1.2 m x 1.2 m (6 ft. x 4 ft. x 4 ft.), with 4.5 m x 1.8 m (15 ft. x 6 ft.) wings, 0.175 mm (0.125 inch) mesh set at high tide and hauled at low tide when the creek was drained. At each small intertidal creek sampled, a net was stretched across the channel with support poles embedded vertically in the sediment. Wings were extended back onto the marsh surface from each end of the net, forming a funnel-shaped weir. Wing support poles were embedded in the sediment directly upstream and lashed to the net support poles, and the "leaded" net line was buried in the bottom sediment to eliminate gaps in the weir. Local topography occasionally prevented the complete draining of the small marsh creeks, therefore, any fish remaining in standing pools of water immediately in front of the net were seined into the weir. Fish and blue crabs were identified and enumerated, and up to 50 individuals per species per sample were measured, using the same techniques as for the trawl collections. A total of five sites were sampled monthly using weirs deployed during the day totaling 98 sets (Table 7-1).

DATA ANALYSIS

Species composition and abundances were calculated as percent frequency of occurrence (percent of samples containing each species), percent composition (proportion of individual species to the total number of fish collected), and catch-per-unit-effort (CPUE) (mean numbers of individuals collected per sample). Length frequency distributions were used to interpret age distributions for target species.

RESULTS AND DISCUSSION

LOWER BAY REGION

Physical and Chemical Parameters

Temperature

The pattern in mean water temperature observed in 2008 exhibited the typical seasonal pattern found in a temperate climate (Figure 7-7). Over the period of sampling, mean water temperatures increased from May through July, and then declined through November. Relative to the two Lower Bay Region sites, values were similar throughout the sampling season. Moores Beach values ranged from 10.1°C in November to 28.9°C in July; Commercial Township values ranged from 11.2°C in November to 29.3°C in July.

Salinity

The Lower Bay Region sites mean salinity values, as observed during the 2008 "Marsh Fish Assemblage" sampling season, are presented in Figure 7-7. Generally, over the period of sampling the average salinity in the Lower Bay Region increased from relatively low values in May to a seasonal plateau beginning in August, where values ranged from 21.1 to 22.8 ppt through the remainder of the season. Relative to the two Lower Bay Region sites of Moores Beach and Commercial Township, the mean values of salinity were generally similar. Moores Beach values ranged from 17.1 ppt in June to 22.8 ppt in October; Commercial Township ranged from 16.3 ppt in May to 22.7 ppt in August. The greatest difference in salinity occurred in June when Moores Beach was 1.2 ppt lower than Commercial Township; in all other months the difference was between 0.1 to 0.9 ppt.

Dissolved Oxygen

Monthly mean dissolved oxygen values for the 2008 sampling season are depicted in Figure 7-7. In general, mean dissolved oxygen decreased from May to the seasonal low in July, and then increased through November. Seasonal lows for the Moores Beach and Commercial Township sites occurred in July, at 3.7 and 5.4 mg/L, respectively. However, the seasonal high at Moores Beach occurred in November at 8.2 mg/L. At the Commercial Towship site the seasonal high was recorded in May at 8.6 mg/L. When comparing the values of Moores Beach and Commercial Township, their seasonal trends more or less mimic one another.

Moores Beach Reference Site

General Catch Composition

A total of 4,301 fish, representing 23 species and 16 families, was collected in 126 otter trawl collections and 14 weir sets from May through November 2008 in the Moores Beach reference site (Tables 7-1, 7-2 and 7-3). The species collected were composed primarily of transients (74%), i.e. those that spend a portion of their life history outside of the Delaware Bay, and secondarily of residents (26.0%), i.e. those that spend their entire life history in the Bay. In addition, two invertebrates, i.e., blue crab (n = 517) and horseshoe crab (12), and one reptile, i.e., diamondback terrapin (8), were included in the catches.

Large Marsh Creeks

A total of 1,473 fish, representing 19 species and 14 families, was collected in otter trawl collections during 2008 (Table 7-2 and 7-3). The total CPUE was 11.69. In the aggregate, four species comprised 92% of the total catch, and in order of decreasing abundance they were; Atlantic menhaden (46%), Atlantic croaker (28%), spot (13%), and bay anchovy (5%). While Atlantic menhaden was the most numerically abundant species, Atlantic croaker and spot were collected more frequently, with similarly high frequencies of occurrence in trawl collections of 40 and 38%, respectively. Bay anchovy occurred in 27% of the collections, Atlantic menhaden occurred in 24%, and striped bass occurred in 21% of the collections. No other species occurred in more than 9% of the collections. Striped bass was the only other species collected comprising > 1% of the total catch. Fish abundance in the large marsh creeks, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected by otter trawls, was highest in June with a monthly mean CPUE of 42.50, and CPUE's were ≤16.72 during the other months of sampling (Fig. 7-8). When viewed from a monthly perspective, species composition and predominance data illustrates a dynamic progression of species utilization underlying the aggregate data (Figure 7-9). Each of the following species comprised ≥51% of the total catch in their respective months; Atlantic menhaden in June, spot in July, and Atlantic croaker in October.

Small Marsh Creeks

A total of 2,828 fish, representing 10 species and seven families, was collected in weir sets during 2008 (Table 7-2 and 7-3). The total CPUE was 202.00. Two species comprised 99% of the total catch, and in order of decreasing abundance they were; mummichog (73%) and Atlantic silverside (26%). Mummichog occurred in all of the weir sets, and Atlantic silverside was taken in 64% of the sets. All other species occurred in ≤ 14% of the collections. Fish abundance in the small marsh creeks, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected by weir, was highest in August with a monthly mean CPUE of 518.00, and mummichog was the predominant species comprising 76% (Figure 7-8 and 7-9). Mummichog comprised 100% of the catch in May and June, and was the predominant species during all months of sampling. Atlantic silversides comprised 44% of the catch in September, in its highest month of occurrence (Figure 7-9).

Commercial Township Restoration Site

General Catch Composition

A total of 6,452 fish, representing 20 species and 15 families, was collected in 126 otter trawl collections and 14 weir sets from May through November 2008 in the Commercial Township restoration site (Tables 7-1, 7-2 and 7-4). The species collected were composed primarily of transients (65%), and secondarily of residents (35%). In addition, two invertebrates, i.e., blue crab (n = 385) and horseshoe crab (35), and one reptile, i.e., diamondback terrapin (8), were included in the catches.

Large Marsh Creeks

A total of 4,577 fish, representing 16 species and 11 families, was collected in otter trawl collections during 2008 (Table 7-2 and 7-4). The total CPUE was 36.33. Three species comprised 93% of the total catch, and in order of decreasing abundance they were; bay anchovy (54%), Atlantic croaker (22%), and spot (17%). All other species collected individually comprising ≤ 3% of the total fish catch. While, bay anchovy was the numerically abundant species, Atlantic croaker was the species most frequently taken, occurring in 59% of the trawl collections. Spot, bay anchovy, and weakfish, were represented in the catch at relatively high frequencies of 44, 38, and 23%, respectively. No other species occurred in more the 15% of the collections. Fish abundance in the large marsh creeks, decreased each month from May to July, followed by a seasonal high in August with a monthly mean CPUE of 73.17, CPUE decreased in September, then rose slightly in October and November (Figure 7-10). Spot was the predominant species in May and June comprising 57 and 46% of the catch, respectively. Bay anchovy was the predominant species in August, September and October, comprising 90, 96 and 97% of the catch, respectively. In July and November Atlantic croaker was the predominant species comprising 41 and 68 % of the catch, respectively (Figure 7-11).

Small Marsh Creeks

A total of 1,875 fish, representing nine species and six families, was collected in weir sets during 2008 (Table 7-2 and 7-4). The total CPUE was 133.93. Four species comprised 90% of the total fish catch, and in order of decreasing abundance they were; mummichog (45%), Atlantic silverside (19%), spot (15%), and bay anchovy (11%). Mummichog was taken in 86% of the weir sets, and Atlantic silverside occurred in 71% of the sets. Spot and black drum were taken in 50 and 43% of the sets, respectively. No other species occurred in more the 29% of the collections. Fish abundance in the small marsh creeks was highest in August with a monthly mean CPUE of 396.50 (Figure 7-10). Abundance was lowest in November, with a monthly mean CPUE of 14.50. Each of the following species comprised ≥52 % of the total catch in their respective months; spot in May and June, Atlantic silverside in July and September, and mummichog in August and November (Figure 7-11).

Target Species Accounts for the Lower Bay Region

Bay anchovy

In the large marsh creeks of the Lower Bay Region, bay anchovy comprised 5 and 54% of the total catch at the Moores Beach Reference and Commercial Township Restoration Sites, respectively, occurring in 27 and 38% of the respective otter trawl collections (Tables 7-3 and 7-4). At Moores Beach a total, of 73 individuals, was collected and their mean CPUE for the study period was 0.58. At Commercial Township a total, of 2,478, was taken and the CPUE was 19.67. Bay anchovy was collected at Moores Beach during all months except June. Bay anchovy abundance was highest in November at 1.72, and was intermediately high in May and August with CPUE's of 0.89 and 0.94, respectively. In all other months of sampling CPUE's were ≤0.28 (Figure 7-12). At Commercial Township, bay anchovy abundance was highest in August with a CPU of 65.61. Their abundance was secondarily high in October at 37.94; CPUE's were ≤20.67 in all other months of sampling. Individuals collected at Moores Beach ranged from 13 to 73 mm FL (Figure 7-13). All specimens collected in May were age 1+; all specimens collected in August and November were age 0+. Individuals collected at Commercial Township ranged from 18 to 88 mm FL (Figure 7-14). All specimens measured in May and June were age 1+. During July through November age 0+ were predominant comprising from 98 to 100% of the specimens measured. During July 60% of the specimens measured were 43 and 58 mm FL; in August 57% were 23 and 28mm; in September 68% were 28 and 33 mm; in October 52% were 33 and 38 mm; and in November 48% were 33 to 38mm.

In the small marsh creeks of the Lower Bay Region, two bay anchovy were collected at the Moores Beach Reference Site and 209 were taken at the Commercial Township Restoration Site (Tables 7-3 and 7-4). At the Moores Beach site, the mean CPUE for the study period for bay anchovy was 0.14. The fish were collected in October, the monthly mean CPUE was 1.00, and they were age 0+ at 48 and 58 mm FL (Figures 7-13 and 7-15). At the Commercial Township Restoration Site bay anchovy occurred in 29% of the weir collections. Bay anchovy was collected at Commercial Township only during September and October with CPUE's of 21.50 and 83.00, respectively. Individuals collected at Commercial Township ranged from 23 to 83 mm FL; age 0+ were predominant in both months. In September, 65% were 23 and 28 mm; and in October, 51% were 28 and 33 mm FL (Figures 7-13 and 7-14).

Spot

In the large marsh creeks of the Lower Bay Region, spot comprised 13 and 17% of the total catch at the Moores Beach Reference and Commercial Township Restoration Sites, respectively, occurring in 38 and 44% of the respective otter trawl collections (Tables 7-3 and 7-4). At Moores Beach, a total of 197 spot was collected, and their mean CPUE for the study period was 1.56. At Commercial Township, a total of 762 was taken and the CPUE was 6.05. At Moores Beach, spot abundance increased from 1.34 in May to a peak of 4.78 in July, and declined thereafter (Figure 7-16). Spot abundance was highest at Commercial Township in May with a CPUE of 30.22, and it steadily declined through November. Individuals collected at Moores Beach ranged from 23 to 163 mm TL , and all but one were age 0+ (Figure 7-17). During May, 46% of the specimens measured were 43 and 48 mm TL; in June, 37% were 63 and 68 mm; and in July 31% were 93 and 98 mm. Individuals collected at Commercial Township ranged from 23 to 163 mm TL, and all but nine were age 0+ (Figure 7-18). During May, 44% of the specimens measured were 43 and 48 mm TL; in June 39% were 63 to 73 mm; and in July 36% were 88 to 98 mm.

In the small marsh creeks of the lower bay region, spot comprised <1% and 15% of the total catch at the Moores Beach Reference and Commercial Township Restoration Sites, respectively, occurring in 14 and 50% of the respective weir collections (Tables 7-3 and 7-4). At Moores Beach, a total of 24 spot was collected, and their mean CPUE for the study period was 1.71. At Commercial Township, a total of 283 was taken and the CPUE was 20.21. Spot abundance was highest at Moores Beach in July with a CPUE of 8.00 (Figure 7-19). At Commercial Township, spot was most abundant in June with a CPUE of 70.50. Individuals collected at Moores Beach ranged from 93 to 133 mm TL (Figure 7-17). Individuals collected at Commercial Township ranged from 23 to 138 mm TL (Figure 7-18). All spot collected in the small marsh creeks of the lower bay region were age 0+.

Weakfish

In the large marsh creeks of the Lower Bay Region, weakfish comprised 1 and 3% of the total catch at the Moores Beach Reference and Commercial Township Restoration Sites, respectively, occurring in 9 and 23% of the respective otter trawl collections (Tables 7-3 and 7-4). At Moores Beach, a total of 17 individuals was collected, and their mean CPUE for the study period was 0.13. While at Commercial Township, a total of 140 was taken, and the CPUE was 1.11. At Moores Beach, weakfish was collected in July through October, with the peak in abundance occurring in August through September with identical CPUE's of 0.28 (Figure 7-20). However at Commercial Township, weakfish was collected June through September with a seasonal peak in abundance in June at 3.72, followed by a secondary peak at 3.50 in August. Individuals collected at Moores Beach ranged from 23 to 103 mm TL, and all were age 0+ (Figure 7-21). Individuals collected at Commercial Township ranged from 13 to 173 mm TL; all were age 0+ (Figure 7-22). During July, individuals ranging from 33 to 43 mm TL comprised 34% of the specimens measured; during August 57% of the individuals measured ranged from 28 to 43 mm TL. No weakfish were taken in the small marsh creeks of the Lower Bay Region.

White perch

In the large marsh creeks of the Lower Bay Region, white perch comprised <1% of the total catch at both the Moores Beach Reference and Commercial Township Restoration Sites, occurring in 7 and 11% of the respective otter trawl collections (Tables 7-3 and 7-4). At Moores Beach, a total of 9 individuals was collected and their mean CPUE for the study period was 0.07. At Commercial Township, a total of 30 was taken, and the CPUE was 0.24. At Moores Beach, white perch was collected in June, July, October, and November (Figure 7-23). The mean monthly CPUE was highest in June at 0.17. In months to follow, the CPUE decreased to 0.11. At Commercial Township, white perch was collected during all months of sampling, except September and October. Their abundance was highest during November at 0.83, abundance in all other months was ≤0.33. Individuals collected at Moores Beach ranged from 113 to 258 mm FL; all were age 1+ or older, possibly including individuals age 8+ (Figure 7-24). Individuals collected at Commercial Township ranged from 128 to 263 mm FL; all but one were age 1+ or older and maybe including individuals age 8+ (Figure 7-25).

In the small marsh creeks of the Lower Bay region, no white perch were caught at the Commercial Township Restoration Site. At Moores Beach Reference Site, one individual was collected, comprising <1% of the total catch, and the mean CPUE for the study period was 0.07. The mean monthly CPUE for September, the only month that white perch were collected was 0.5. The individual collected at Moores Beach was 198 mm FL (Table 7-3 and Figure 7-26).

Effects of Restoration at Lower Bay Salt Hay Farms

Abundance of all species collected in the large marsh creeks of the lower bay was 3.2 times greater at the Commercial Township Restoration Site (CPUE = 36.33) than at the Moores Beach Reference Site (11.69) (Tables 7-3 and 7-4; Figure 7-27). This difference was largely the result of the predominance of bay anchovy at the Commercial Township Site. If the bay anchovy contribution to total CPUE is subtracted from both sites, then the resulting aggregate CPUE's for all other species is more similar, 11.11 at Moores Beach and 16.66 at Commercial Township. The remaining difference in overall fish abundance may be attributed to the higher abundance of the target species, weakfish and spot, and the non-target species, Atlantic croaker and hogchoker at Commercial Township. The abundance of weakfish was 8 times greater at Commercial Township (1.11) than at Moores (0.13), and spot were four times more abundant, with respective CPUE's of 6.05 and 1.56. White perch were equally abundant at both sites, with respective CPUE's of 0.24 and 0.07. The abundance of the non-target species listed above ranged from 2 to 3 times higher at Commercial Township than at Moores Beach.

Fish species richness in trawls was similar at both sites with 19 species at Moores Beach and 16 at Commercial Township (Figure 7-27). There were 13 species common to both sites, though differing in rank order. Those species taken exclusively at one site or the other were incidental to infrequent captures represented by < 10 individuals. The top seven species at the two sites had six species in common; Atlantic croaker, spot, weakfish, Atlantic menhaden, bay anchovy, and hogchoker. Atlantic menhaden was ranked first at Moores Beach and fifth at Commercial Township; Atlantic croaker was ranked second at Moores Beach and Commercial Township; spot was ranked third at Moores Beach and Commercial Township; bay anchovy ranked fourth at Moores Beach and first at Commercial Township; weakfish ranked sixth at Moores Beach and fourth at Commercial Township; and hogchoker ranked seventh at Moores Beach and sixth at Commercial Township. Other species of note include striped bass which ranked fifth at Moores Beach and eighth at Commercial Township; and white perch which ranked eighth at Moores Beach and seventh at Commercial Township.

Abundance of all species collected in the small marsh creeks of the lower bay was generally similar at the Moores Beach Reference Site (CPUE = 202.00) and at the Commercial Township Restoration Site (133.93) (Tables 7-3 and 7-4; Figure 7-27). Fish species richness was similiar at both sites with ten species at Moores Beach and nine species at Commercial Township. There were seven species common to both sites, though differing somewhat in rank order. Mummichog and Atlantic silverside ranked first and second at both sites, respectively. Other species of note included spot ranking third at both Moores Beach and at Commercial, black drum ranking fourth at Moores Beach and seventh at Commercial, and bay anchovy ranking third at Commercial but only two individuals were taken at Moores Beach, Atlantic menhaden ranked fifth at Commercial, but was not taken at Moores Beach, and Atlantic croaker ranking sixth at Commercial, but it also was not taken at Moores Beach. The catches of the other species were ≤2 individuals, making their occurrences more or less incidental.

UPPER BAY REGION

Physical And Chemical Parameters

Temperature

The pattern in mean water temperature observed in 2008 exhibited the typical seasonal pattern found in a temperate climate (Figure 7-28). Over the period of sampling, in the upper bay region, mean water temperatures generally increased from May through July, and then generally declined through November. Monthly differences in mean water temperature among sites during the sampling season ranged from 0.4 °C in August to 2.5°C in September. Monthly regional low and high mean water temperature was not recorded consistently at any one site. Site-specific maximum and minimum values were recorded in July and November, respectively, at all sites. Mad Horse Creek minimum and maximum values ranged from 10.8 to 28.1°C; Alloway Creek ranged from 12.40 to 28.0 °C; Mill Creek ranged from 10.1 to 28.6 °C.

Salinity

The upper bay region mean salinity values, as observed during the 2008 "Marsh Fish Assemblage" sampling season, are presented in Figure 7-28. Mean salinity at Mad Horse Creek, a designated upper bay site but geographically intermediate, was always higher than the other two sample areas, ranging from a low of 8.2 ppt in May to a high of 15.1 ppt in October. Over the period of sampling at the Alloway Creek and Mill Creek areas, mean salinity values generally increased from May through October, then slightly decreased in November. Through the sampling period, mean salinity at Alloway Creek ranged from 2.9 ppt in May to 8.7 ppt in October, and at Mill Creek it ranged from 2.1 ppt in May to 7.5 ppt in October. Observed mean salinities were generally lowest at Mill Creek.

Dissolved Oxygen

Monthly upper bay region sites mean dissolved oxygen values for the 2008 sampling season are depicted in Figure 7-28. There were no clear overall trends in mean dissolved oxygen values at all three sites. At Mad Horse Creek values generally decreased from May to August, then increased to a seasonal high in November. In contrast the seasonal peak at Alloway Creek was reached in May, then values decreased through September and reached a secondary peak in October. The seasonal high mean dissolved oxygen value occurred in July at Mill Creek. At Mad Horse Creek, mean dissolved oxygen ranged from 5.4 to 9.0 mg/L; at Alloway Creek it ranged from 5.3 to 9.4 mg/L; and at Mill Creek it ranged from 5.2 to 10.2 mg/L.

Mad Horse Creek Reference Site

General Catch Composition

A total of 1,017 fish, representing 20 species and 12 families, was collected in 126 otter trawl collections and 14 weir sets from May through November 2008 in the Mad Horse Creek Reference Site (Tables 7-1, 7-2, and 7-5). Most species collected were transients (70%), i.e. those that spend a portion of their life history outside of the Delaware Bay, and the remaining species were residents (30%), i.e. those that spend their entire life history in the Bay. In addition, one invertebrate, i.e., blue crab (n = 463) and one reptile, i.e., diamondback terrapin (3), were included in the catches.

Large Marsh Creeks

A total of 900 fish, representing 19 species and 11 families, was collected in otter trawl collections during 2008 (Table 7-5). The total CPUE was 7.14. In the aggregate, six species comprised 85% of the total catch. Bay anchovy and spot comprised nearly half of the catch at 28 and 17%, respectively, and they were commonly taken, occurring in 52 and 35% of the trawl collections, respectively. The other four species of note were, in order of decreasing abundance, Atlantic menhaden (14%), white perch (11%), hogchoker (8%), and Atlantic croaker (7%). White perch were commonly taken occurring in 41% of the collections, however no other species occurred in >24% of the collections. Fish abundance in the large marsh creeks at the Mad Horse Creek site, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected by otter trawls, was highest in July with a CPUE of 10.22 (Fig. 7-29). A similar secondary peak was recorded in May at 10.00. As the aggregate data above indicated, bay anchovy was clearly predominant species. On a monthly basis, bay anchovy was the predominant species in September and October comprising 70 and 48% of the total catch, respectively. However in the other months, no species comprised > 38% of the catch (Figure 7-30).

Small Marsh Creeks

A total of 117 fish, representing seven species and seven families, was collected in weir sets during 2008 (Table 7-5). The total CPUE was 8.36. Two species comprised 86% of the total catch. They were mummichog (60%) and Atlantic menhaden (26%). Mummichog occurred in 57% of the weir sets, however Atlantic menhaden occurred in only 7% of the weir sets. Other species occurring in 21% of the collections were bay anchovy and naked goby. Fish abundance in the small marsh creeks at the Mad Horse Creek site, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected in weir sets, was highest in May at 24.00, secondarily high in November at 20.00, and relatively stable but lower during June through October, with CPUE's ranging from 0.50 to 7.00 (Fig. 7-29). Given the relatively low total catch (n=117), no clearly predominant species can be meaningfully identified (Figure 7-30).

Alloway Creek Watershed Restoration Site – Alloway Creek Sampling Area

General Catch Composition

A total of 1,192 fish, representing five species and five families, was collected in 42 weir sets from May through November 2008 in the Alloway Creek Sampling Area (Tables 7-1, 7-2 and 7-6). The representation of transient and resident species was two and three, respectively. In addition, one invertebrate, i.e., blue crab (n = 38) was included in the catches. The total CPUE was 28.38. Mummichog comprised 86% of the total catch, and occurred in 95% of the weir sets. Atlantic menhaden comprised 12% of the total catch, and occurred in 2% of the weir sets. All other species were represented by eight specimens or less, and occurred in no more than 10% of the sets. Fish abundance in the small marsh creeks at the Alloway Creek area, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected in weir sets, was highest in

September, with a CPUE of 64.33 (Fig. 7-31). During the other months of sampling, CPUE ranged from 3.50 to 38.67. In May, Atlantic menhaden comprised 64% of the catch. Mummichog was the predominant species for all other months at the Alloway Creek Sampling Area, comprising from 90 to 100% of the catch (Figure 7-32).

Alloway Creek Watershed Restoration Site – Mill Creek Sampling Area

General Catch Composition

A total of 7,748 fish, representing 21 species and 12 families, was collected in 126 otter trawl collections and 14 weir sets from May through November 2008 in the Mill Creek Sampling Area (Tables 7-1, 7-2, and 7-7). Most species collected were transients (57%), i.e. those that spend a portion of their life history outside of the Delaware Bay, and the remaining species were residents (43%), i.e. those that spend their entire life history in the Bay. In addition, one invertebrate, i.e., blue crab (n = 141) and two reptiles, i.e., diamondback terrapin (4), and painted turtle (1), were included in the catches.

Catch in Large Marsh Creeks

A total of 3,193 fish, representing 20 species and 11 families, was collected in otter trawl collections during 2008 (Table 7-7). The total CPUE was 25.34. Three species comprised 81% of the total catch. They were white perch (36%), bay anchovy (24%), and spot (21%). White perch, the most numerically abundant species, was also collected most frequently, occurring in 70% of the trawl collections. Spot and bay anchovy were taken in 63 and 51% of the collections, respectively. All other species individually comprised ≤ 8% of the catch, and occurred in ≤ 37% of the collections. Fish abundance in the large marsh creeks at the Mill Creek area, as expressed by monthly catch-per-unit-effort (CPUE) for all fish collected by otter trawls, was highest in June at 35.22; it declined thereafter to 14.11 in September; then increased to 25.94 in October (Fig. 7-33). Spot was the dominant species during the temporal peak in June, comprising 60% of the total catch (Figure 7-34). White perch was the predominant species in May and August, comprising 53 and 55% of the total catch, respectively. Two species comprised 56% of the total catch in October; they were white perch and bay anchovy at 31 and 25%, respectively.

Catch in Small Marsh Creeks

A total of 4,555 fish, representing 14 species and 12 families, was collected in weir sets during 2008 (Table 7-7). The total CPUE was 325.36. Mummichog comprised 81% of the total catch, and occurred in 100% of the weir sets. All other species individually comprised ≤ 7% of the catch. While collected in relatively low numbers, Atlantic silverside, white perch and brown bullhead were commonly taken, occurring in 79, 64 and 57%, respectively. Fish abundance in the small marsh creeks at the Mill Creek area was secondarily high in July with a CPUE of 757.00; it was highest in August at 786.00; and it decreased thereafter to 5.50 in November (Fig. 7-33). Mummichog was the predominant species during all months except May and October. During their months of predominance, they comprised from 72 to 96% of the catch (Figure 7-34). Atlantic menhaden comprised 80% in May, and no species comprised > 22% of the total catch in October.

Target Species Accounts for the Upper Bay Region

Bay Anchovy

In the large marsh creeks of the Upper Bay Region, bay anchovy comprised 28 and 24% of the total catch at the Mad Horse Creek Reference Site and Mill Creek Area of the Alloway Creek Restoration Sites, respectively, occurring in 52 and 51% of the respective otter trawl collections (Tables 7-5 and 7-7). At Mad Horse Creek, a total, of 256 individuals, was collected and their mean CPUE for the study period was 2.03. At Mill Creek, a total of 752 was taken, and the CPUE was 5.97. Bay anchovy was collected in all months of sampling at Mad Horse, and abundance was highest in September with a CPUE of 4.50 (Figure 7-35). During the other months of sampling CPUE was ≤3.33. Similarly at Mill Creek, bay anchovy was collected in all months of sampling. Their abundance was highest at 13.06 during July, and the CPUE was ≤7.78 in the other months of sampling. Individuals collected at Mad Horse Creek ranged from 23 to 83 mm FL (Figure 7-36). All specimens collected in May and June were age 1+ and older. Age 0+ were predominant in July through September and November, comprising from 71 to 100% of the specimens measured. During October, when abundance was highest, age composition was equally divided between age 0+ and age 1+. Individuals 53 to 68 mm FL comprised 72% of the specimens measured in October. Individuals collected at Mill Creek ranged from 18 to 63 mm FL (Figure 7-37). All specimens measured in May and June were age 1+ and older. Age 0+ were predominant in July through November, comprising from 97 to 100% of the specimens measured. In July, when abundance was high at Mill Creek, specimens 28 and 33 mm FL comprised 72% of the specimens measured. In September, when abundance also was high at Mill Creek, specimens 33 and 48 mm FL comprised 80%.

No bay anchovy were collected in the small marsh creeks at the Alloway Creek Area of the Upper Bay Region during 2008. Bay anchovy comprised 3 and <1% of the total catch at the Mad Horse Creek Reference Site, and the Mill Creek Area within the Alloway Creek Restoration Site, respectively, occurring in 21 and 29% of the respective weir sets at both locations (Tables 7-5, 7-6 and 7-7). At Mad Horse Creek, a total of four individuals was collected, and their mean CPUE for the study period was 0.29. At the Mill Creek Area, a total 28 was collected, and the CPUE was 2.00. At Mad Horse Creek, bay anchovy were collected only in May and November with CPUE's of 0.50 and 1.50, respectively (Figure 7-38). At Mill Creek, bay anchovy were collected in July, September, and October, with the highest CPUE of 12.00 in October. Individuals collected at Mad Horse Creek ranged from 43 to 53 mm FL, and those individuals collected at Mill Creek ranged from 28 to 43 mm FL (Figures 7-36 and 7-37). Two of the bay anchovy collected in weir sets in the small marsh creeks of the Upper Bay Region were age 1+, all others were age 0+.

Spot

In the large marsh creeks of the Upper Bay Region, spot comprised 17 and 21% of the total catch at the Mad Horse Creek Reference and Mill Creek Area of the Alloway Creek Restoration Sites, respectively, occurring in 35 and 63% of the respective otter trawl collections (Tables 7-5 and 7-7). At Mad Horse Creek, a total of 153 spot was collected and their mean CPUE for the study period was 1.21. At Mill Creek, a total of 659 was taken, and the CPUE was 5.23. At Mad Horse Creek, spot were collected in all months; CPUE was highest in May at 3.61, declining thereafter

(Figure 7-39). At Mill Creek, spot were collected during May through October. Abundance peaked in June at 21.22, and CPUE was ≤5.11 in the other months of their occurrence. Individuals collected at Mad Horse Creek ranged from 23 to 158 mm FL, and all but one specimen was age 0+ (Figure 7-40). Individuals collected at Mill Creek ranged from 23 to 163 mm FL, and all but seven individuals were age 0+ (Figure 7-41).

No spot were collected in the small marsh creeks at the Alloway Creek Area of the Upper Bay Region during 2008. Spot comprised 2 and <1% of the total catch at Mad Horse Creek Reference and Mill Creek Area of the Alloway Creek Restoration Sites, respectively, occurring in 14 and 43% of the respective weir collections. At Mad Horse Creek, a total of two spot were collected and their mean CPUE for the study period was 0.14. Individuals collected at Mad Horse Creek were 33 and 118 mm TL, and were only collected in May and October with a monthly CPUE of 0.5 in both months. At Mill Creek in July through October a total of 39 spot was taken, and the CPUE was 2.79. Individuals collected at Mill Creek ranged from 68 to 148 mm TL; abundance was highest in July with a CPUE of 9.5; abundance was secondarily high in October with a CPUE of 7.00; and CPUE was ≤2.00 in all other months of occurrence (Figures 7-41 and 7-42).

Weakfish

In the large marsh creeks of the Upper Bay Region, weakfish comprised 3 and <1% of the total catch at the Mad Horse Creek Reference and Mill Creek Area of the Alloway Creek Restoration Sites, respectively, occurring in 12 and 10% of the respective otter trawl collections (Tables 7-5 and 7-7). At Mad Horse Creek, a total of 23 weakfish was collected and their mean CPUE for the study period was 0.18. At Mill Creek, a total of 16 was taken, and the CPUE was 0.13. At Mad Horse Creek, weakfish were collected June through October, and the CPUE was highest in July at 0.39 (Figure 7-43). At Mill Creek, weakfish were collected July through October; CPUE was highest in July at 0.50. Individuals collected at Mad Horse Creek ranged from 18 to 153 mm FL (Figure 7-44). Individuals collected at Mill Creek ranged from 78 to 133 mm FL, (Figure 7-45). All weakfish measured were age 0+. No weakfish were taken in the small marsh creeks of the Upper Bay Region.

White perch

In the large marsh creeks of the Upper Bay Region, white perch comprised 11 and 36% of the total catch at the Mad Horse Creek Reference and the Mill Creek Area of the Alloway Creek Restoration Sites, respectively, occurring in 41 and 70% of the respective otter trawl collections (Tables 7-5 and 7-7). At Mad Horse Creek, a total of 100 individuals were collected and their mean CPUE for the study period was 0.79. At Mill Creek, a total of 1,134 was taken, and the CPUE was 9.00. White perch were collected in all months of sampling at Mad Horse, and abundance was highest in May with CPUE of 1.72 (Figure 7-46). During the months to follow, CPUE decreased to a low of 0.11 in August, and then increased to similar secondary fall peaks of 1.22 and 1.44 during October and November, respectively, suggestive of a seasonally bimodal temporal distribution. At Mill Creek, white perch also were collected in all months of sampling. CPUE was high in May at 11.89, decreased to 5.60 in June, then rose to the seasonal high of 15.00 in August, declined to 2.61 in September, and then increased to a fall peak of 9.61 in November. Individuals collected at Mad Horse Creek ranged from 83 to 268 mm FL; all specimens measured were age 1+ or older, possibly including individuals age 8+ (Figure 7-47). During May, when abundance was highest, individuals 83 to 103 mm FL comprised 32% of the specimens measured. During October and November, when abundance was secondarily and similarly high, individuals 168 to 198 mm FL and 168 to 193 mm FL comprised 72 and 69% of the specimens measured, respectively. Individuals collected at Mill Creek ranged from 23 to 238 mm FL (Figure 7-48). Similar to Mad Horse Creek, age 1+ and older individuals appear to be predominant at Mill Creek. However unlike Mad Horse Creek, age 0+ individuals were represented in the Mill Creek catch. During May and November, when abundance was similarly high, individuals 23 to 83 mm FL (probably age 0+) comprised 41 and 31% of the specimens measured, respectively.

No white perch were collected in the small marsh creeks at the Mad Horse Creek Reference Site. In the small marsh creeks of the Upper Bay Region, white perch comprised <1 and 2% of the total catch at the Alloway and Mill Creek Areas within the Alloway Creek Restoration Site, respectively; occurring in 7 and 64% of the respective weir sets (Tables 7-5, 7-6 and 7-7). At the Alloway Creek Area, a total of five white perch was taken, and the CPUE was 0.12. At the Mill Creek Area, a total of 100 was collected, and the CPUE was 7.14 (Figure 7-49). At Alloway Creek, they were collected only in June, October, and November with respective CPUE's of 0.17, 0.50, and 0.17. At Mill Creek, white perch were collected in May through October. Their abundance was highest in July with a CPUE of 24.50, abundance was secondarily high in October at 12.00, and CPUE was ≤6.50 in the other months of their occurrence. Individuals collected at Alloway Creek ranged from 93 to 183 mm FL, and all were age 1+. Those collected at Mill Creek ranged from 48 to 163 mm FL, and were predominantly age 1+ (Figures 7-47, 7-48 and 7-50).

Effects of Restoration at Upper Bay *Phragmites*-Dominated Marshes

Abundance of all species collected in the large marsh creeks of the upper bay was 3.6 times greater at the Mill Creek Sampling Area of the ACW Site (CPUE = 25.34) than at the Mad Horse Creek Reference Site (CPUE = 7.14) (Tables 7-5 and 7-7; Figure 7-51). Even though white perch, spot, and bay anchovy were the predominant species at both sites, this difference in overall fish abundance was largely the result of their higher absolute abundance at the Mill Creek area. If the combined contribution of white perch, spot, and bay anchovy to the total CPUE is subtracted from both sites, then the resulting aggregate CPUE's for all other species are more similar, i.e., 3.11 at Mad Horse Creek and 5.14 at Mill Creek. The contribution to overall fish abundance at Mill Creek made by the other one target species, weakfish, was more dubious. Weakfish was slightly more abundant at Mad Horse Creek (0.18) than at Mill Creek (0.13).

Fish species richness was similar at Mad Horse Creek and at Mill Creek with 19 and 20 species, respectively (Figure 7-51). There were 16 species common to both sites, though differing in rank order. Those species taken exclusively at one site or the other were incidental captures represented by ≤2 individuals, with the exception of brown bullhead. They were taken only at Mill Creek where a total of 63 was collected comprising 2% of the total catch. White perch ranked first at Mill Creek and fourth at Mad Horse; and bay anchovy ranked first at Mad Horse and second at Mill Creek. While both sites are located in the "upper bay", they also are in the transitional portion of the estuary where generally freshwater and saltwater assemblages intermingle at the boundaries of their favored distributions. During 2008, this intermingling exhibited similarities and commonalities of note. The fish assemblage at the Mad Horse Creek site consisted of 14 transient, four estuarine resident and two freshwater resident species. Similarly at the Mill Creek area, the fish assemblage consisted of 12 transient, three estuarine resident and six freshwater resident species. A total of 12 transient species were common to both sites; three of the estuarine residents occurred at both sites; and one freshwater resident species were common to both sites. However, summer flounder, a species which is typically more associated with the higher salinity waters of the "lower bay", was taken exclusively at Mad Horse Creek. Similarly, carp and eastern silvery minnow, species which are typically more associated with the low or no salinity waters of the freshwater tidal river, were taken exclusively at Mill Creek.

Abundance of all species collected in the small marsh creeks of the upper bay was higher at both restoration sampling areas than at the Mad Horse Creek Reference Site. At Alloway Creek, the total CPUE (28.38) was 3.4 times greater than that at Mad Horse Creek (8.36), and at Mill Creek (325.36) it was 38.9 times greater (Tables 7-5, 7-6 and 7-7; Figure 7-51). These differences were driven by the disproportionate predominance of mummichog at both restoration areas. This was particularly notable at both Mill Creek and Alloway Creek where mummichog abundance was two orders of magnitude higher than at Mad Horse Creek. Like abundance, fish species richness was higher at Mill Creek than at the Mad Horse Creek Reference Site, with 14 and 7 species, respectively (Figure 7-51). Species richness at Alloway Creek was five, and similar to Mad Horse Creek. Four of seven species taken at Mad Horse Creek, i.e., mummichog, Atlantic silverside, Atlantic menhaden and naked goby, were common to both Alloway and Mill Creeks, and all species taken at Alloway Creek were common to Mill Creek. The typically ubiquitous bay anchovy was taken at both Mad Horse and Mill Creek, but were curiously absent from weir sets at Alloway Creek. There were six species taken only at Mill Creek, each comprised <1% of the total catch. Regarding species rank order, mummichog was first at all three sites; Atlantic menhaden was ranked second at all three sites; naked goby was ranked third at Mad Horse and Alloway Creek, but only one individual was caught at Mill Creek; bay anchovy was ranked fourth at Mad Horse, sixth at Mill Creek, but absent from Alloway Creek; and white perch was ranked fourth at Alloway and Mill Creek, but was absent from Mad Horse.

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Table 7-1. Summary of sampling efforts for the 2008 Marsh Fish Assemblage sampling season.

Site	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Site Totals
Lower Bay **Moores Beach**								
Trawl	18	18	18	18	18	18	18	126
Weir	2	2	2	2	2	2	2	14
Commercial Township								
Trawl	18	18	18	18	18	18	18	126
Weir	2	2	2	2	2	2	2	14
Upper Bay **Mad Horse Creek**								
Trawl	18	18	18	18	18	18	18	126
Weir	2	2	2	2	2	2	2	14
Mill Creek								
Trawl	18	18	18	18	18	18	18	126
Weir	2	2	2	2	2	2	2	14
Alloway Creek								
Weir	6	6	6	6	6	6	6	42
Monthy Totals								
Trawl	72	72	72	72	72	72	72	504
Weir	14	14	14	14	14	14	14	98
Combined	86	86	86	86	86	86	86	602

Table 7-2 Checklist of Delaware Bay Fauna collected from May 2008 to November 2008.
Key: T = Tansient, R = Resident.

	Species	Common Name	Pattern of Utilizations
Invertebrates			
	Callinectes sapidus	Blue claw crab	R
	Limulus polyphemus	Horseshoe crab	T
Achiridae			
	Trinectes maculatus	Hogchoker	R
Anguillidae			
	Anguilla rostrata	American eel	T
Atherinopsidae			
	Menidia menidia	Atlantic silverside	T
Batrachoididae			
	Opsanus tau	Oyster toadfish	R
Carcharhinidae			
	Mustelus canis	Smooth dogfish	T
Clupeidae			
	Alosa aestivalis	Blueback herring	T
	Alosa mediocris	Hickory shad	T
	Alosa sapidissima	American shad	T
	Brevoortia tyrannus	Atlantic menhaden	T
	Dorosoma cepedianum	Gizzard shad	R
Cyprinidae			
	Cyprinus carpio	Common carp	R
	Hybognathus regius	Eastern silvery minnow	R
Cyprinodontidae			
	Cyprinodon variegatus	Sheepshead minnow	R
Emydidae			
	Chrysemys picta	Painted Turtle	R
Engraulidae			
	Anchoa mitchilli	Bay anchovy	T
Fundulidae			
	Fundulus luciae	Spotfin killifish	T
	Fundulus heteroclitus	Mummichog	R
	Fundulus majalis	Striped killifish	T
Gobiidae			
	Gobiosoma bosc	Naked goby	R
Ictaluridae			
	Ameiurus catus	White catfish	R
	Ameiurus nebulosus	Brown bullhead	R
	Ictalurus punctatus	Channel catfish	R
Moronidae			
	Morone americana	White perch	R
	Morone saxatilis	Striped bass	T
Mugilidae			
	Mugil curema	White mullet	T
Ophidiidae			
	Ophidion marginatum	Striped cusk eel	T
Paralichthyidae			
	Paralichthys dentatus	Summer flounder	T

Table 7-2. Continued.

Phycidae			
	Uropycis regia	Spotted hake	T
Pomatomidae			
	Pomatomus saltatrix	Bluefish	T
Sciaenidae			
	Bairdiella chysoura	Silver perch	T
	Cynoscion regalis	Weakfish	T
	Leiostomus xanthurus	Spot	T
	Mircopogonias undulatus	Atlantic croaker	T
	Pogonias cromis	Black drum	T
	Menticirrhus saxatilis	Northern kingfish	T
Serranidae			
	Centropristis striata	Black sea bass	T
Reptilia			
	Malaclemys terrapin	Diamondback terrapin	R

Table 7-3. Composite species composition, for large marsh creek (otter trawl) and small marsh creek (weir) collections, for Moores Beach from May to November 2008.

	Large Marsh Creeks				**Small Marsh Creeks**			
Species	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**
Alosa mediocris	<1	<1	0.01	1	--	--	--	--
Anchoa mitchilli	**27**	**5**	**0.58**	**73**	**7**	**<1**	**0.14**	**2**
Anguilla rostrata	2	<1	0.02	2	--	--	--	--
Brevoortia tyrannus	24	46	5.34	673	--	--	--	--
Centropristis striata	<1	<1	0.01	1	--	--	--	--
Cynoscion regalis	**9**	**1**	**0.13**	**17**	--	--	--	--
Cyprinodon variegatus	--	--	--	--	14	<1	0.14	2
Fundulus heteroclitus	2	<1	0.02	3	100	73	147.07	2059
Fundulus luciae	--	--	--	--	7	<1	0.14	2
Fundulus majalis	--	--	--	--	7	<1	0.07	1
Gobiosoma bosc	2	<1	0.06	7	7	<1	0.07	1
Leiostomus xanthurus	**38**	**13**	**1.56**	**197**	**14**	<1	**1.71**	**24**
Menidia menidia	--	--	--	--	64	26	52.29	732
Micropogonias undulatus	40	28	3.33	419	--	--	--	--
Morone americana	**7**	**<1**	**0.07**	**9**	**7**	**<1**	**0.07**	**1**
Morone saxatilis	21	3	0.37	46	--	--	--	--
Mugil curema	<1	<1	0.01	1	--	--	--	--
Mustelus canis	<1	<1	0.01	1	--	--	--	--
Ophidion marginatum	<1	<1	0.01	1	--	--	--	--
Opsanus tau	<1	<1	0.01	1	--	--	--	--
Pogonias cromis	2	<1	0.02	2	7	<1	0.29	4
Pomatomus saltatrix	2	<1	0.02	3	--	--	--	--
Trinectes maculatus	7	1	0.13	16	--	--	--	--
Total Fish	--	--	11.69	1473	--	--	202.00	2828
Callinectes sapidus	71	18	2.62	330	79	6	13.36	187
Malaclemys terrapin	6	<1	0.06	8	--	--	--	--
Limulus polyphemus	6	<1	0.08	10	14	<1	0.14	2
Total all species	--	--	14.45	1821	--	--	215.50	3017

Table 7-4. Composite species composition, for large marsh creek (otter trawl) and small marsh creek (weir) collections, for Commercial Township from May to November 2008.

	Large Marsh Creeks				**Small Marsh Creeks**			
Species	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**
Anchoa mitchilli	**38**	**54**	**19.67**	**2478**	**29**	**11**	**14.93**	**209**
Anguilla rostrata	2	<1	0.02	3	--	--	--	--
Brevoortia tyrannus	13	2	0.75	94	14	3	4.50	63
Cynoscion regalis	**23**	**3**	**1.11**	**140**	--	--	--	--
Cyprinodon variegatus	--	--	--	--	7	<1	0.07	1
Dorosoma cepedianum	<1	<1	0.01	1	--	--	--	--
Fundulus heteroclitus	--	--	--	--	86	45	60.64	849
Gobiosoma bosc	--	--	--	--	14	<1	0.14	2
Leiostomus xanthurus	**44**	**17**	**6.05**	**762**	**50**	**15**	**20.21**	**283**
Menidia menidia	--	--	--	--	71	19	25.50	357
Micropogonias undulatus	59	22	7.89	994	21	3	4.43	62
Morone americana	**11**	**<1**	**0.24**	**30**	--	--	--	--
Morone saxatilis	11	<1	0.15	19	--	--	--	--
Mustelus canis	<1	<1	0.01	1	--	--	--	--
Ophidion marginatum	<1	<1	0.01	1	--	--	--	--
Opsanus tau	2	<1	0.02	2	--	--	--	--
Paralichthys dentatus	2	<1	0.02	2	--	--	--	--
Pogonias cromis	2	<1	0.02	2	43	3	3.50	49
Trinectes maculatus	15	1	0.37	46	--	--	--	--
Urophycis regia	2	<1	0.02	2	--	--	--	--
Total Fish	--	--	36.33	4577	--		133.93	1875
Callinectes sapidus	46	5	1.81	228	79	8	11.21	157
Malaclemys terrapin	6	<1	0.06	8	--	--	--	--
Limulus polyphemus	8	<1	0.28	35	--	--	--	--
Total all species	--	--	38.48	4848	--	--	145.14	2032

Table 7-5. Composite species composition, for large marsh creek (otter trawl) and small marsh creek (weir) collections, for Mad Horse Creek from May to November 2008.

	Large Marsh Creeks				**Small Marsh Creeks**			
Species	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**
Alosa aestivalis	<1	<1	0.01	1	--	--	--	--
Alosa mediocris	<1	<1	0.01	1	--	--	--	--
Ameiurus catus	2	<1	0.02	2	--	--	--	--
Anchoa mitchilli	**52**	**28**	**2.03**	**256**	**21**	**3**	**0.29**	**4**
Anguilla rostrata	2	<1	0.02	2	7	2	0.14	2
Bairdiella chrysoura	3	<1	0.06	7	--	--	--	--
Brevoortia tyrannus	21	14	1.02	128	7	26	2.14	30
Cynoscion regalis	**12**	**3**	**0.18**	**23**	**--**	**--**	**--**	**--**
Dorosoma cepedianum	<1	<1	0.01	1	--	--	--	--
Fundulus heteroclitus	--	--	--	--	57	60	5.00	70
Gobiosoma bosc	4	<1	0.04	5	21	5	0.43	6
Leiostomus xanthurus	**35**	**17**	**1.21**	**153**	**14**	**2**	**0.14**	**2**
Menidia menidia	3	3	0.21	27	14	3	0.21	3
Micropogonias undulatus	20	7	0.52	65	--	--	--	--
Morone americana	**41**	**11**	**0.79**	**100**	**--**	**--**	**--**	**--**
Morone saxatilis	18	3	0.21	27	--	--	--	--
Paralichthys dentatus	2	<1	0.02	2	--	--	--	--
Pogonias cromis	11	3	0.20	25	--	--	--	--
Pomatomus saltatrix	2	<1	0.02	2	--	--	--	--
Trinectes maculatus	24	8	0.58	73	--	--	--	--
Total Fish	--	--	7.14	900	--	--	8.36	117
Callinectes sapidus	73	22	2.00	252	86	64	15.07	211
Malaclemys terrapin	2	<1	0.02	3	--	--	--	--
Total all species	--	--	9.17	1155	--	--	23.43	328

Table 7-6. Composite species composition, for small marsh creek (weir) collections, for Alloway Creek area during May to November 2008.

	Small Marsh Creeks			
Species	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**
Brevoortia tyrannus	2	12	3.52	148
Fundulus heteroclitus	95	86	24.50	1029
Gobiosoma bosc	10	<1	0.19	8
Menidia menidia	5	<1	0.05	2
Morone americana	**7**	**<1**	**0.12**	**5**
Total Fish	--	--	28.38	1192
Callinectes sapidus	43	3	0.90	38
Total all species	--	--	29.29	1230

Table 7-7. Composite species composition, for large marsh creek (otter trawl) and small marsh creek (weir) collections, for Mill Creek area from May to November 2008.

	Large Marsh Creeks				**Small Marsh Creeks**			
Species	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**	**Percent frequency of occurrence**	**Percent composition**	**Catch per unit effort**	**Total collected**
Alosa sapidissima	<1	<1	0.01	1	--	--	--	--
Ameiurus nebulosus	31	2	0.50	63	57	<1	2.00	28
Anchoa mitchilli	**51**	**24**	**5.97**	**752**	**21**	**<1**	**2.00**	**28**
Anguilla rostrata	2	<1	0.03	4	14	<1	0.14	2
Bairdiella chrysoura	<1	<1	0.01	1	--	--	--	--
Brevoortia tyrannus	36	8	1.90	240	21	7	22.21	311
Cynoscion regalis	**10**	**<1**	**0.13**	**16**	**--**	**--**	**--**	**--**
Cyprinis carpio	4	<1	0.06	7	--	--	--	--
Dorosoma cepedianum	37	4	0.97	122	36	<1	1.93	27
Fundulus heteroclitus	<1	<1	0.01	1	100	81	264.43	3702
Gobiosoma bosc	--	--	--	--	7	<1	0.07	1
Hybognathus regius	<1	<1	0.01	1	7	<1	0.36	5
Ictalurus punctatus	<1	<1	0.01	1	--	--	--	--
Leiostomus xanthurus	**63**	**21**	**5.23**	**659**	**43**	**<1**	**2.79**	**39**
Menidia menidia	<1	<1	0.01	1	79	7	21.43	300
Micropogonias undulatus	34	4	1.06	133	7	<1	0.07	1
Morone americana	**70**	**36**	**9.00**	**1134**	**64**	**2**	**7.14**	**100**
Morone saxatilis	17	1	0.26	33	--	--	--	--
Pogonias cromis	2	<1	0.02	2	14	<1	0.71	10
Pomatomus saltatrix	6	<1	0.08	10	7	<1	0.07	1
Trinectes maculatus	7	<1	0.10	12	--	--	--	--
Total Fish	--	--	25.34	3193	--	--	325.36	4555
Callinectes sapidus	25	1	0.32	40	79	2	7.21	101
Chrysemys Picta	<1	<1	0.01	1	--	--	--	--
Malaclemys terrapin	3	<1	0.03	4	--	--	--	--
Total all species	--	--	25.70	3238	--	--	332.57	4656

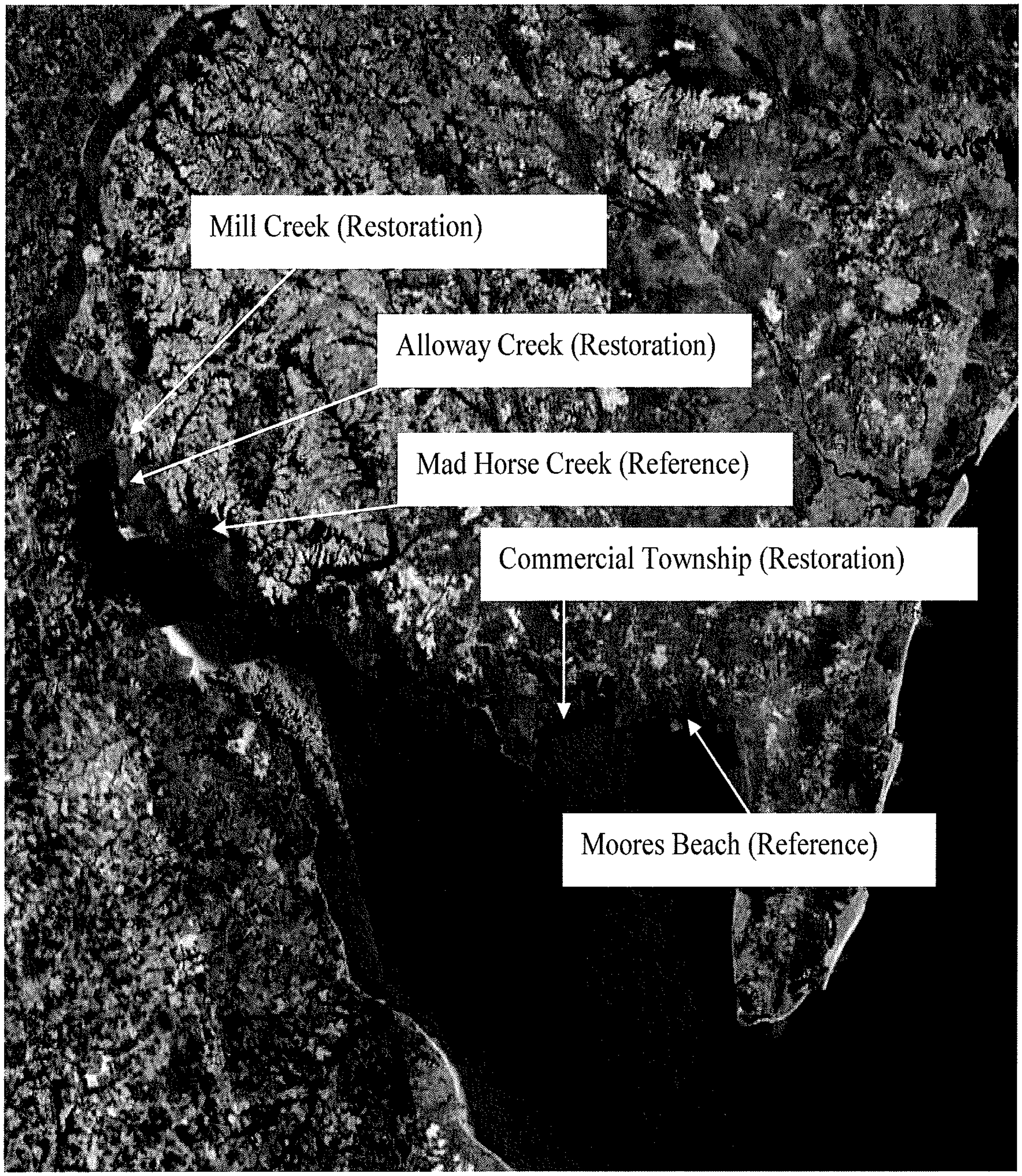


Figure 7-1. Restored and reference marsh study sites in Delaware Bay.

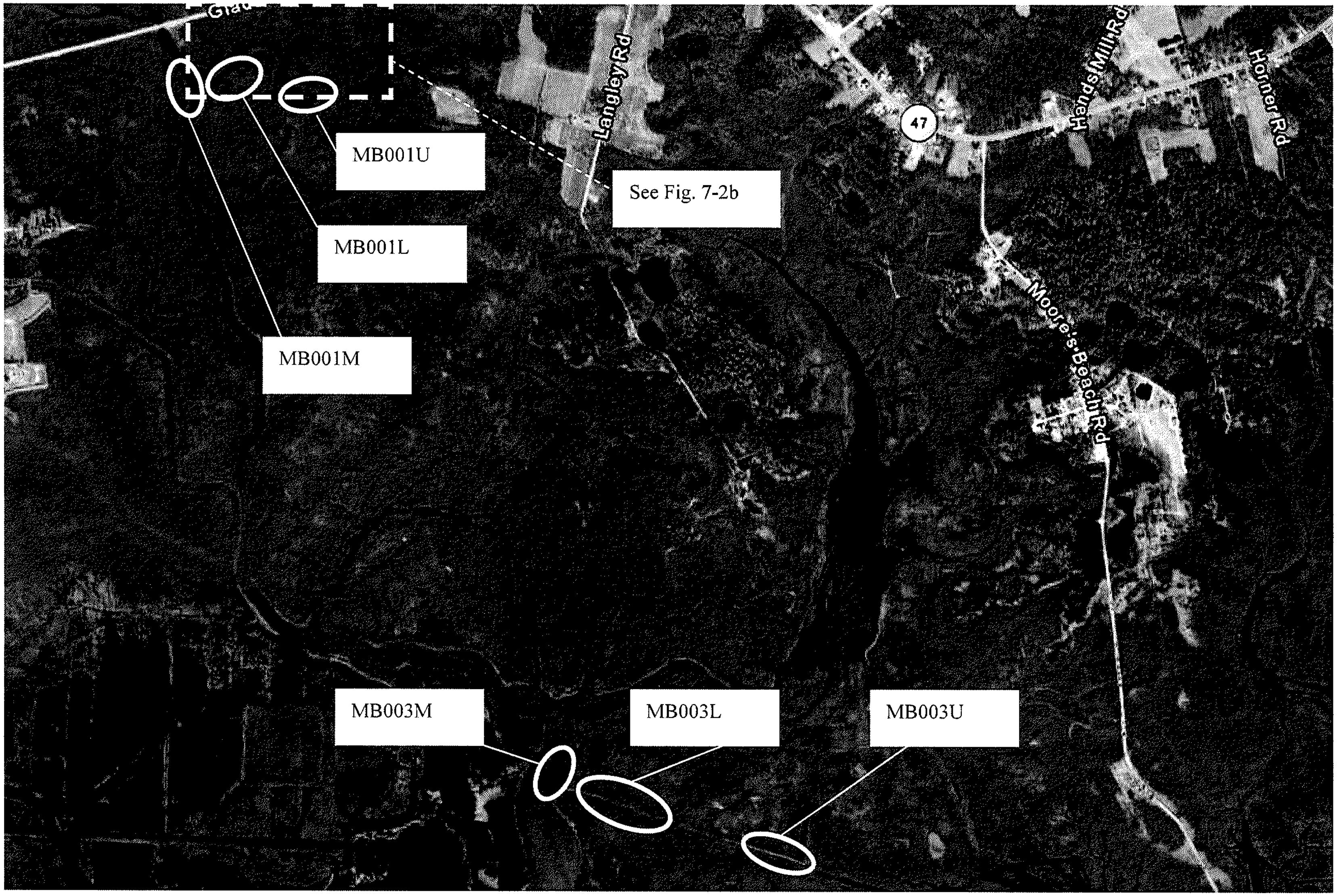


Figure 7-2a. Moores Beach sampling sites (reference) in Delaware Bay during 2008.

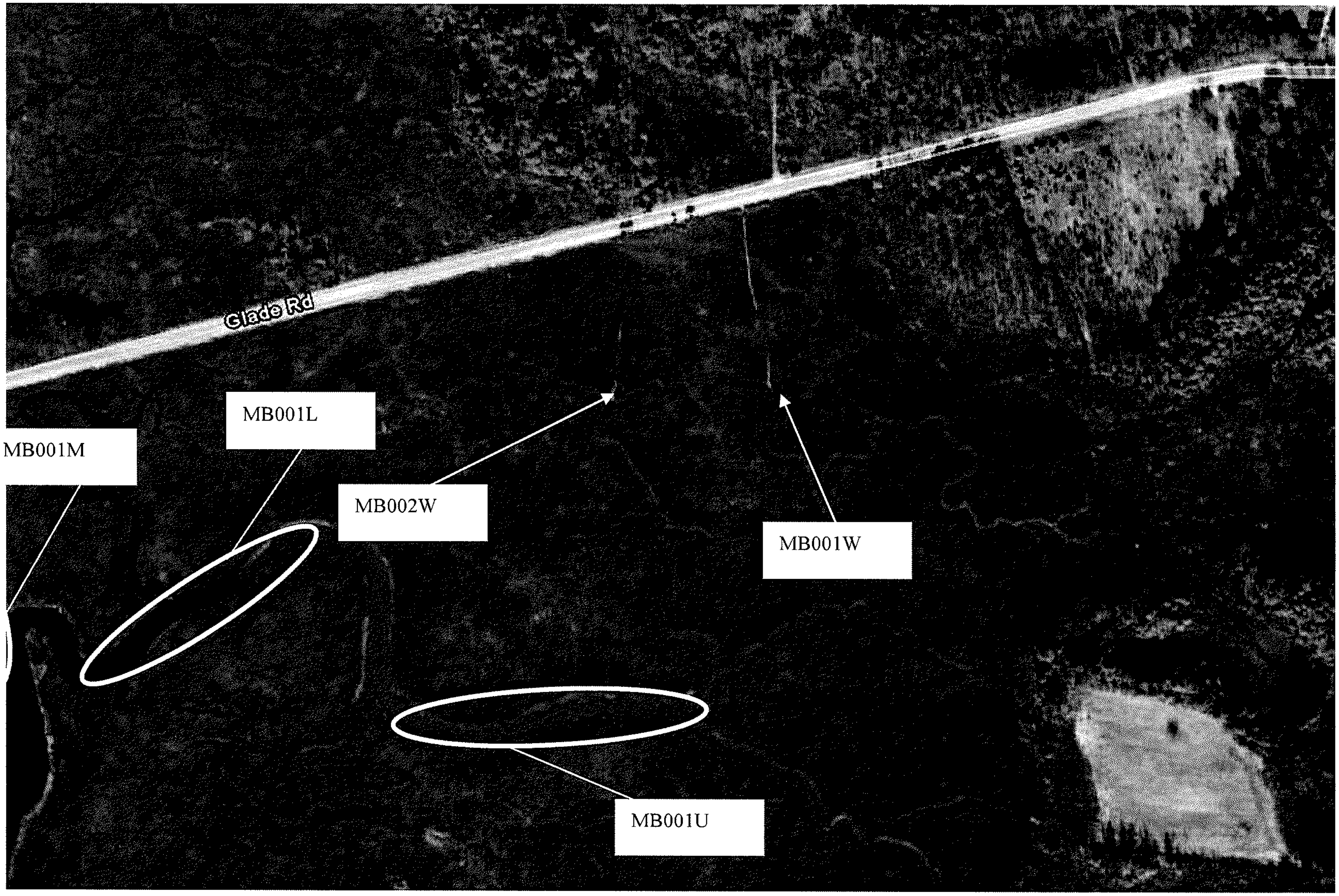


Figure 7-2b. Expanded view of small marsh creeks (weir) at the Moores Beach Reference Site in Delaware Bay during 2008.

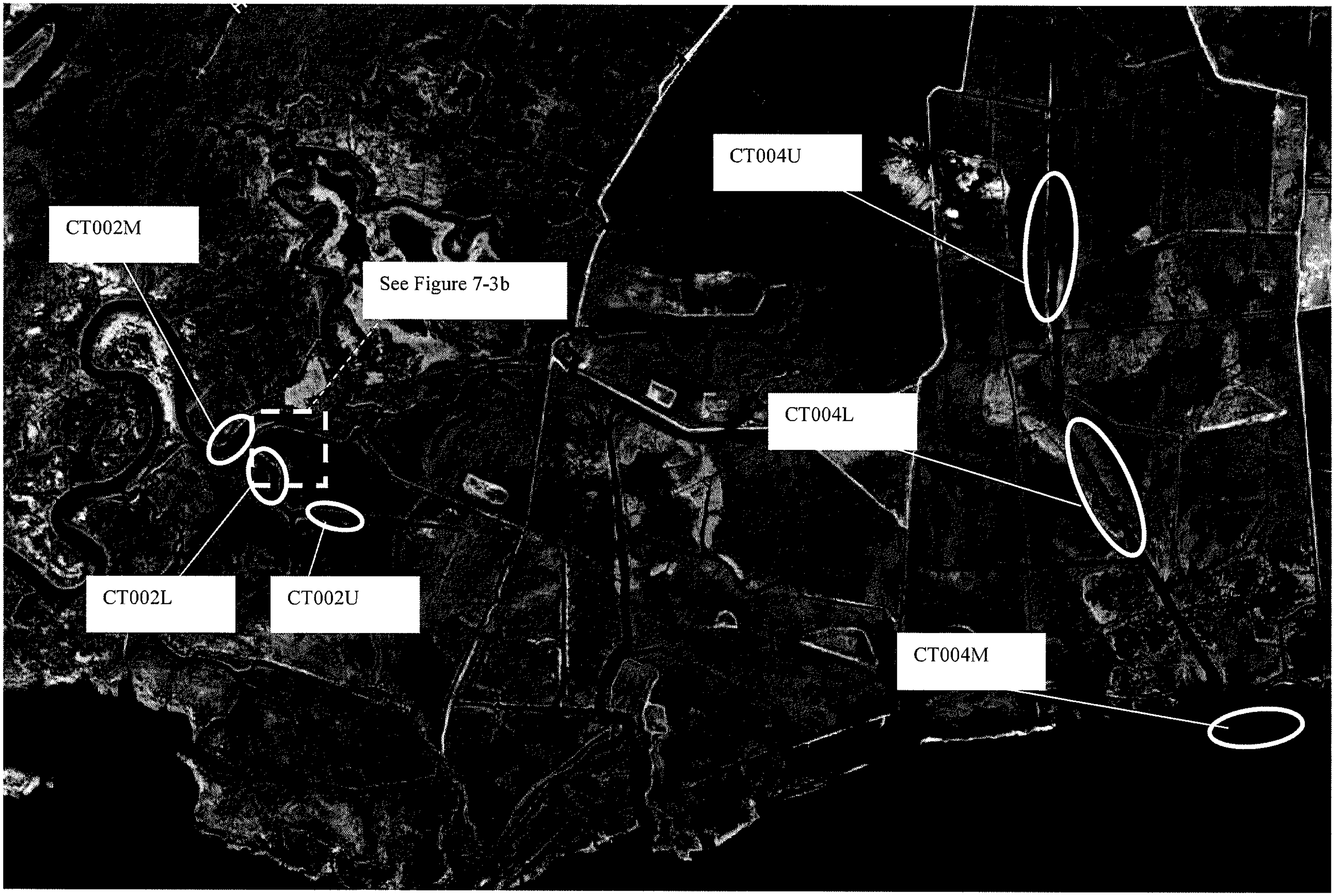


Figure 7-3a. Commercial Township sampling sites (restoration) in Delaware Bay during 2008.

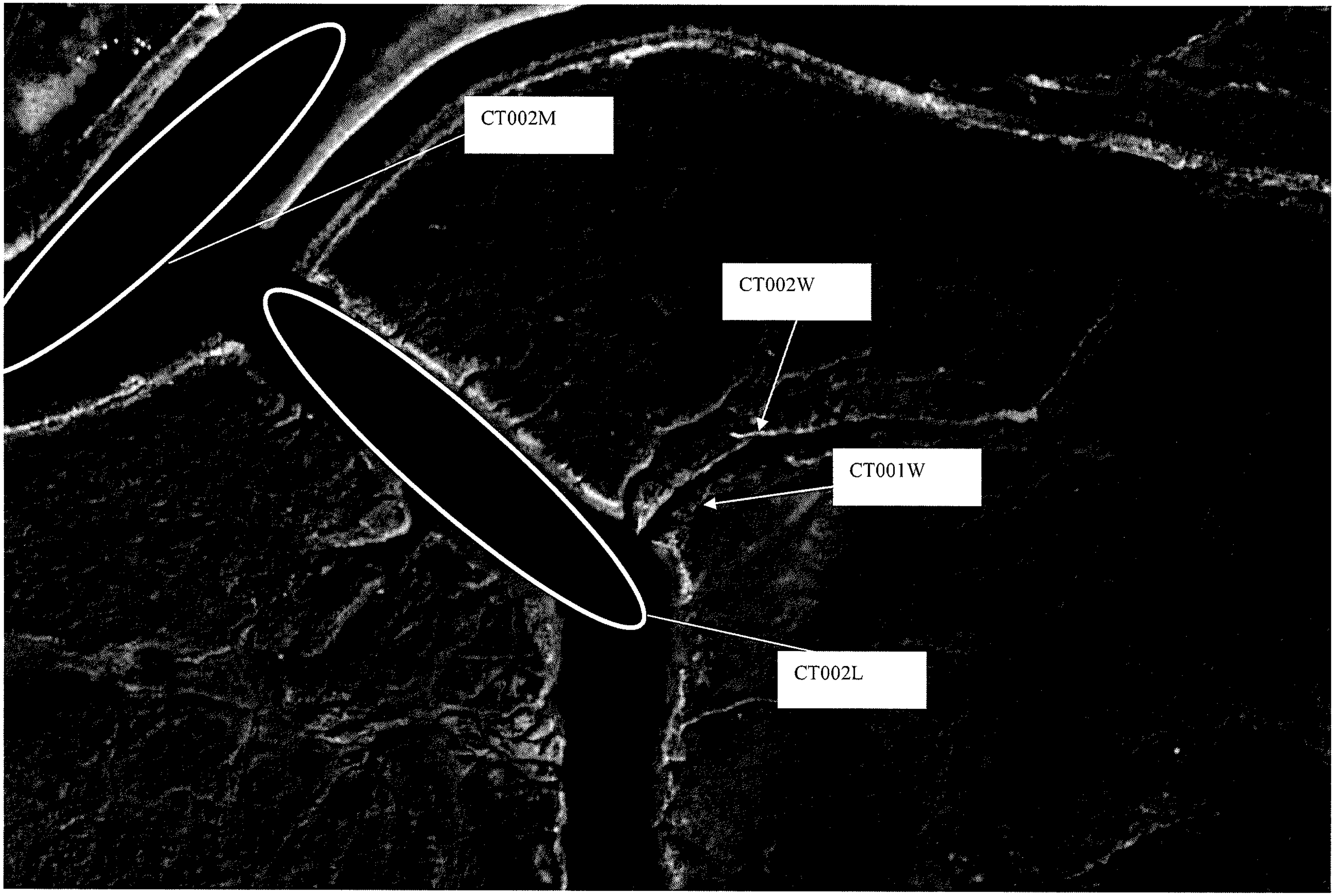


Figure 7-3b. Expanded view of small marsh creeks (weir) at the Commercial Township Restoration Site in Delaware Bay during 2008.

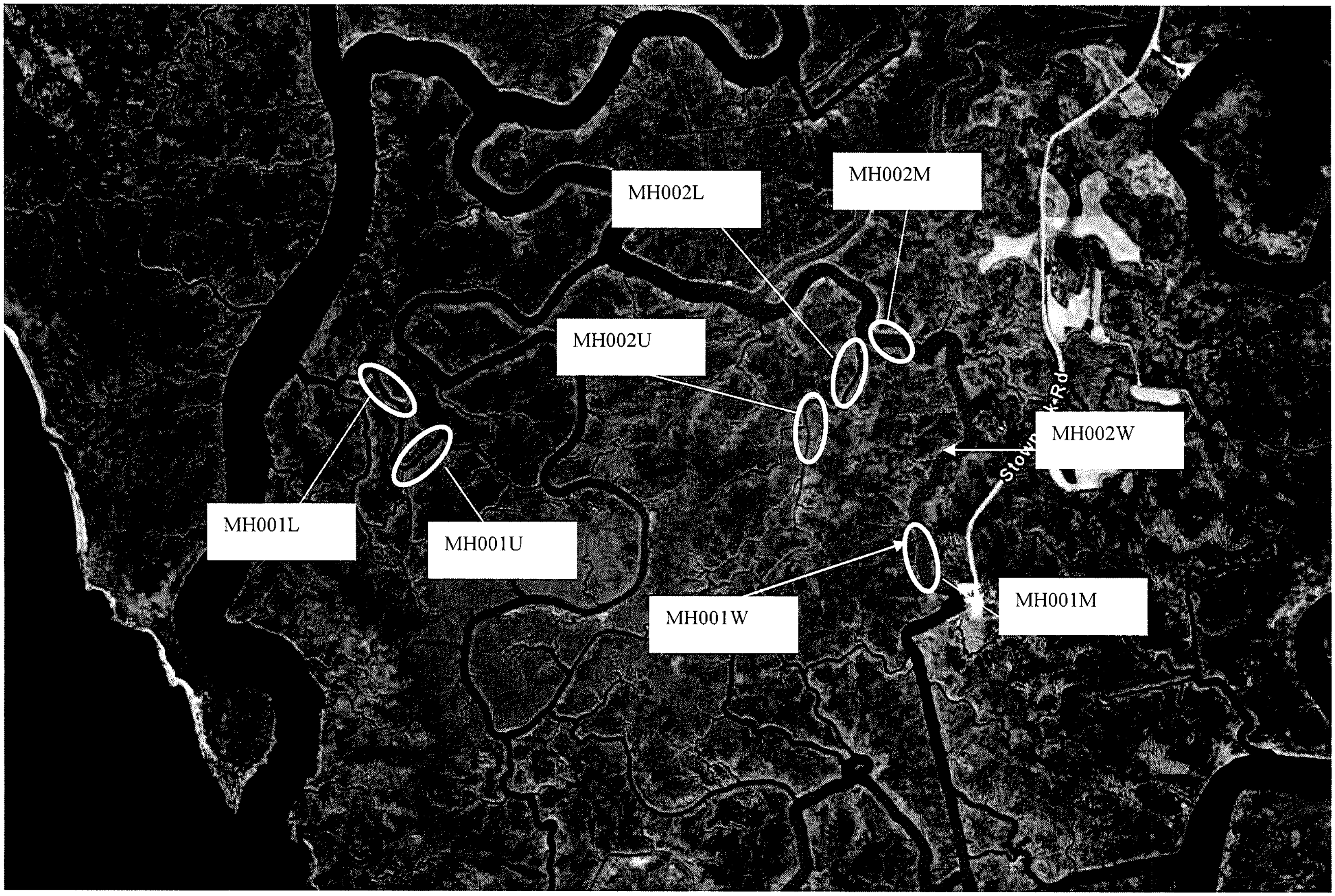


Figure 7-4. Mad Horse Creek sampling sites (reference) in Delaware Bay during 2008.

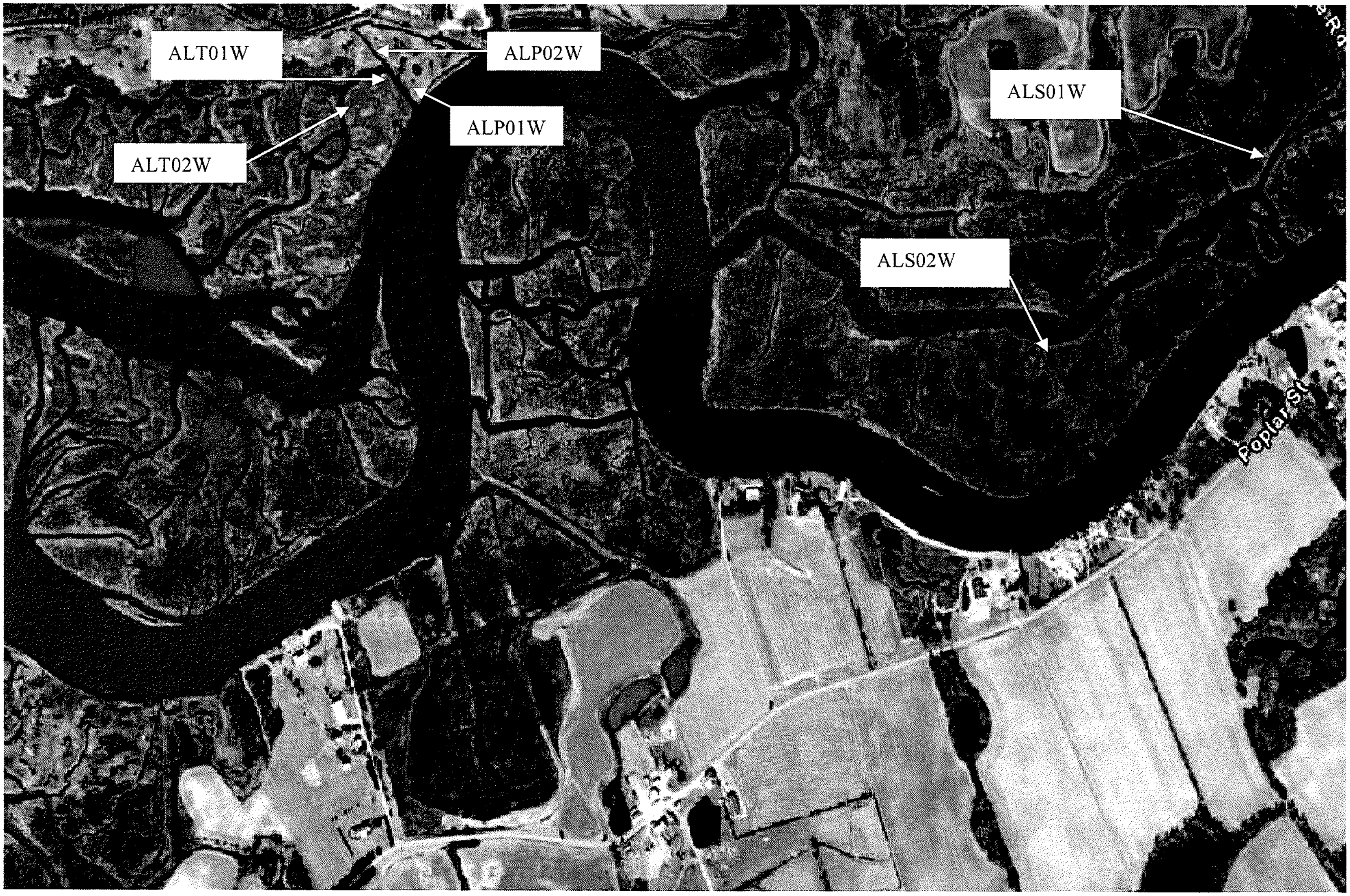


Figure 7-5. Alloway Creek sampling sites (restoration) in Delaware Bay during 2008.

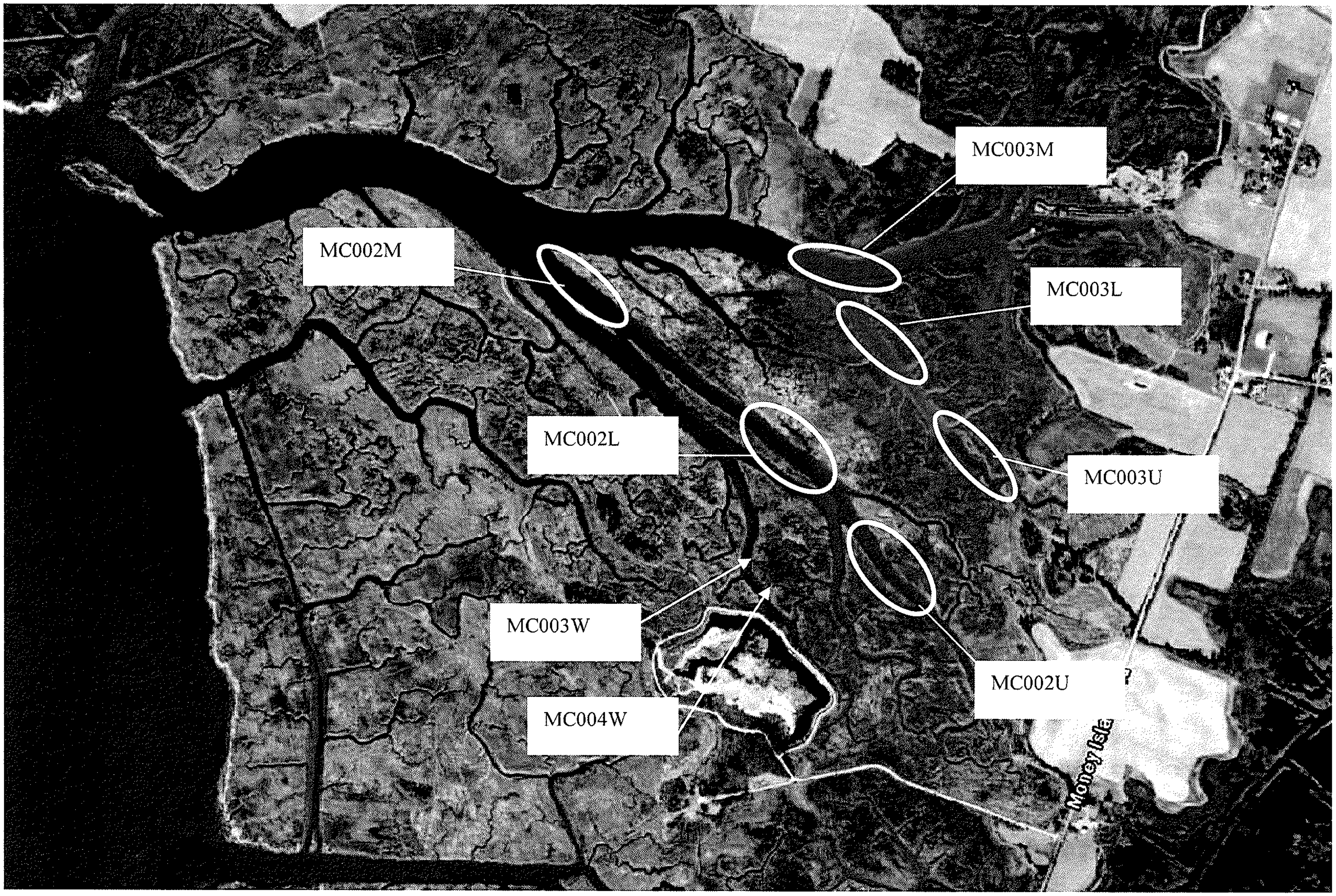


Figure 7-6. Mill Creek sampling (restoration) sites in Delaware Bay during 2008.

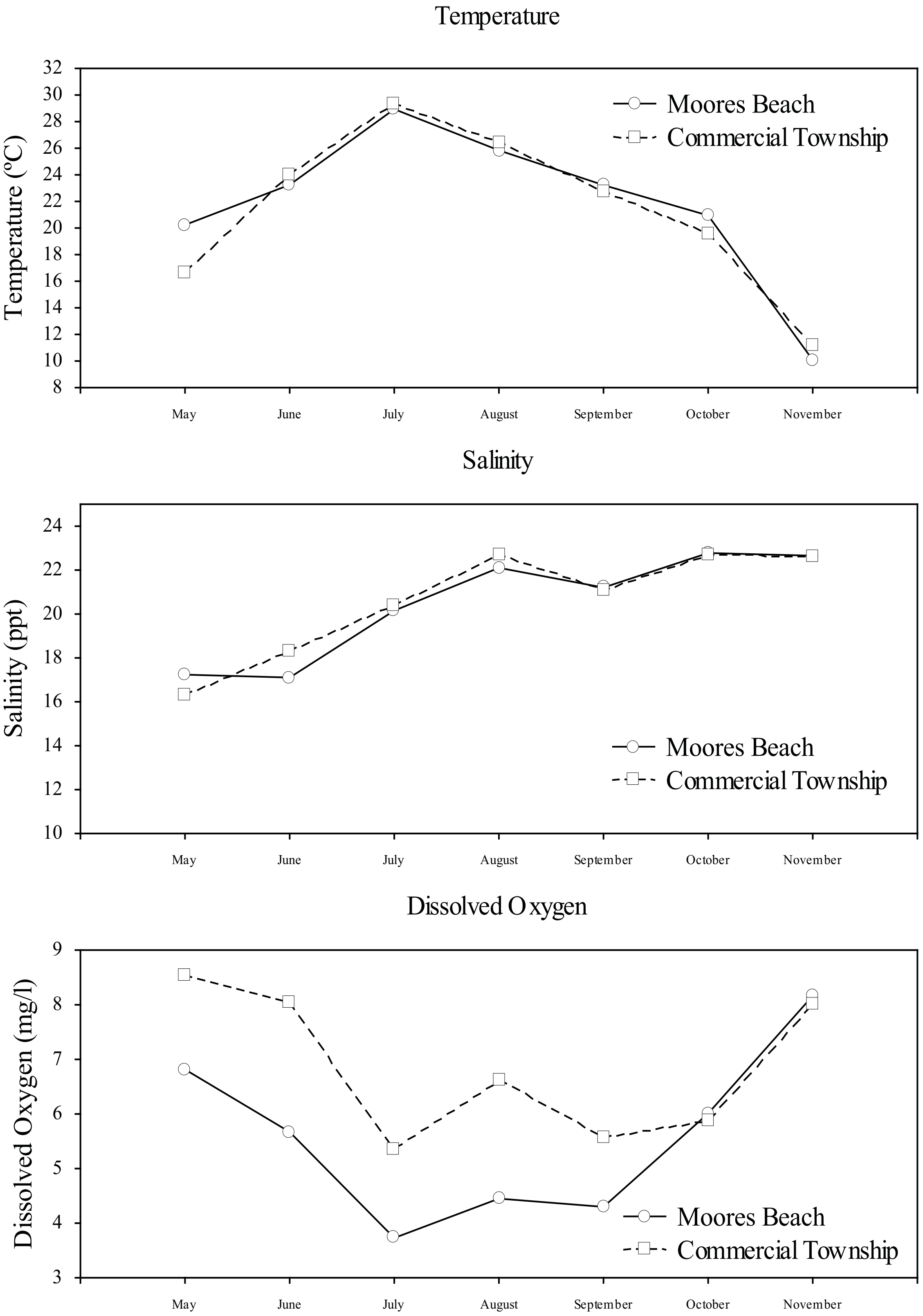
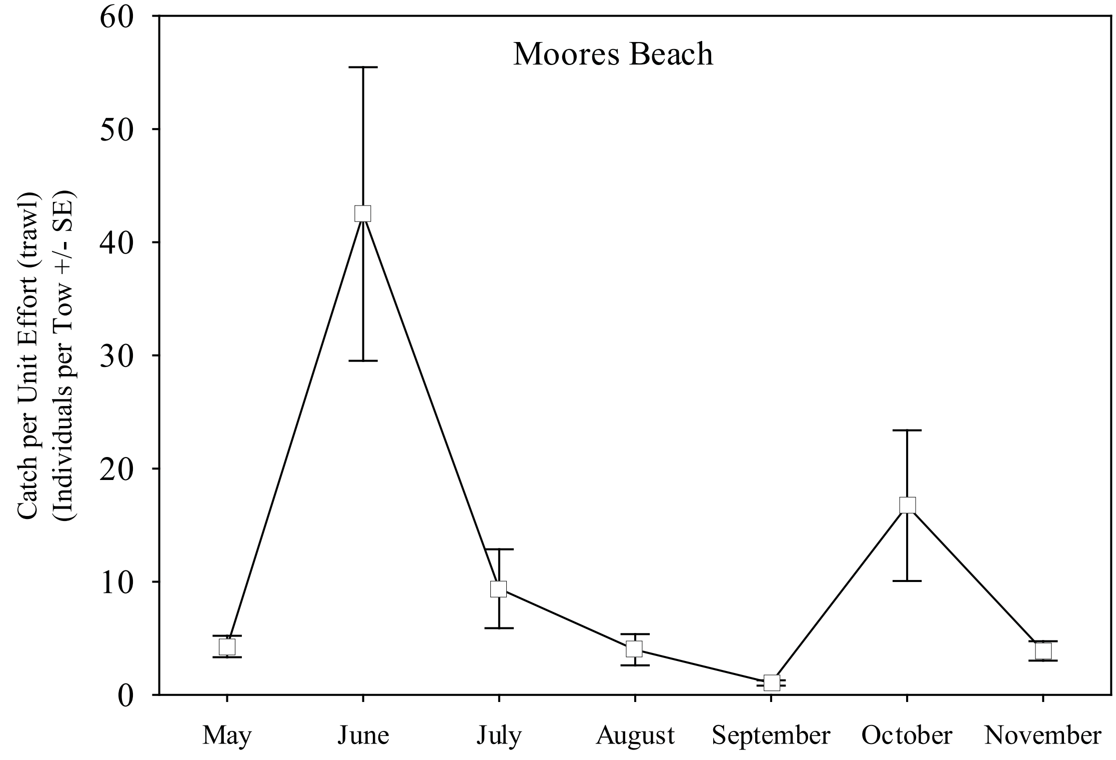


Figure 7-7. Selected physical parameters at regularly sampled sites in the Lower Delaware Bay Region during 2008.



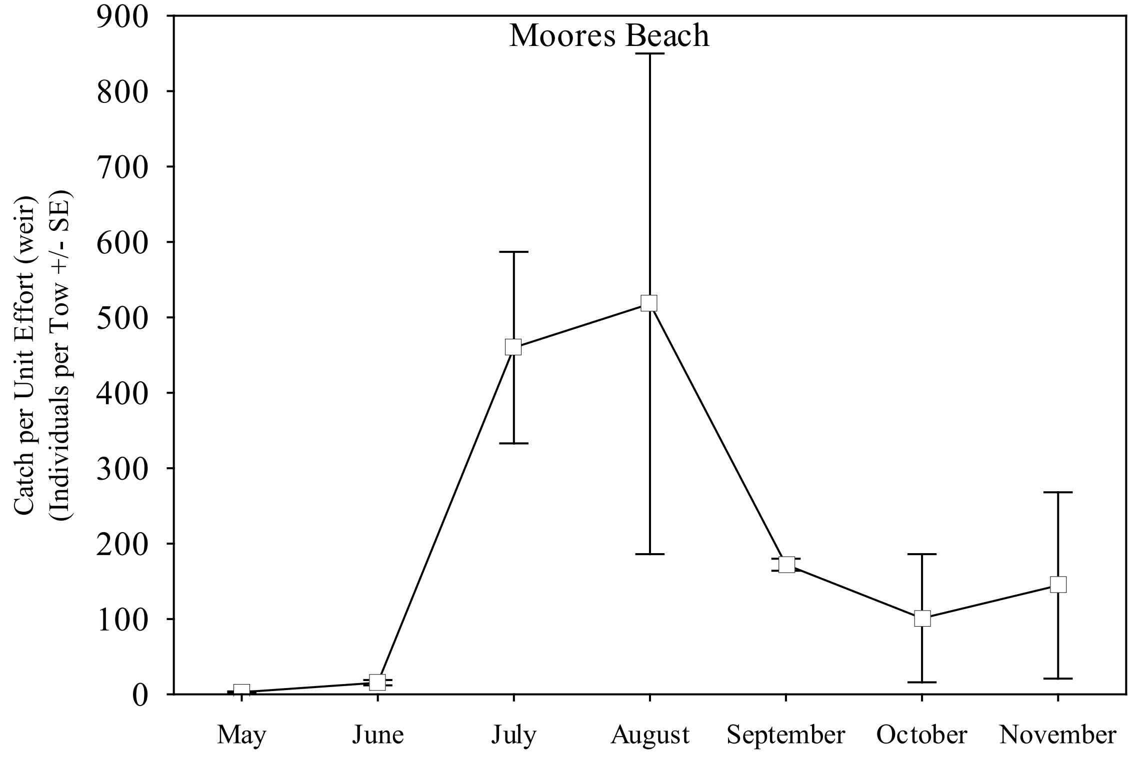
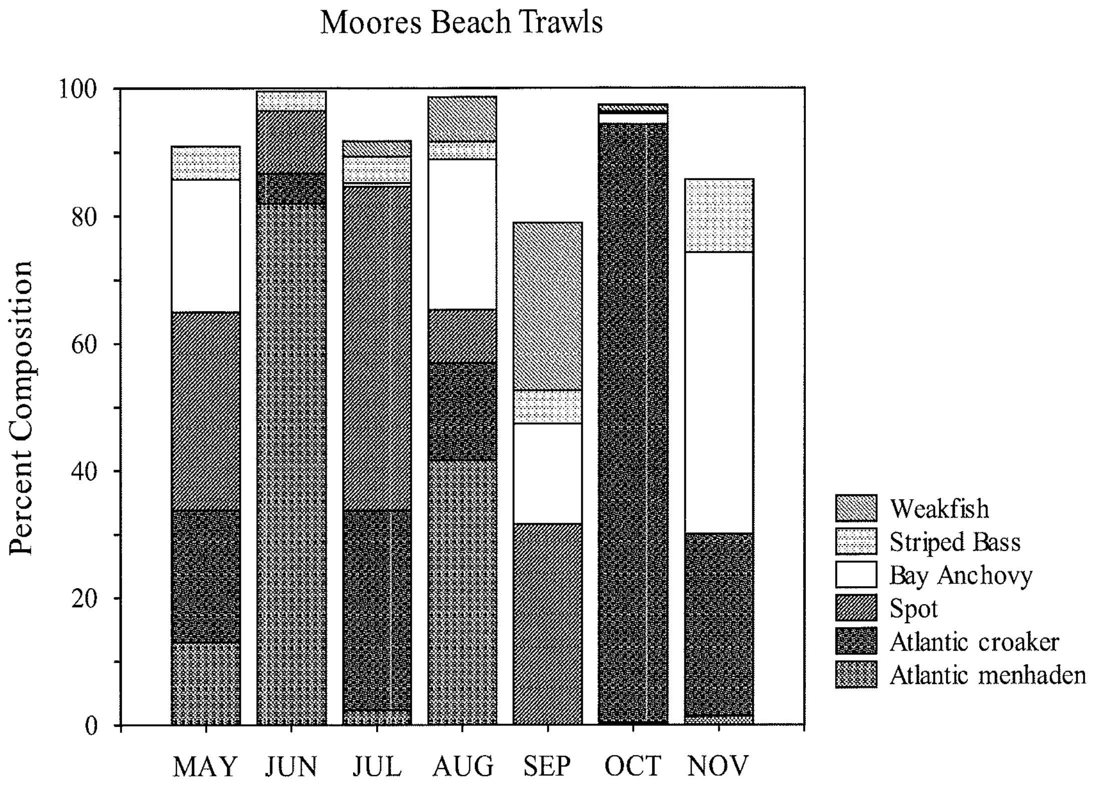


Figure 7-8. Monthly abundance for all fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), at Moores Beach during 2008.



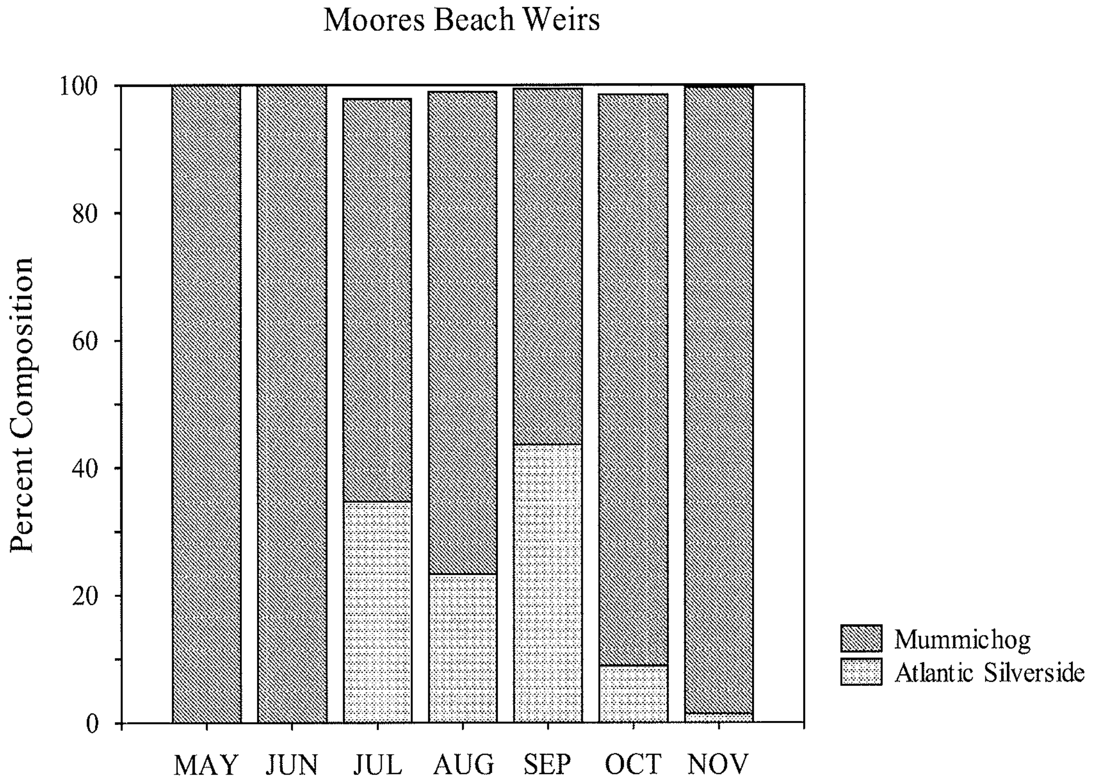
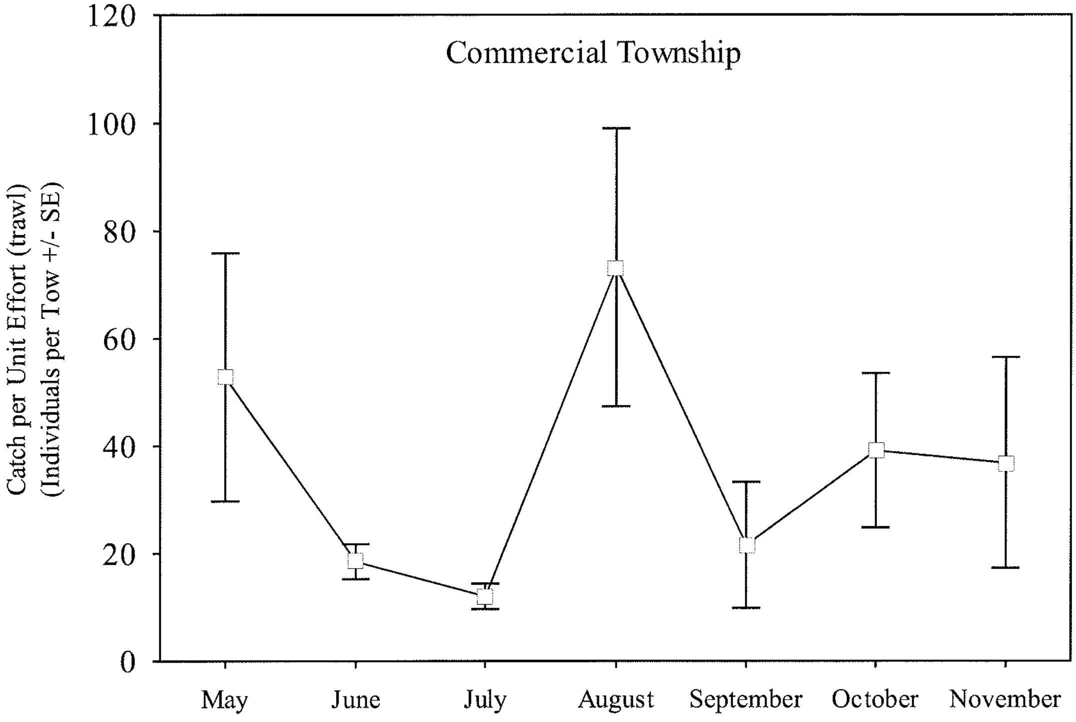


Figure 7-9. Monthly percent composition for fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), in Moores Beach during 2008.



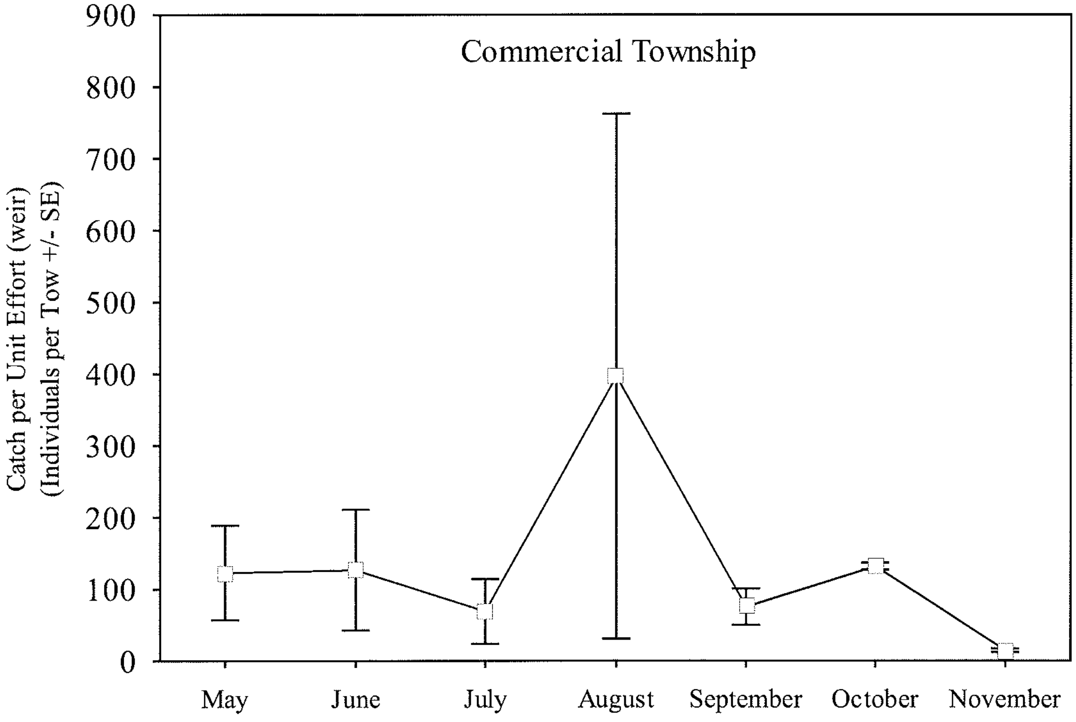


Figure 7-10. Monthly abundance for all fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), at Commercial Township during 2008.

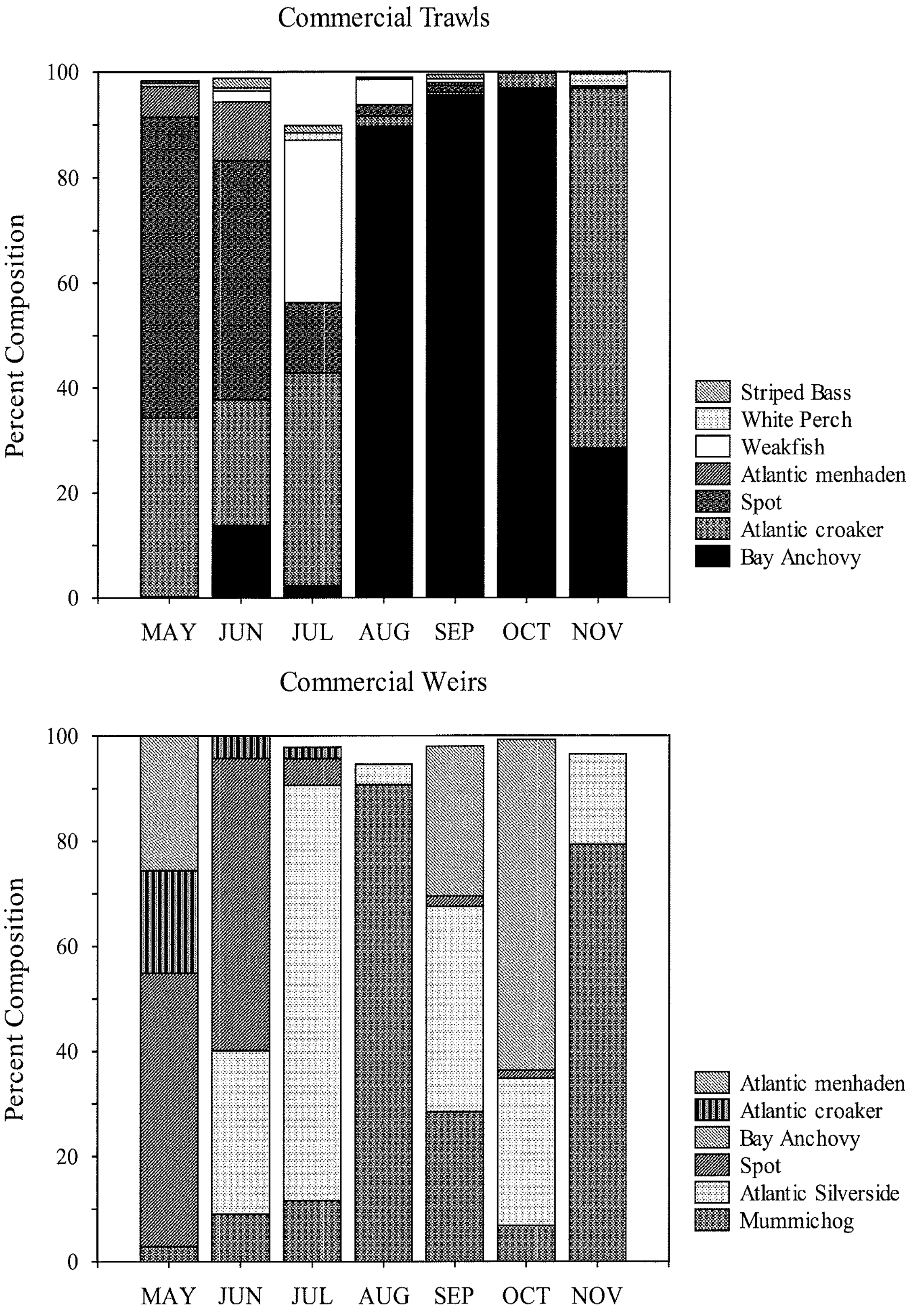


Figure 7-11. Monthly percent composition for fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), in Commercial Township during 2008.

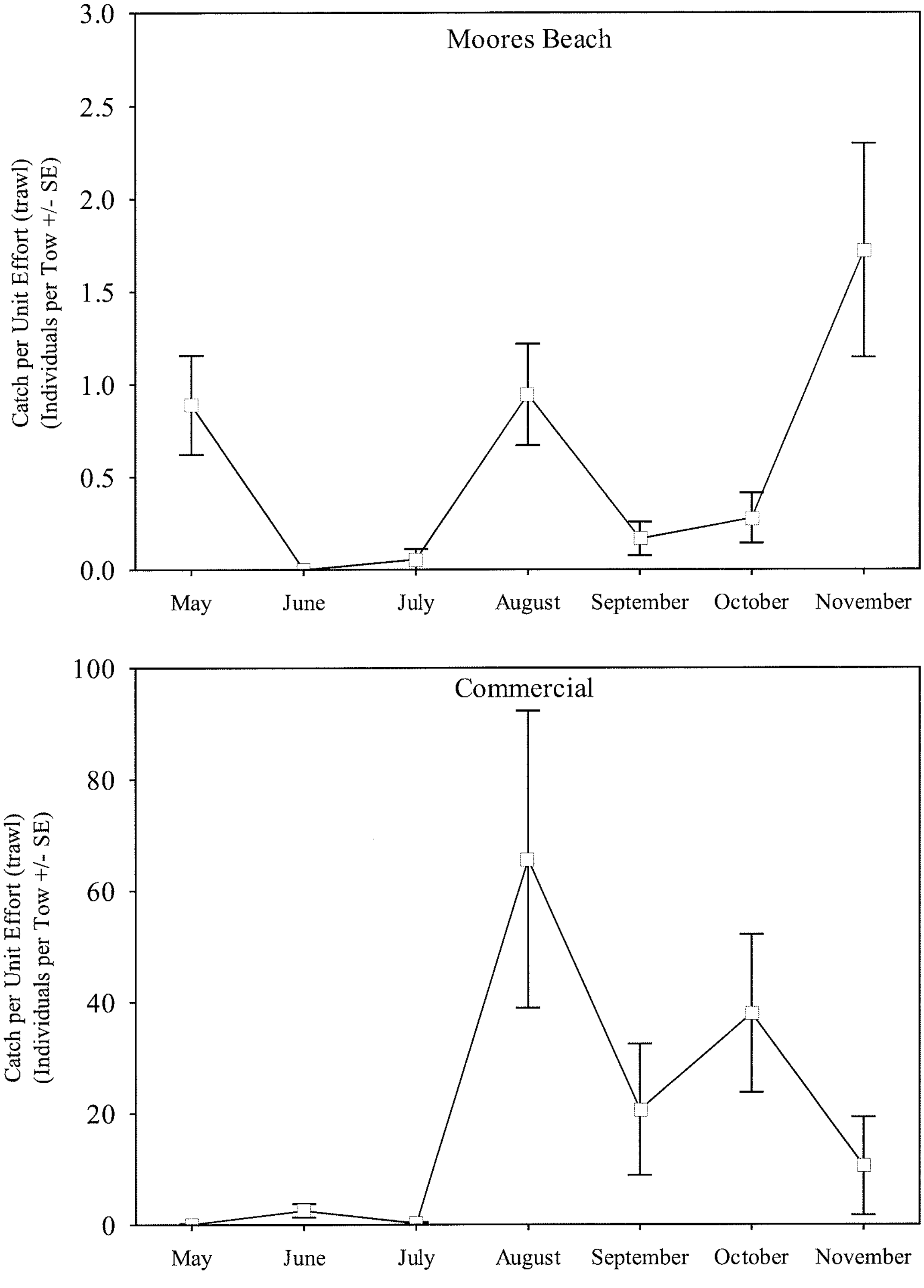


Figure 7-12. Monthly abundance for bay anchovy caught, in large marsh creeks with otter trawls, in the Lower Bay Region during 2008.

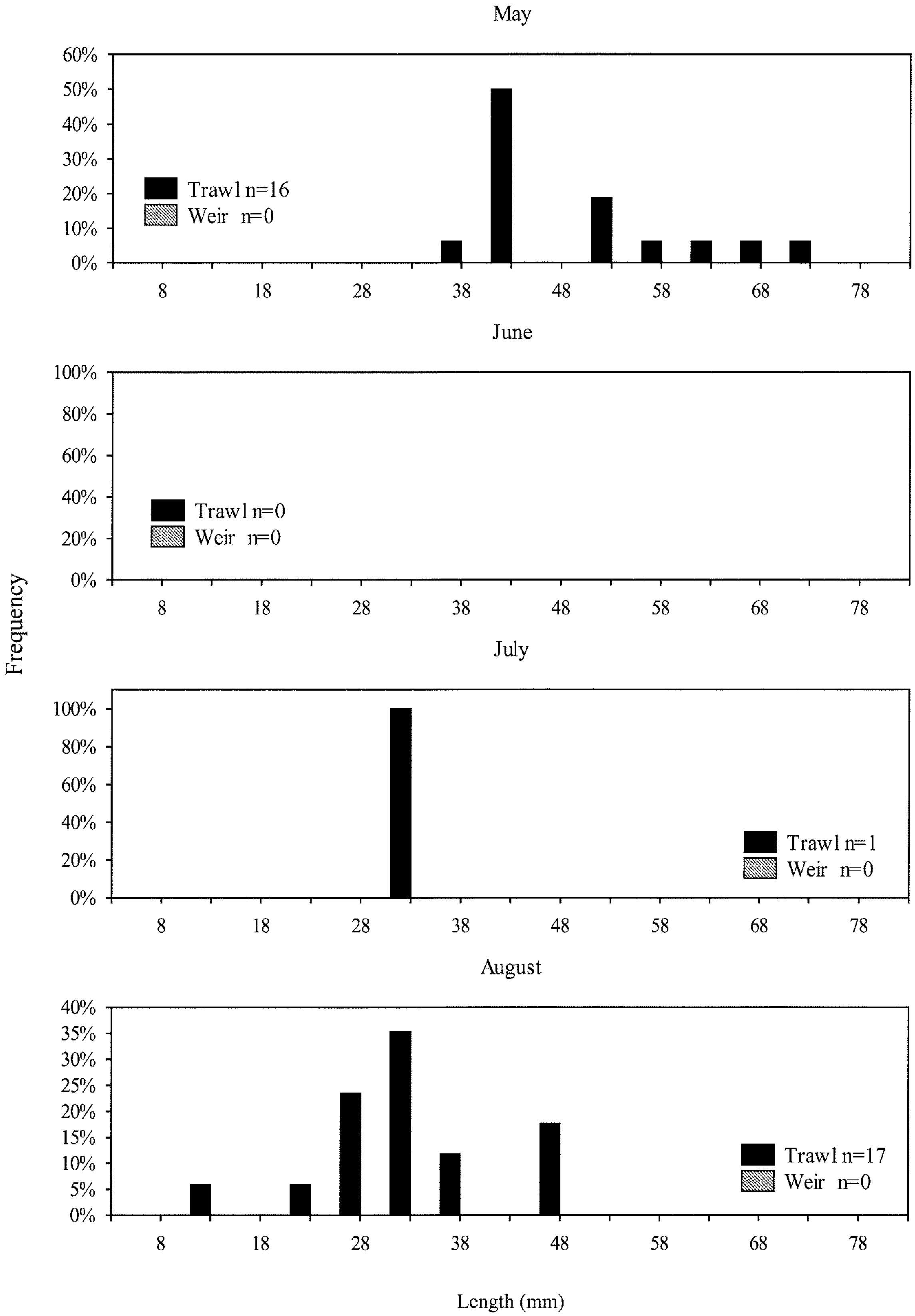


Figure 7-13. Size distribution of bay anchovy, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Moores Beach in 2008.

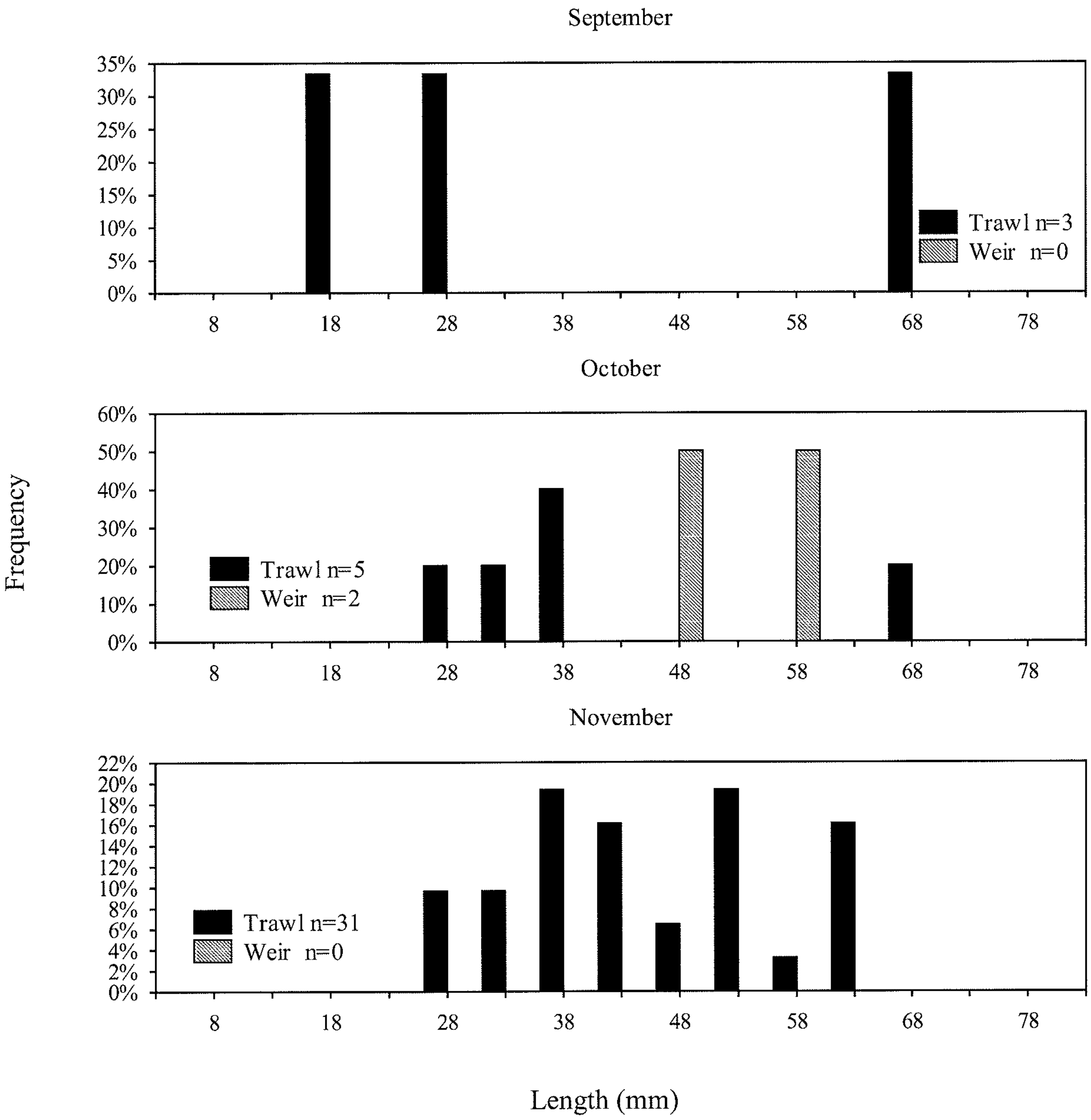


Figure 7-13. Continued.

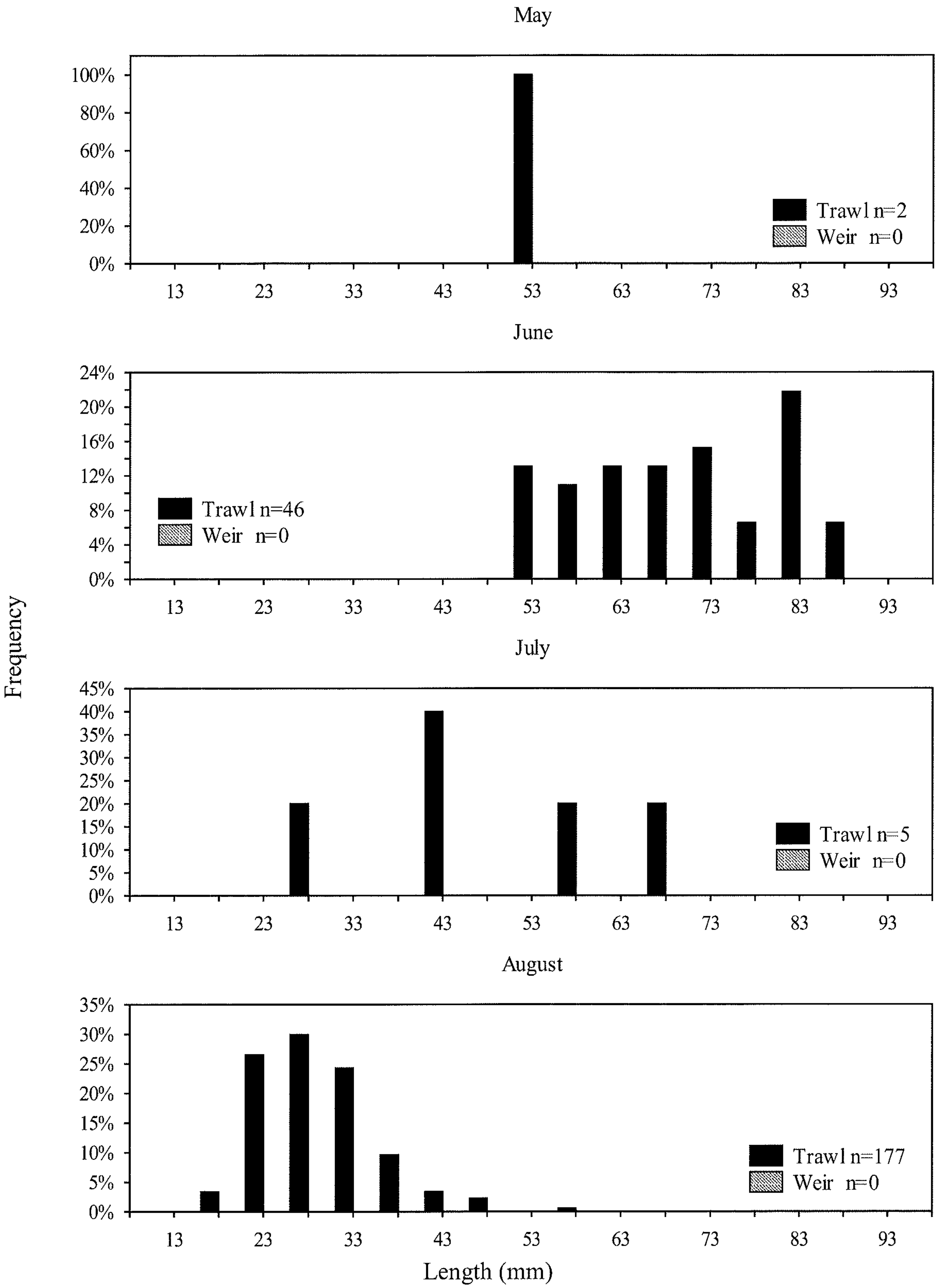


Figure 7-14. Size distribution of bay anchovy, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Commercial Township in 2008.

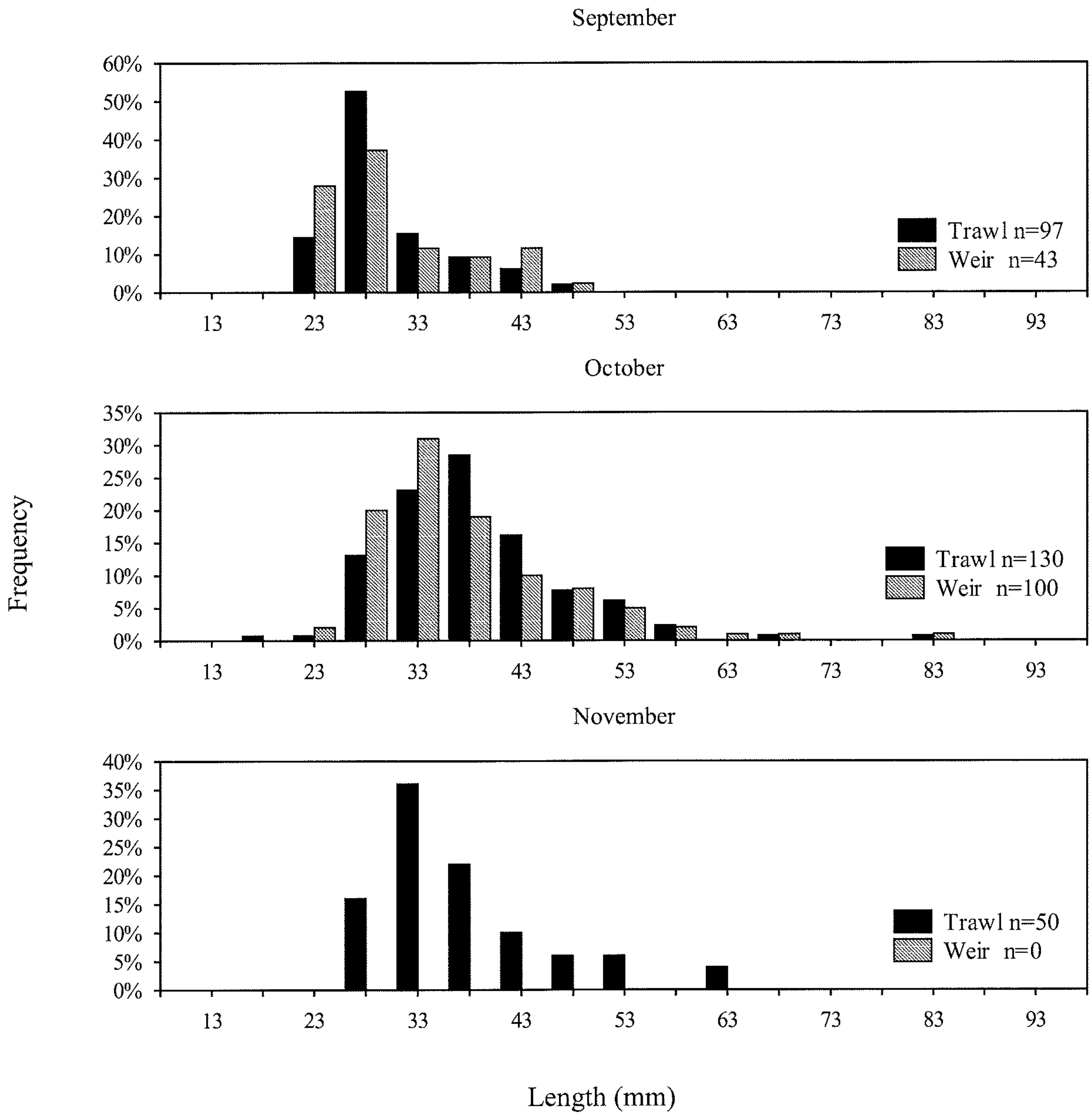


Figure 7-14. Continued.

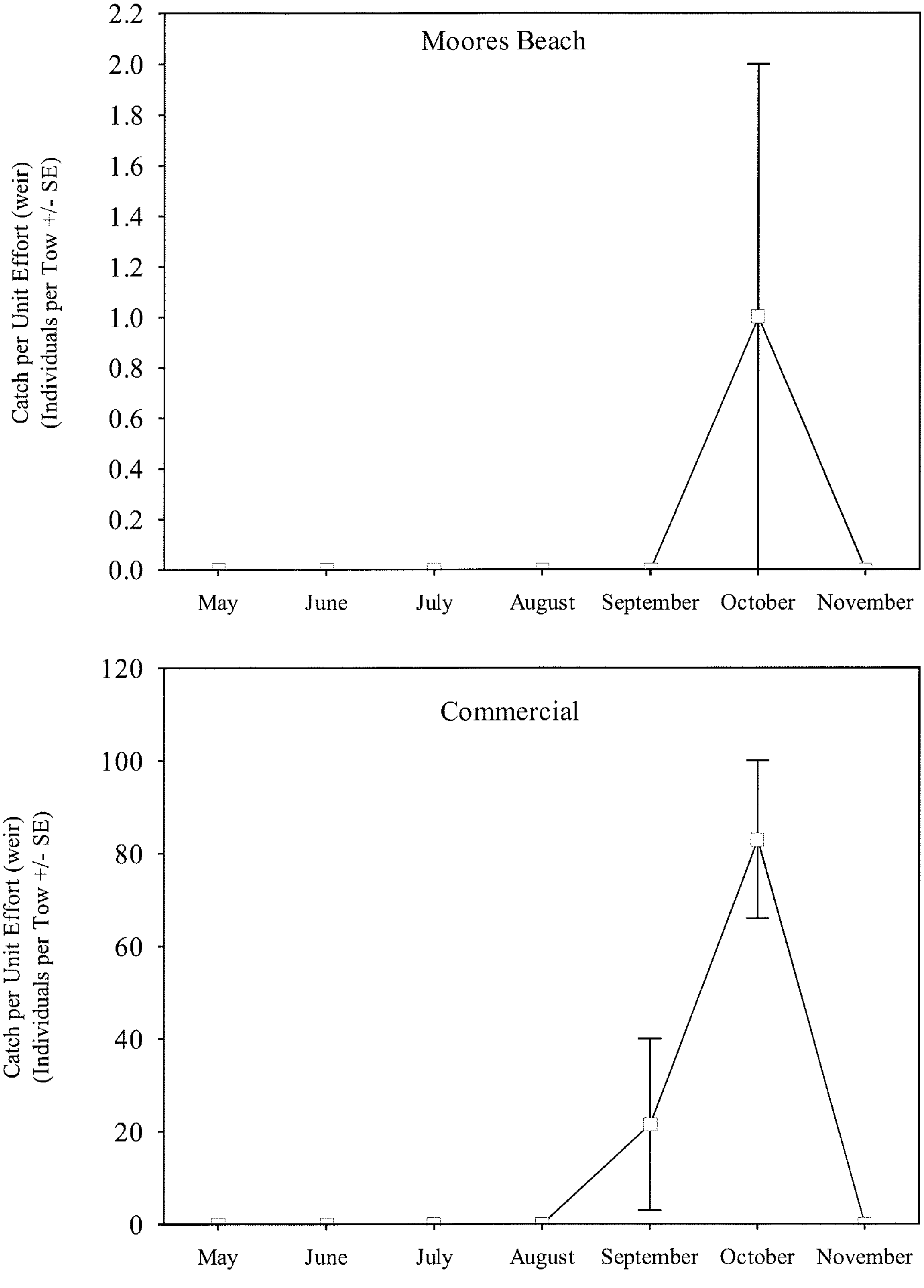


Figure 7-15. Monthly abundance for bay anchovy caught, in small marsh creeks with weirs, in the Lower Bay Region in 2008.

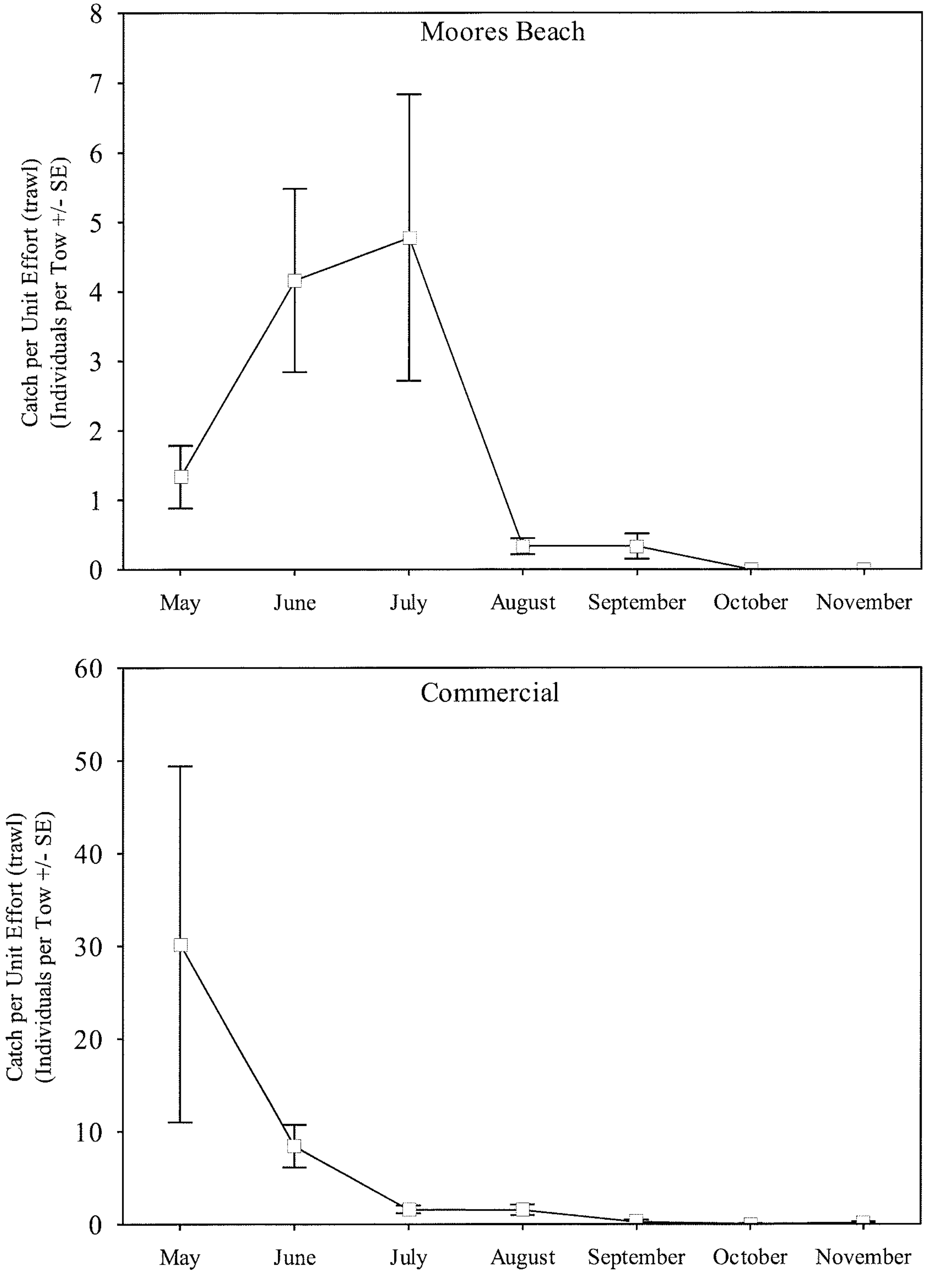


Figure 7-16. Monthly abundance for spot caught, in large marsh creeks with otter trawls, in the Lower Bay Region during 2008.

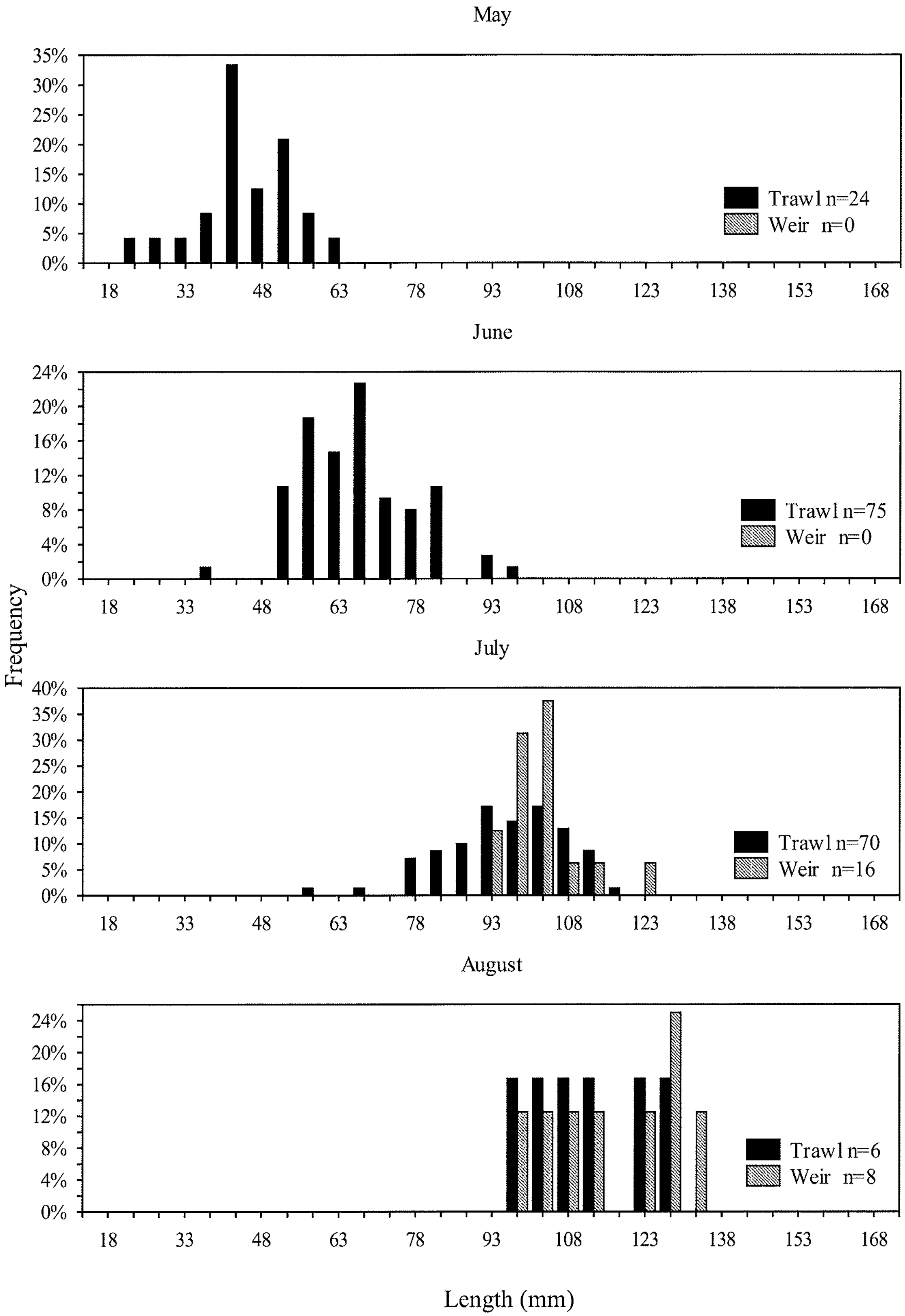


Figure 7-17. Size distribution of spot, from large marsh creeks (otter trawl) and small marsh creeks (weirs), at Moores Beach during 2008.

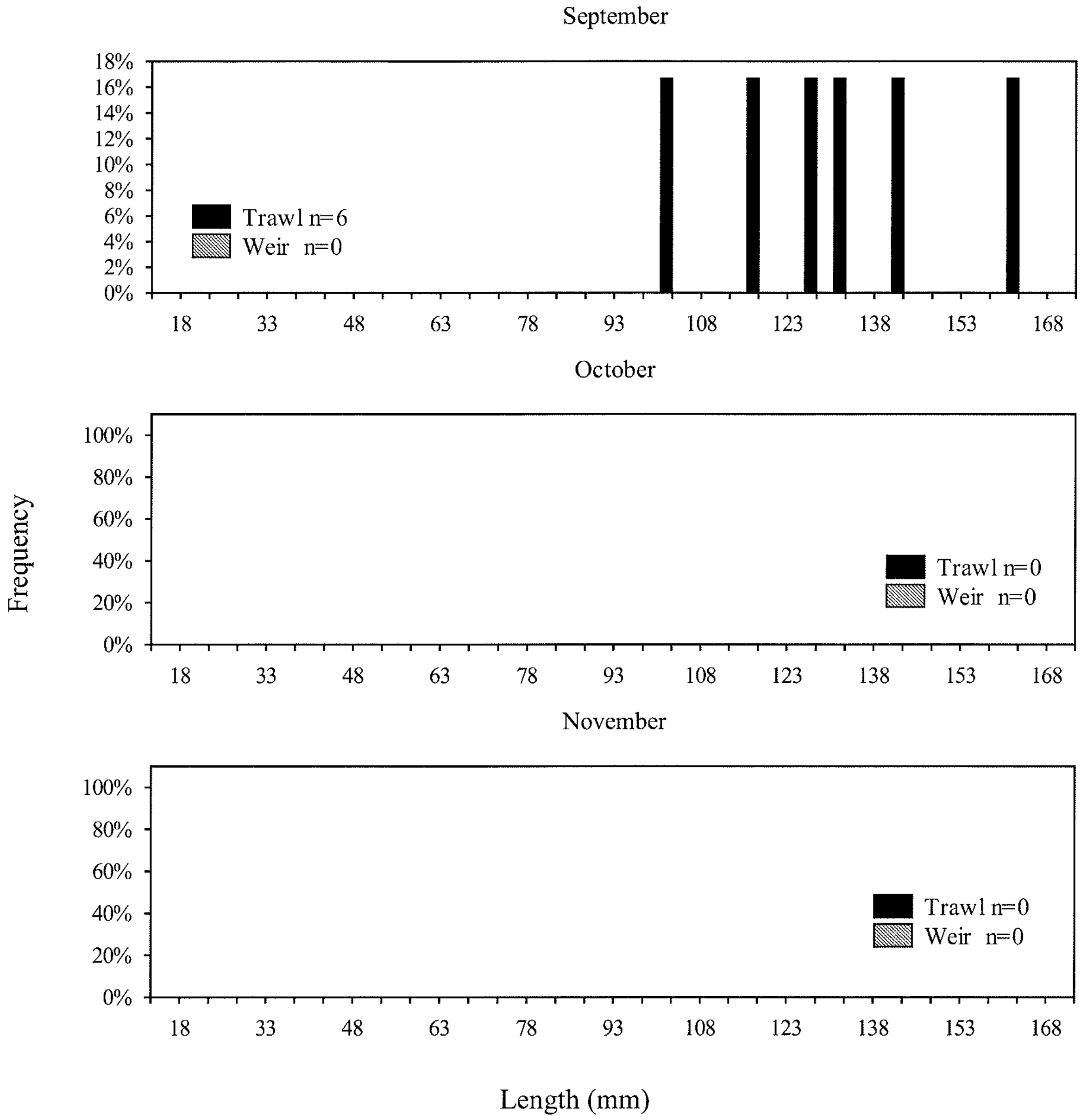


Figure 7-17. Continued.

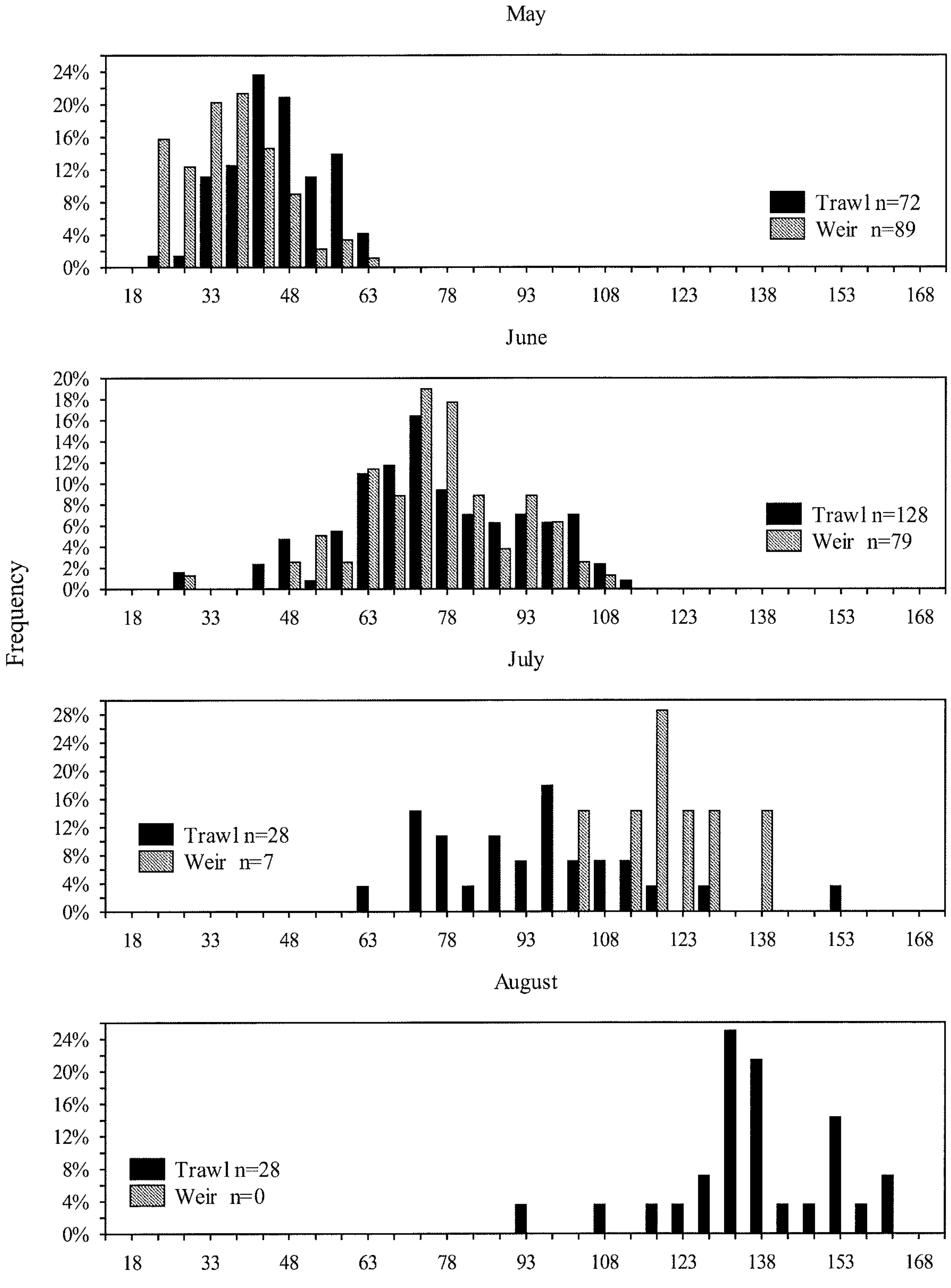


Figure 7-18. Size distribution of spot, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Commercial Township in 2008.

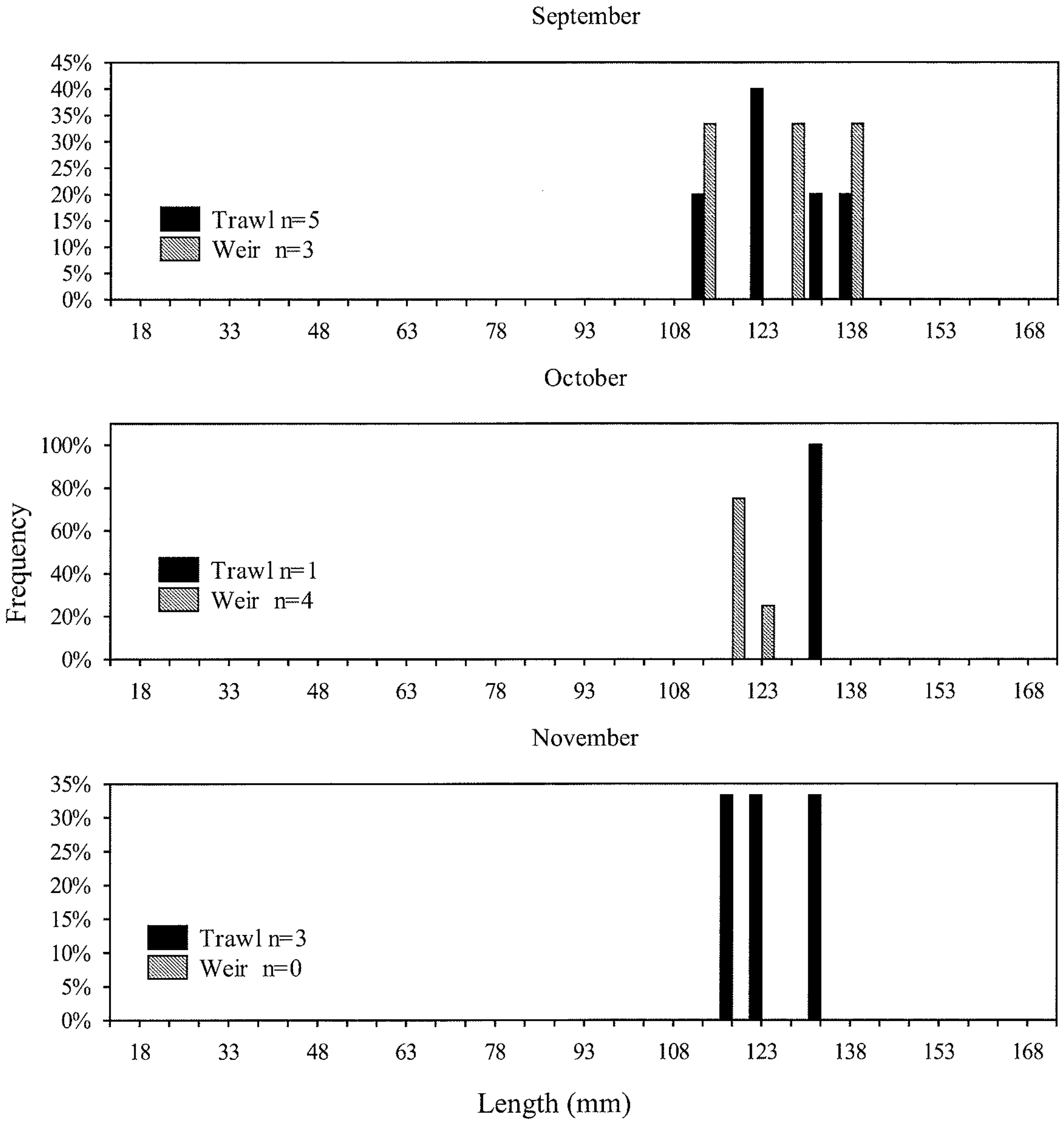


Figure 7-18. Continued.

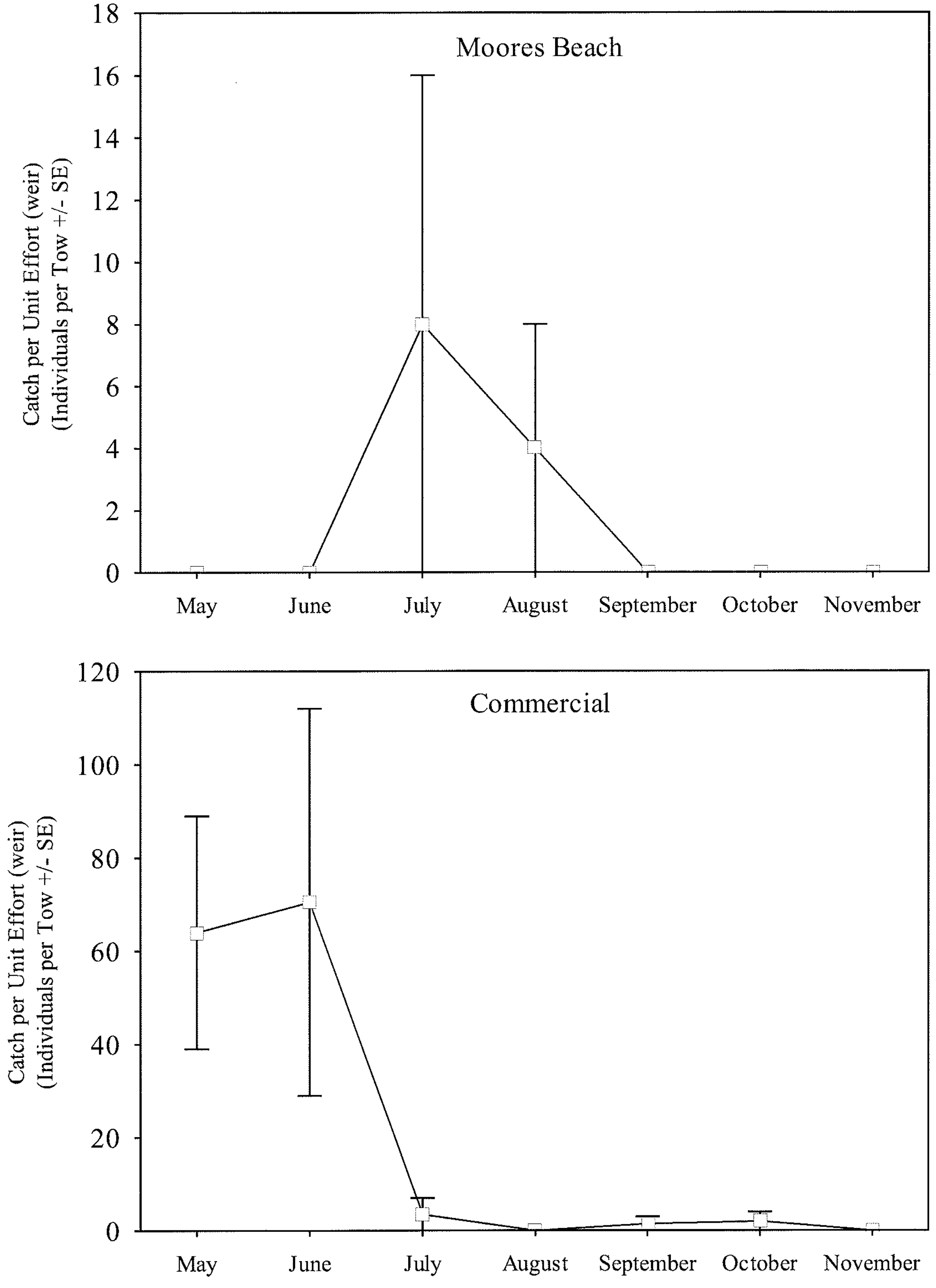


Figure 7-19. Monthly abundance for spot caught, in small marsh creeks with weirs, in the Lower Bay Region in 2008.

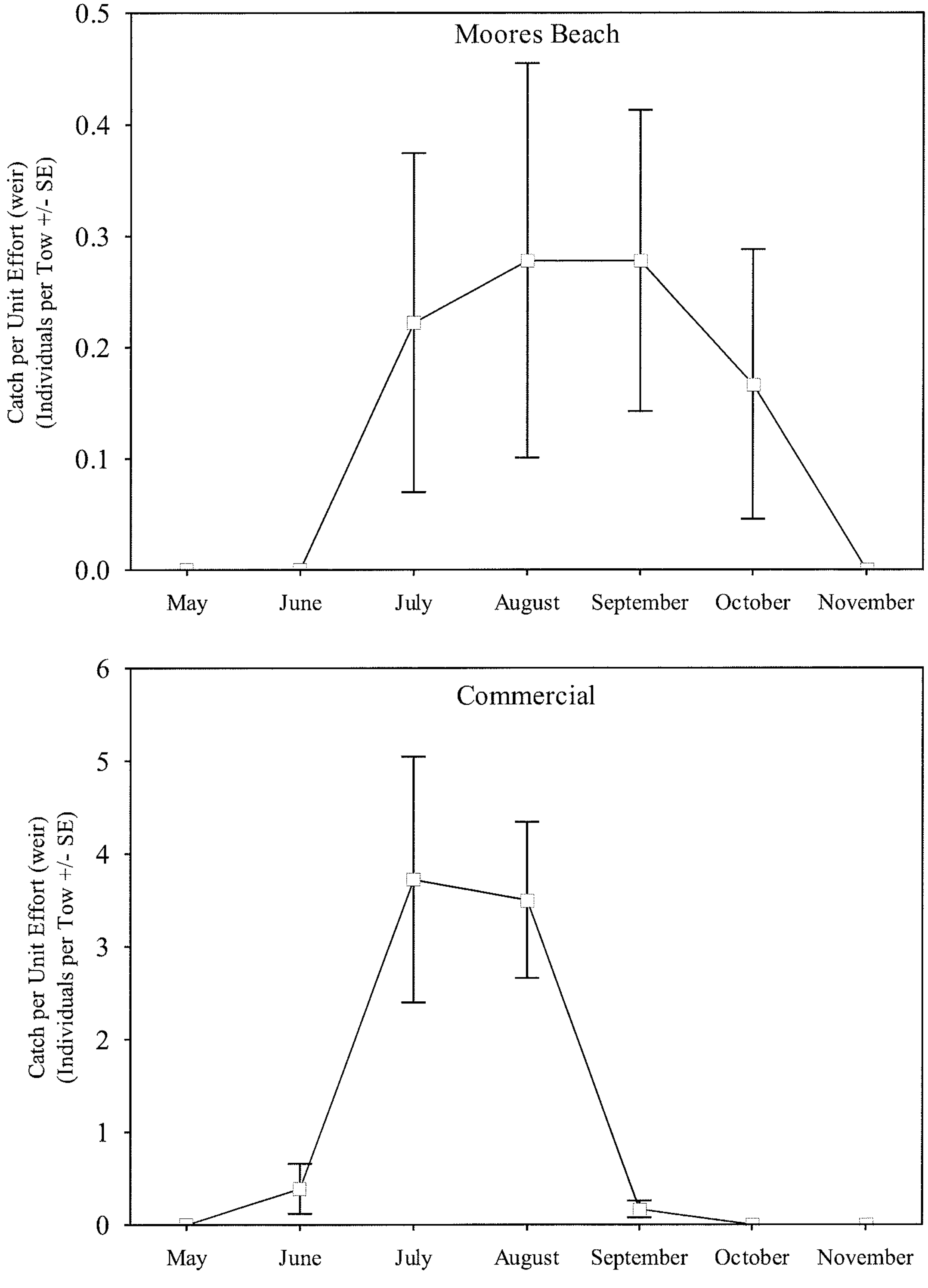


Figure 7-20. Monthly abundance for weakfish caught, in large marsh creeks with otter trawls, in the Lower Bay Region during 2008.

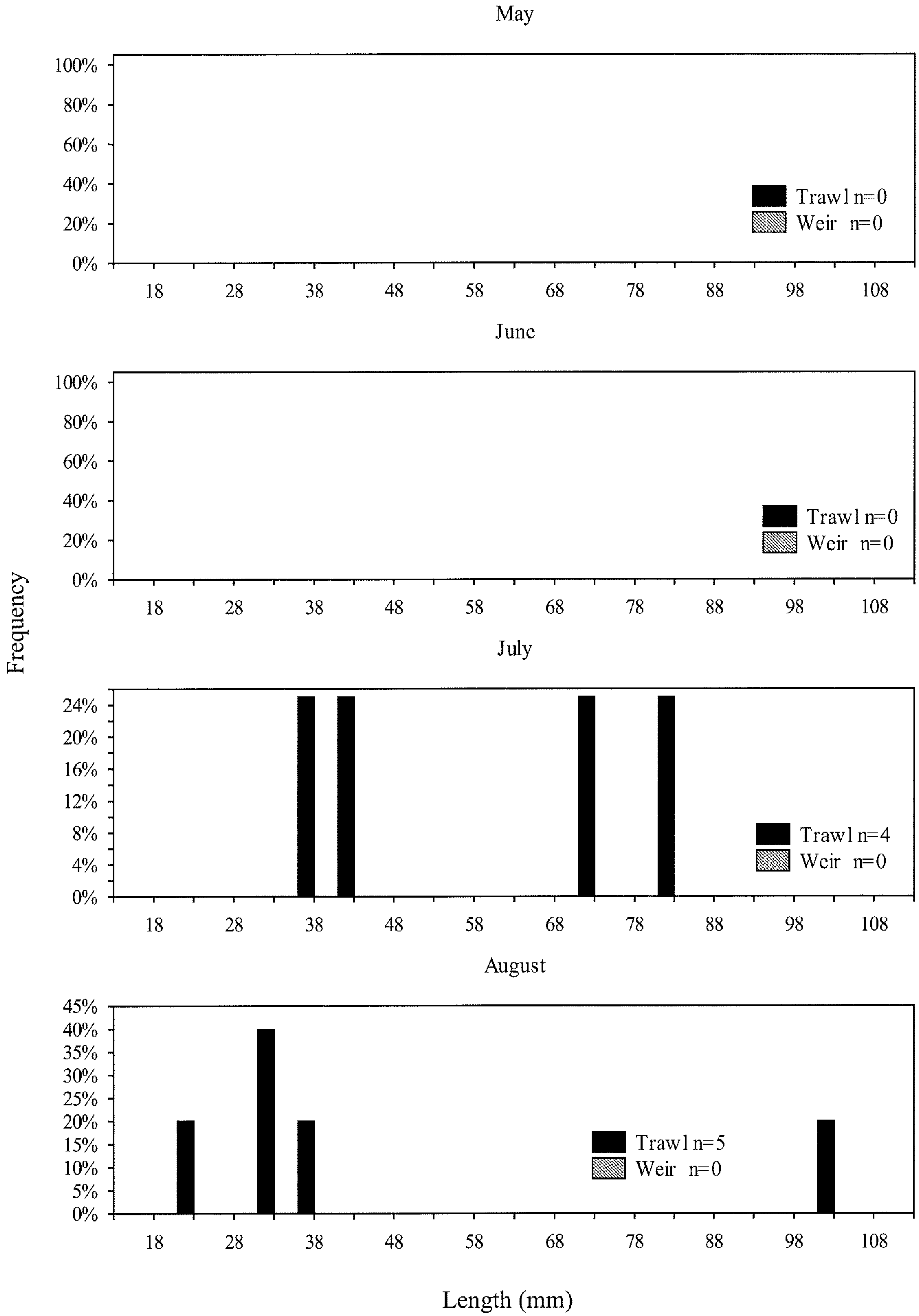


Figure 7-21. Size distribution of weakfish, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Moores Beach during 2008.

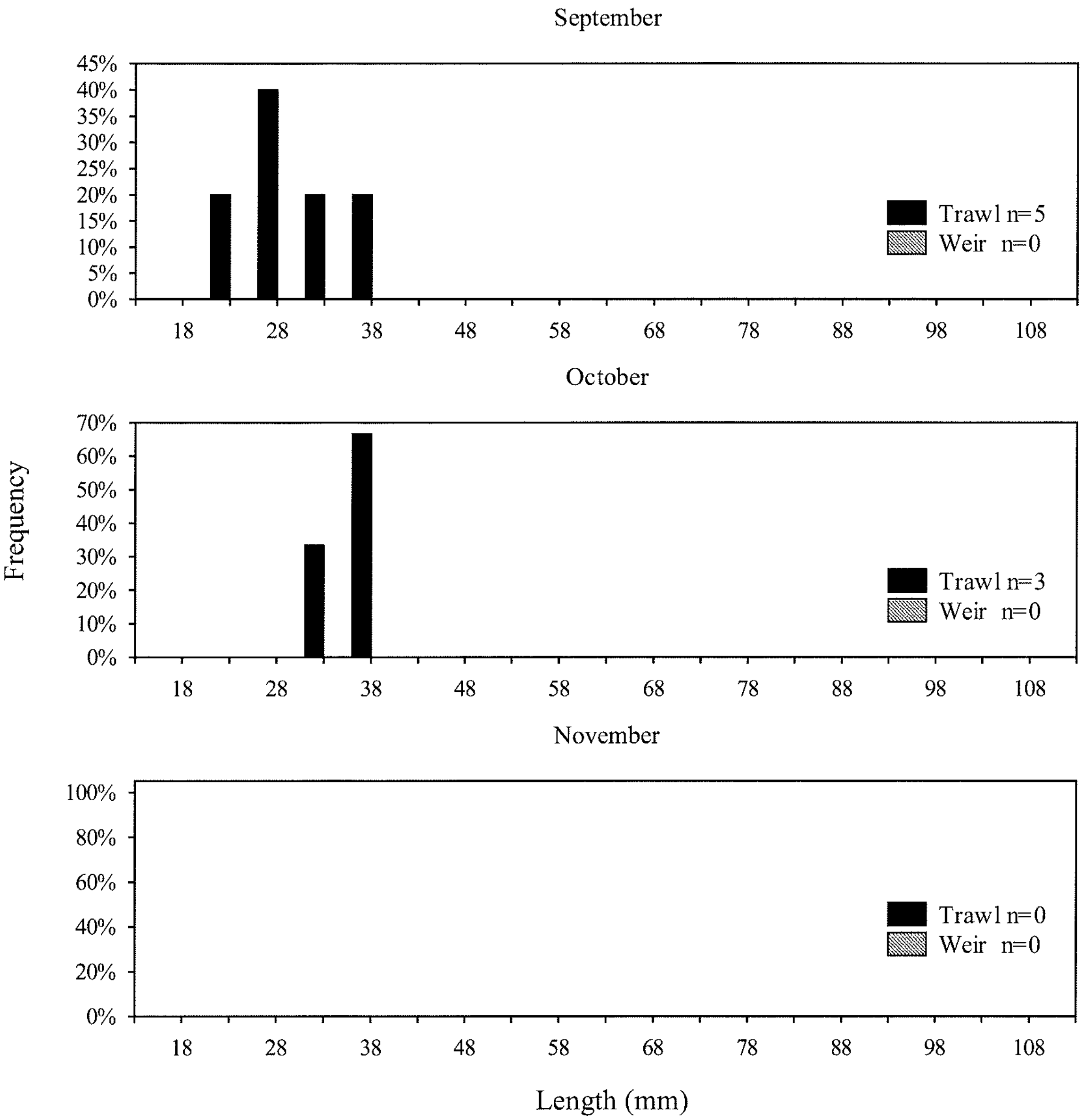


Figure 7-21. Continued.

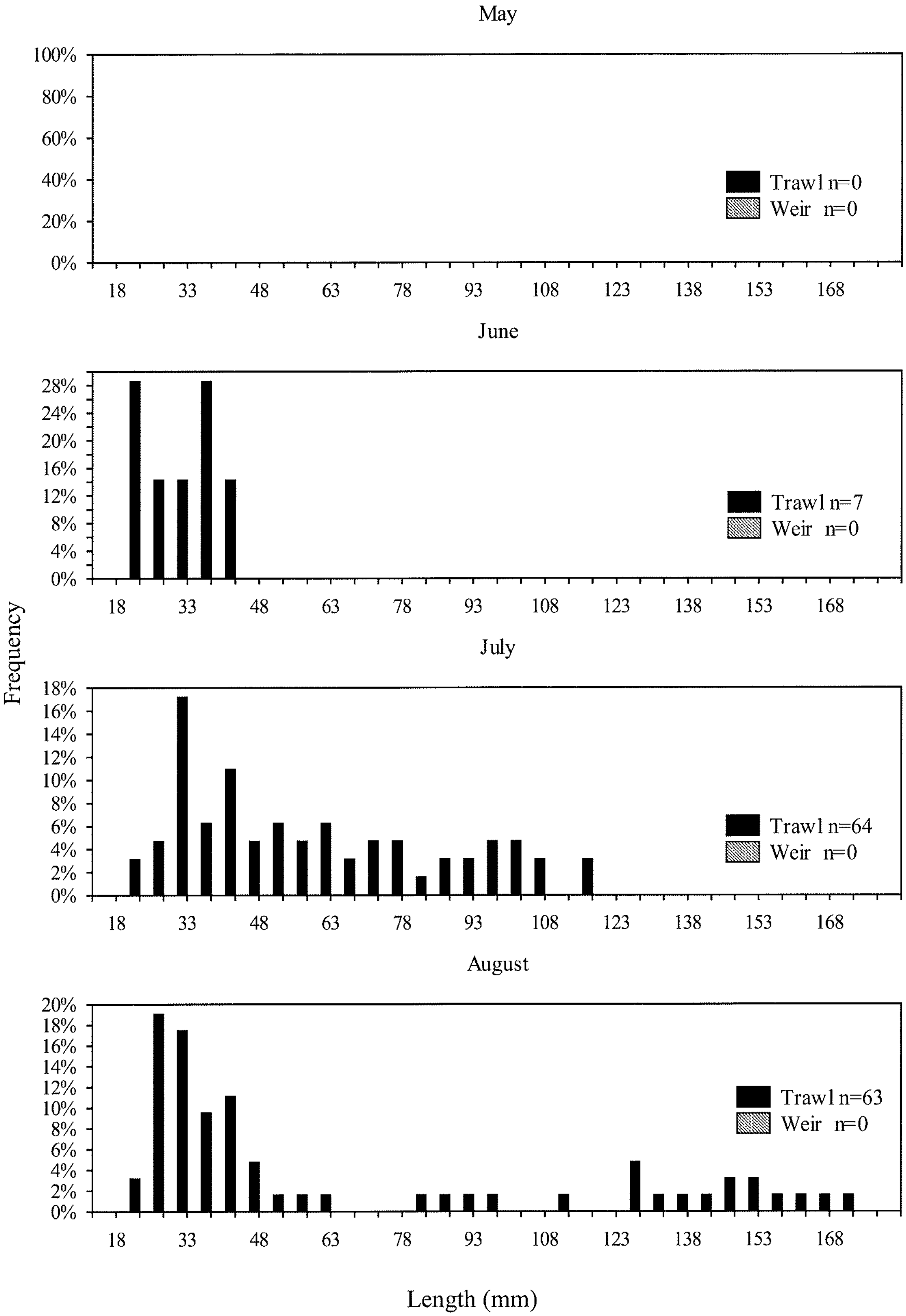


Figure 7-22. Size distribution of weakfish, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Commercial Township during 2008.

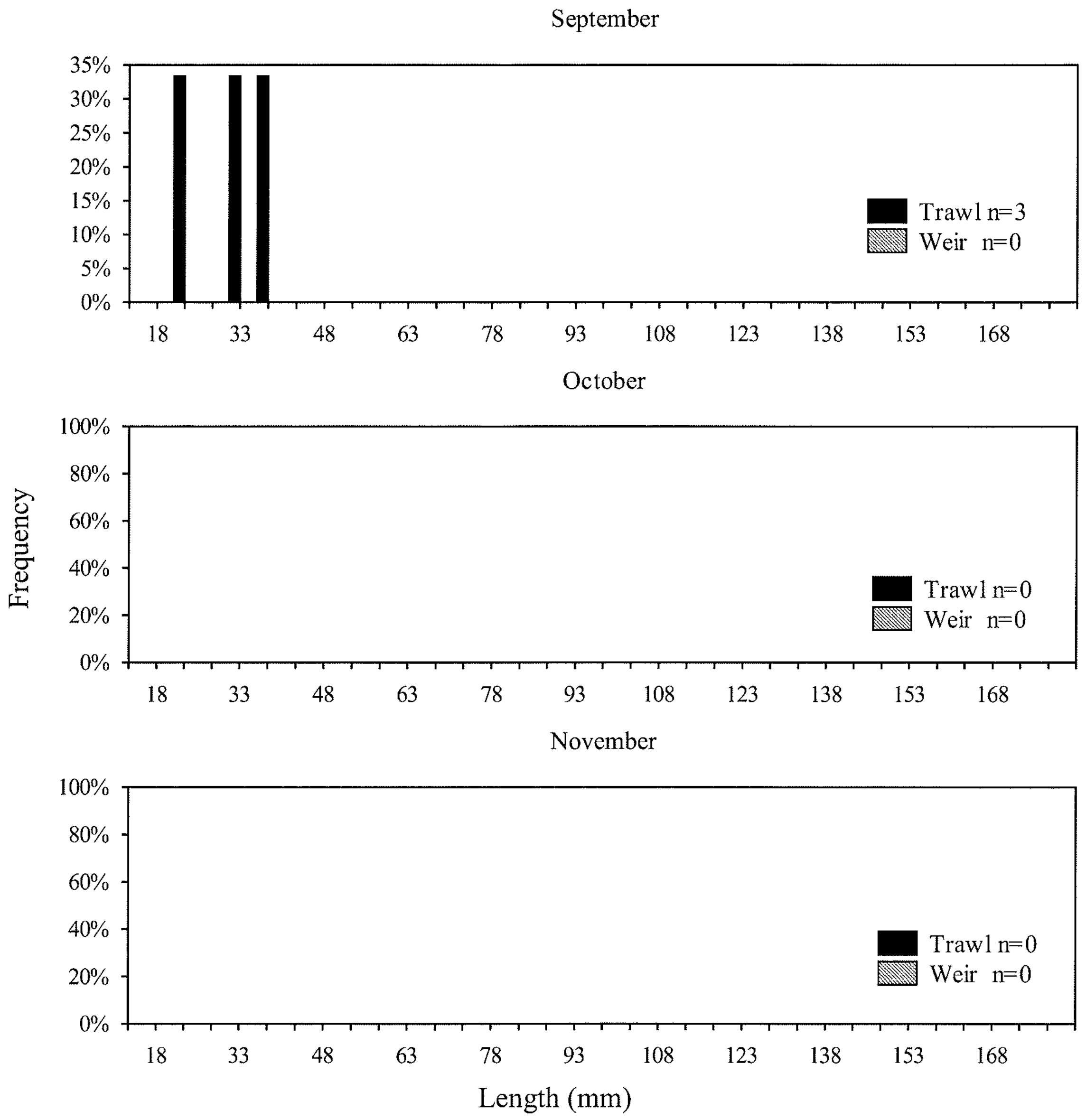


Figure 7-22. Continued.

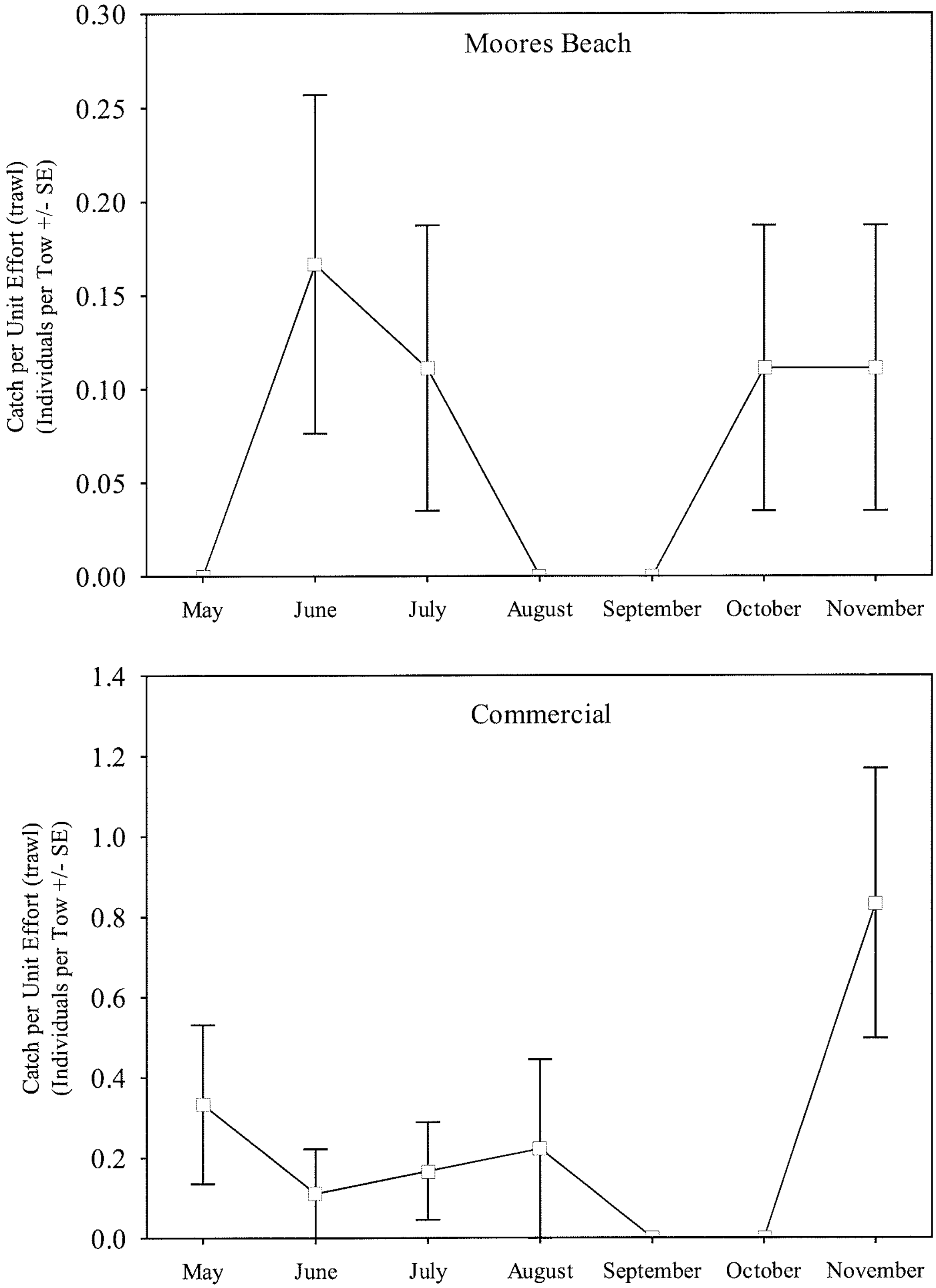


Figure 7-23. Monthly abundance for white perch caught, in large marsh creeks with otter trawls, the Lower Bay Region during 2008.

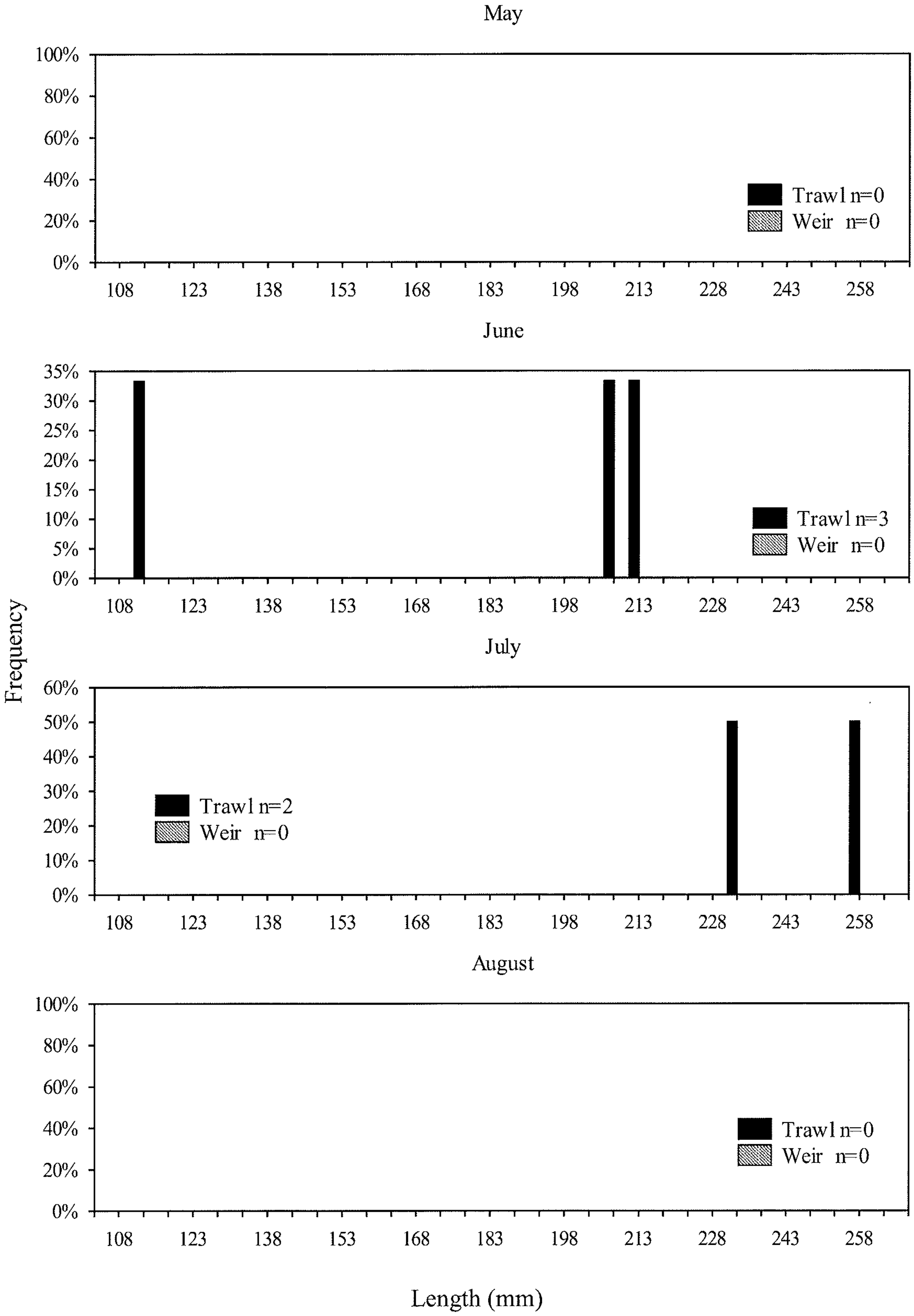
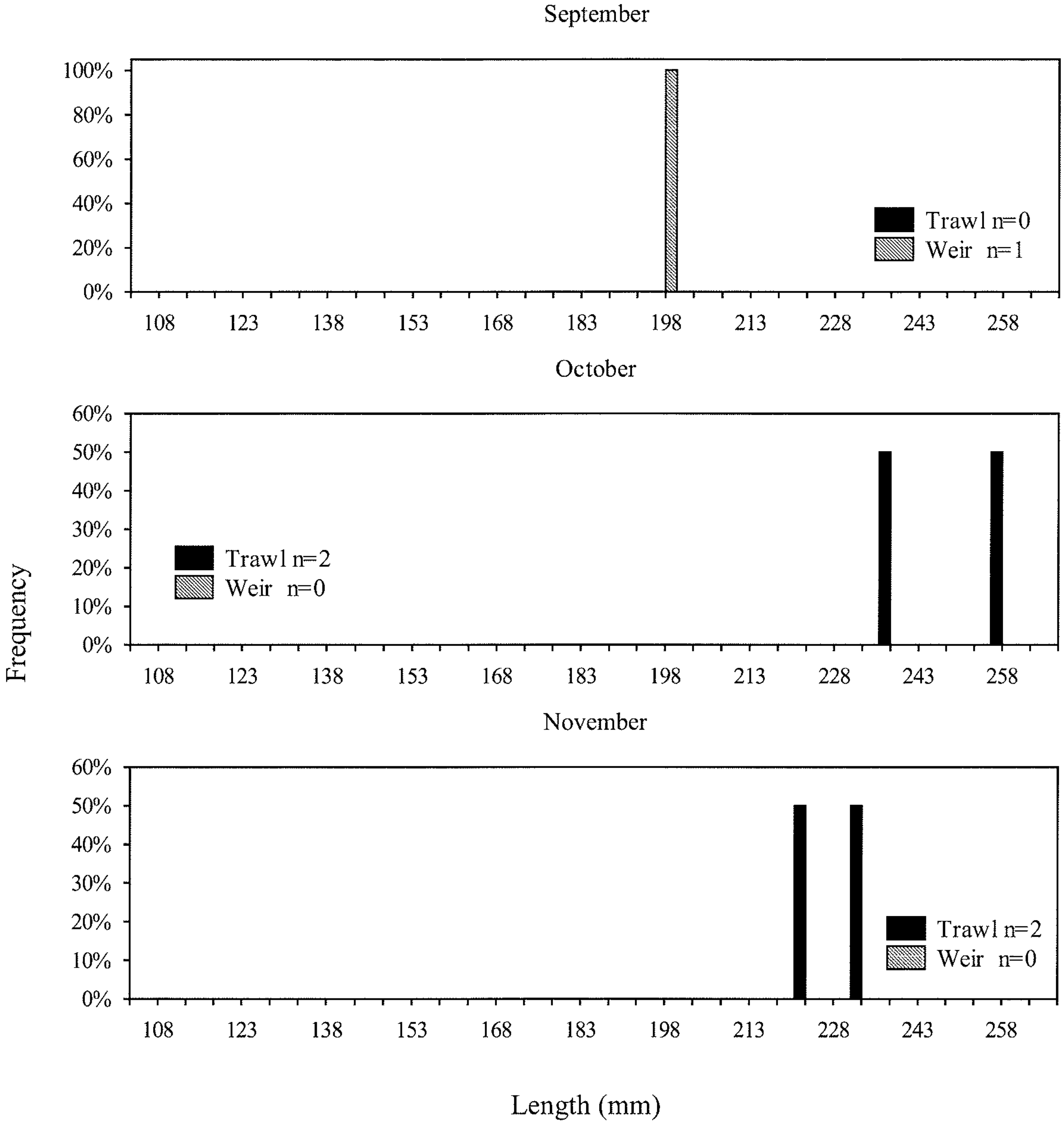


Figure 7-24. Size distribution of white perch, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Moores Beach in 2008.



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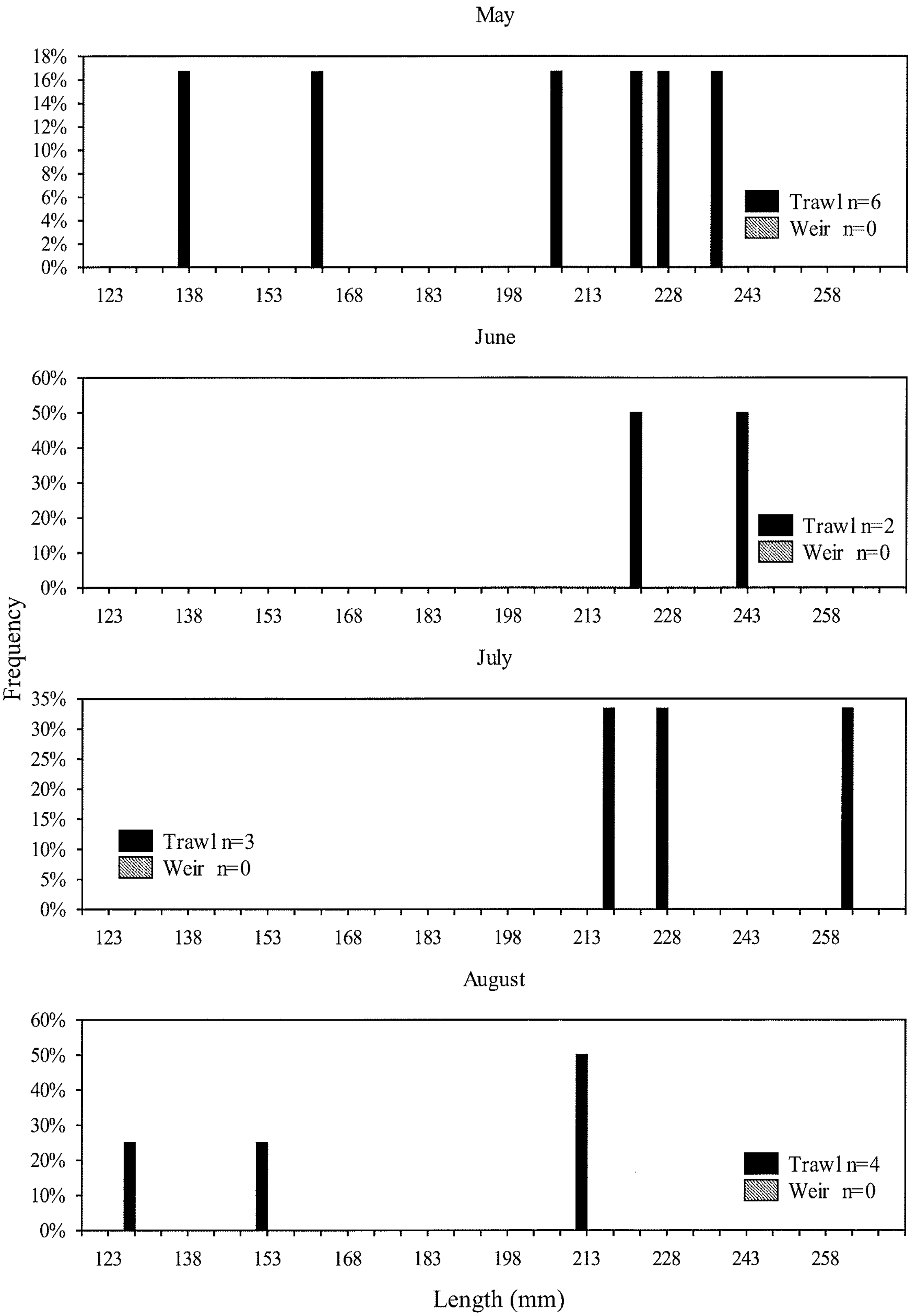
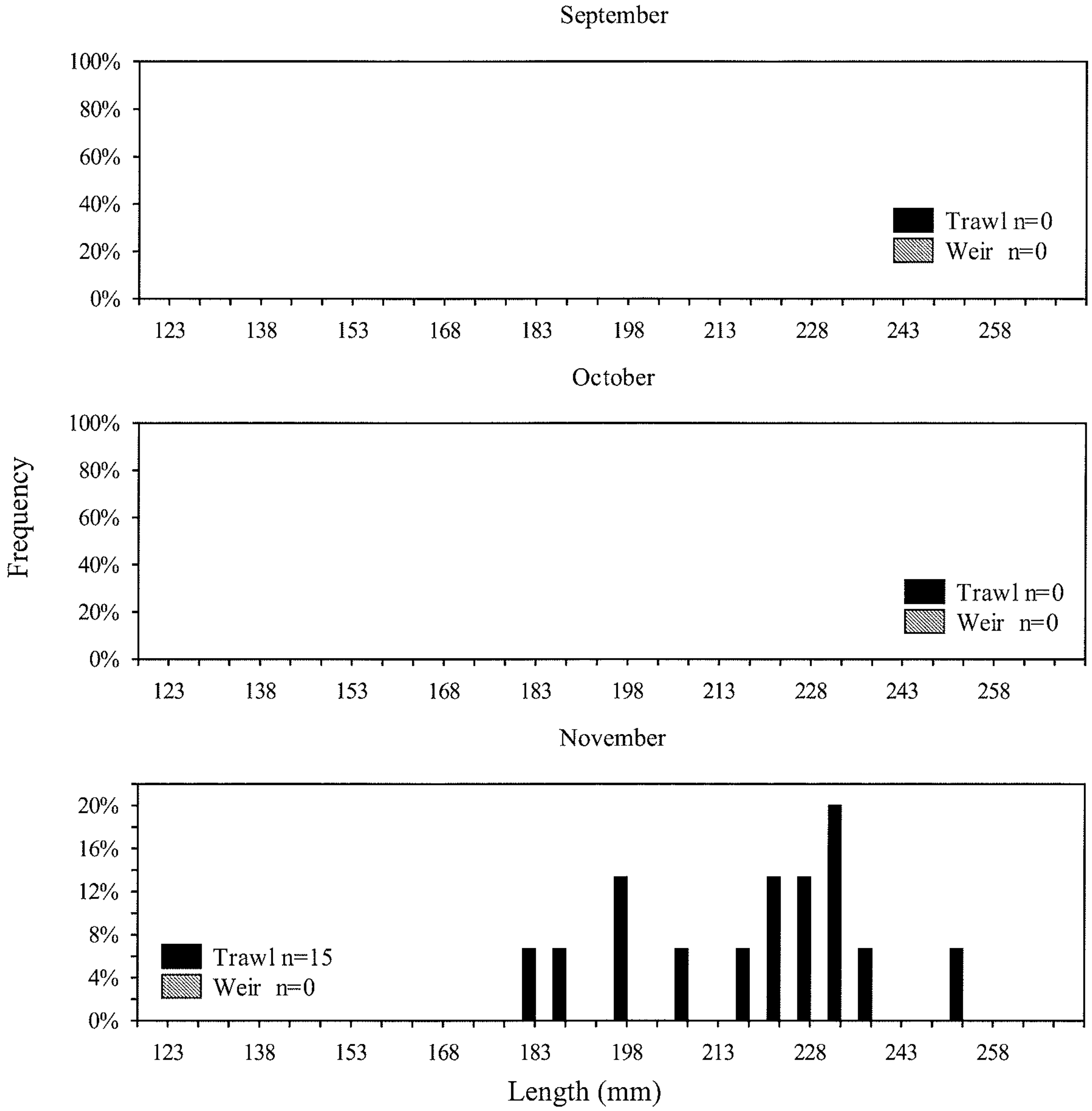


Figure 7-25. Size distribution of white perch, from large marsh creeks (otter trawl) and small marsh creeks (weir), at Commercial Township in 2008.



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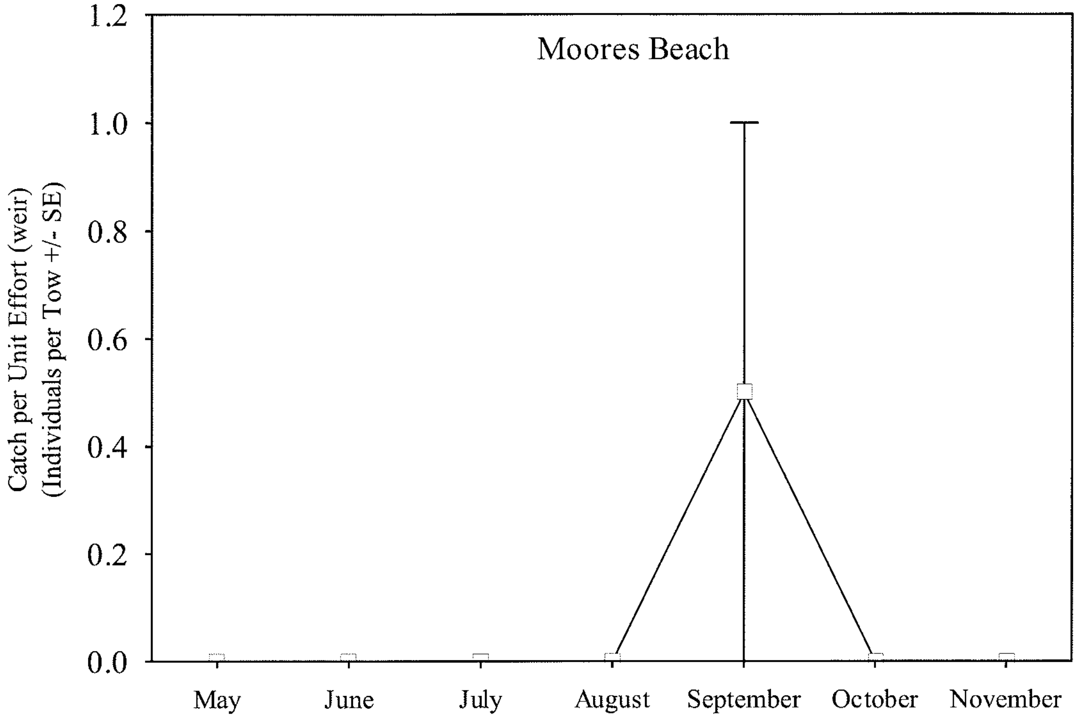


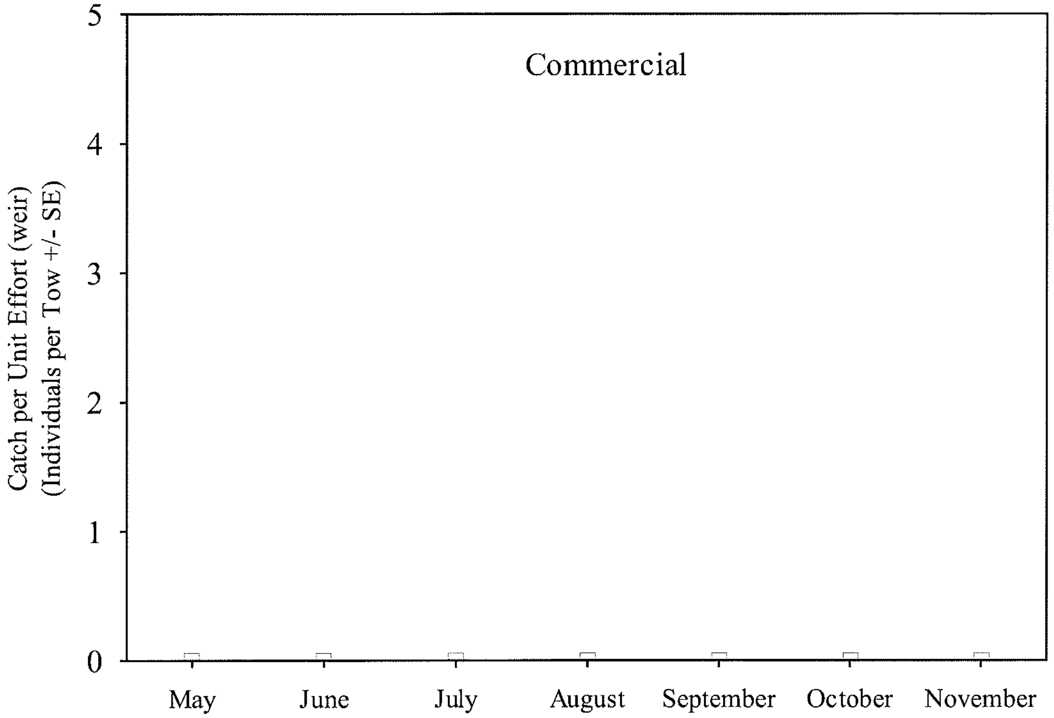


Figure 7-26. Monthly abundance for white perch caught in, small marsh creeks with weirs, in the Lower Bay Region in 2008.

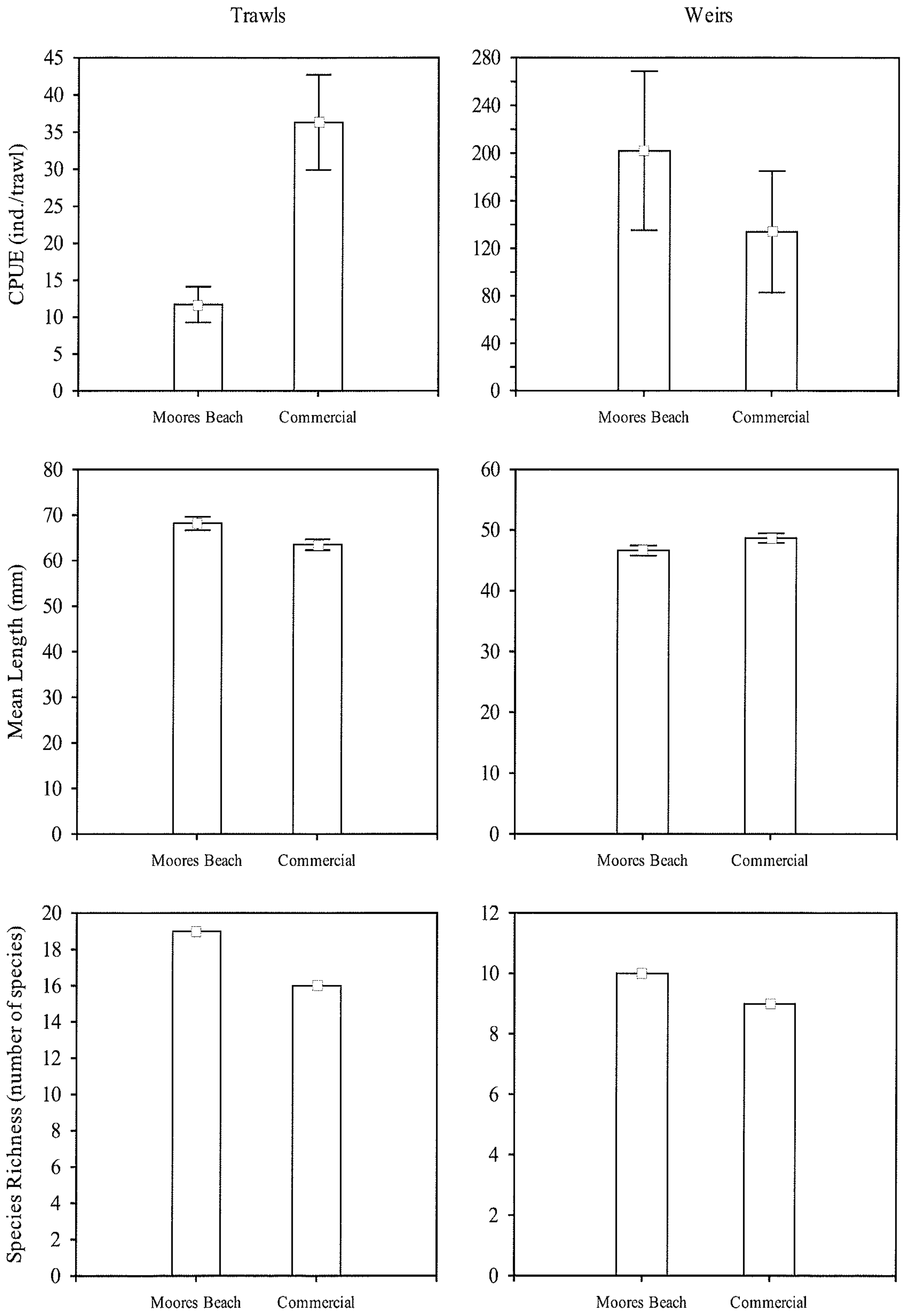


Figure 7-27. Comparisons of abundance, fish length, and species richness among reference (Moores Beach) and restored (Commercial Township) marshes from large and small creeks during 2008.

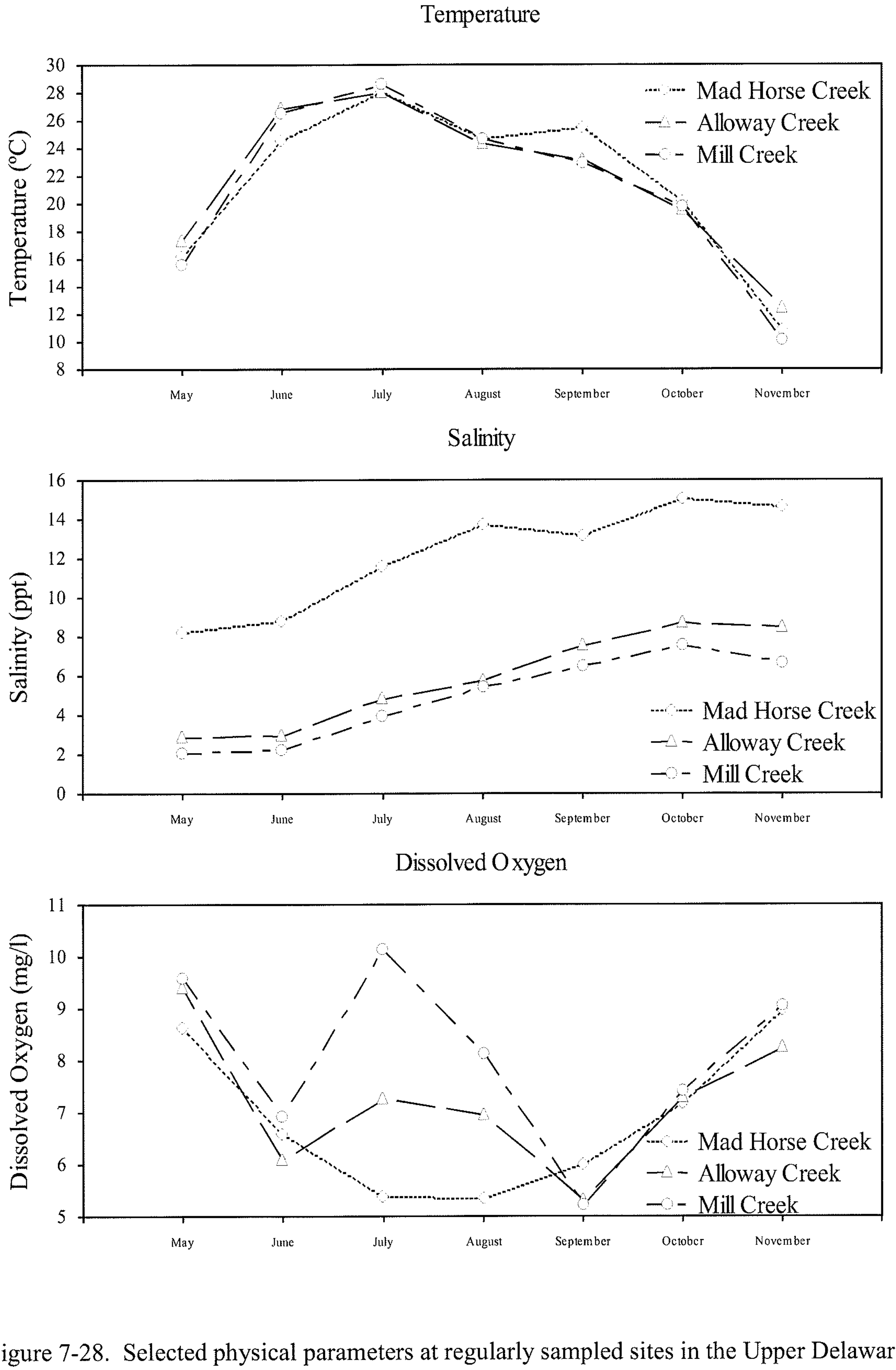


Figure 7-28. Selected physical parameters at regularly sampled sites in the Upper Delaware Bay Region during 2008.

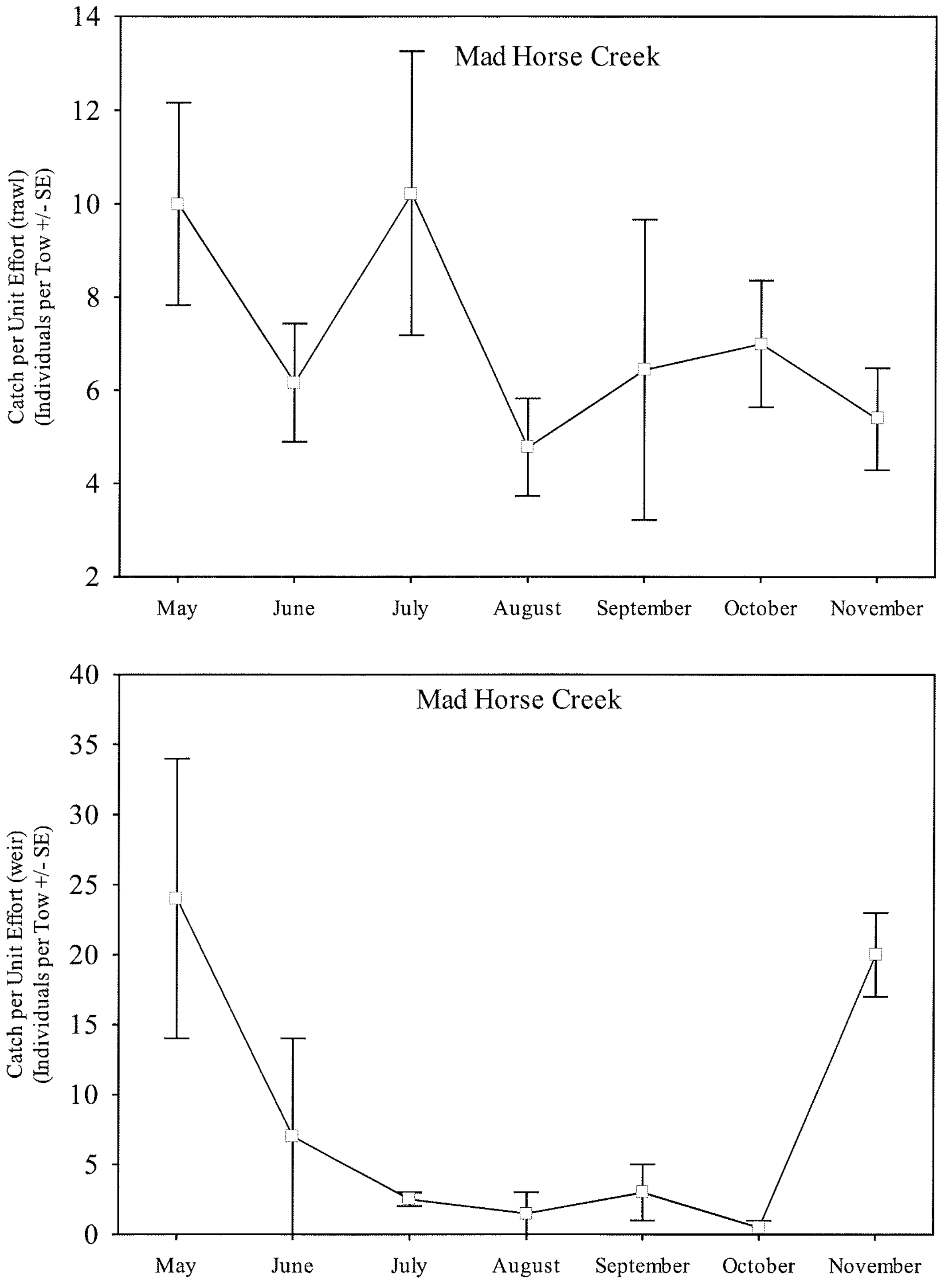


Figure 7-29. Abundance by month for all fish caught, in large marsh creeks (otter trawl) and in small marsh creeks (weir), at Mad Horse Creek during 2008.

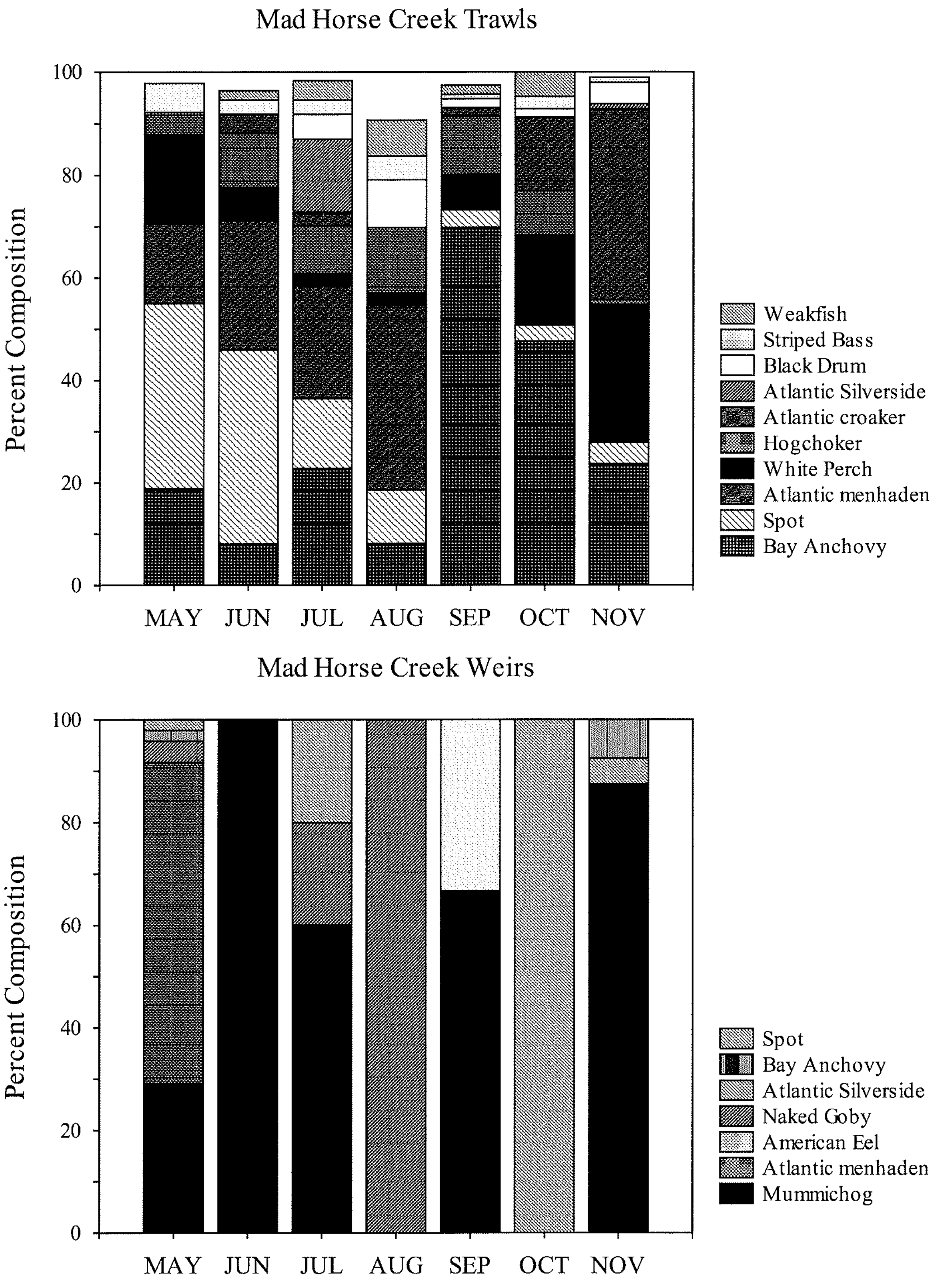


Figure 7-30. Monthly percent composition for fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), in Mad Horse Creek during 2008.

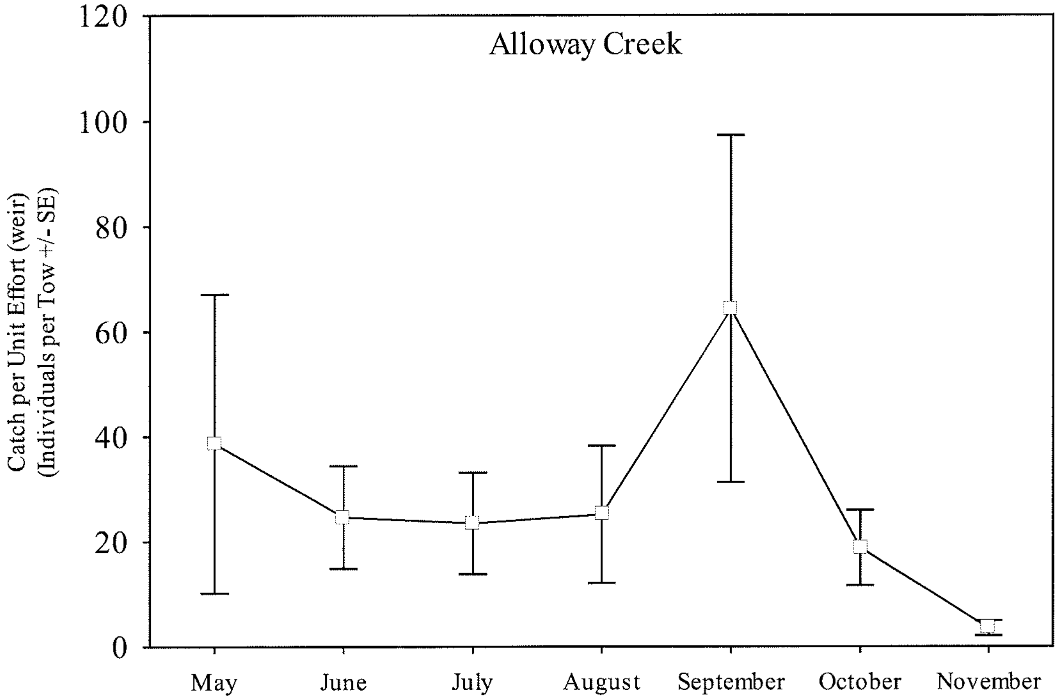


Figure 7-31. Monthly abundance for all fish caught, in small marsh creeks with weirs, at Alloways Creek during 2008.

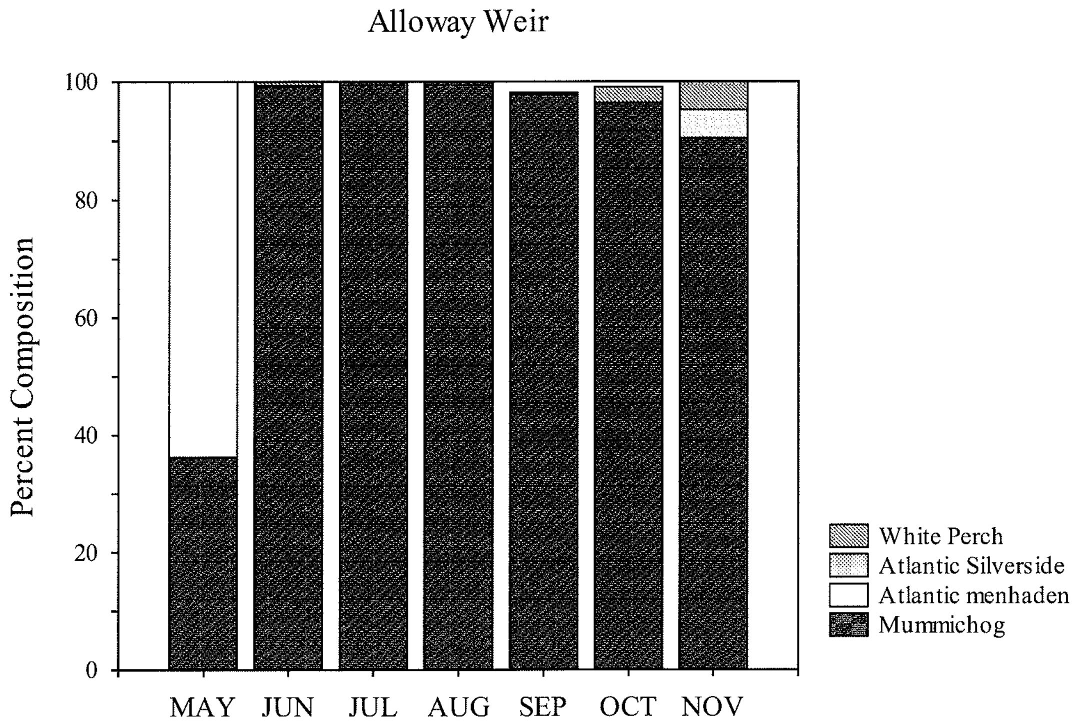


Figure 7-32. Monthly percent composition for fish caught, in small marsh creeks (weir), in Alloway Creek during 2008.

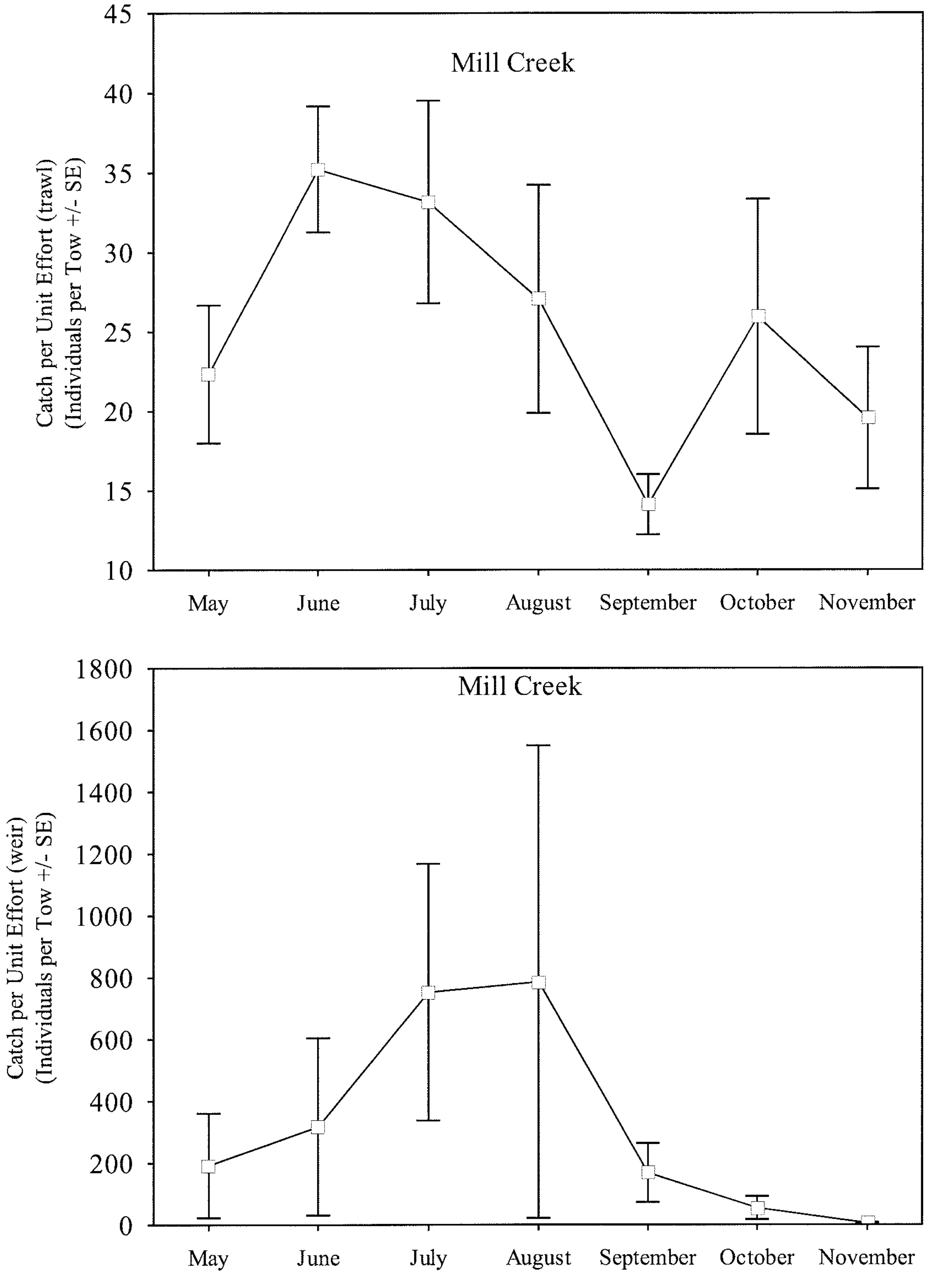


Figure 7-33. Abundance by month for all fish caught, in large marsh creeks (otter trawl) and in small marsh creeks (weir), at Mill Creek during 2008.

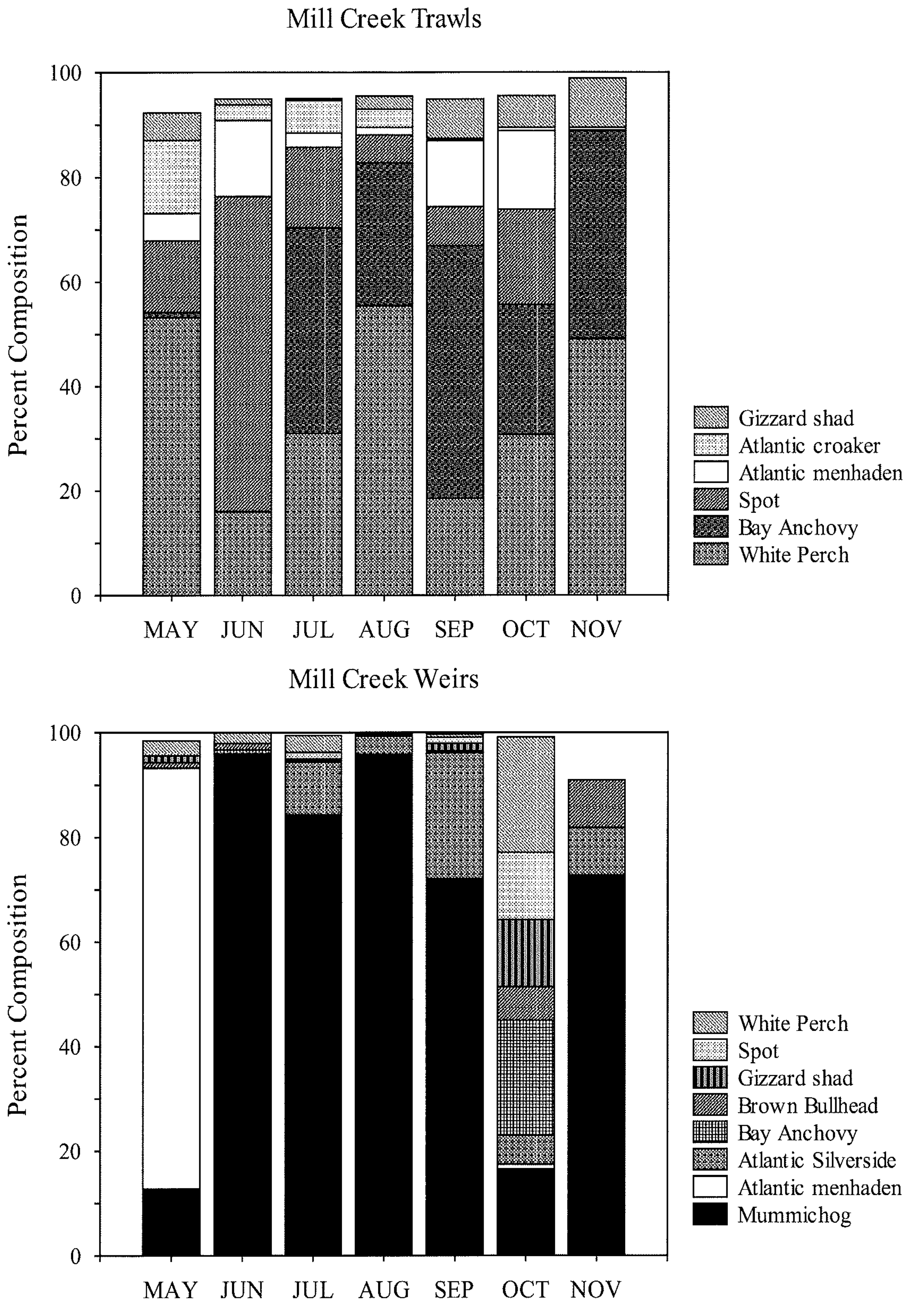


Figure 7-34. Monthly percent composition for fish caught, in large marsh creeks (otter trawl) and small marsh creeks (weir), in Mill Creek during 2008.

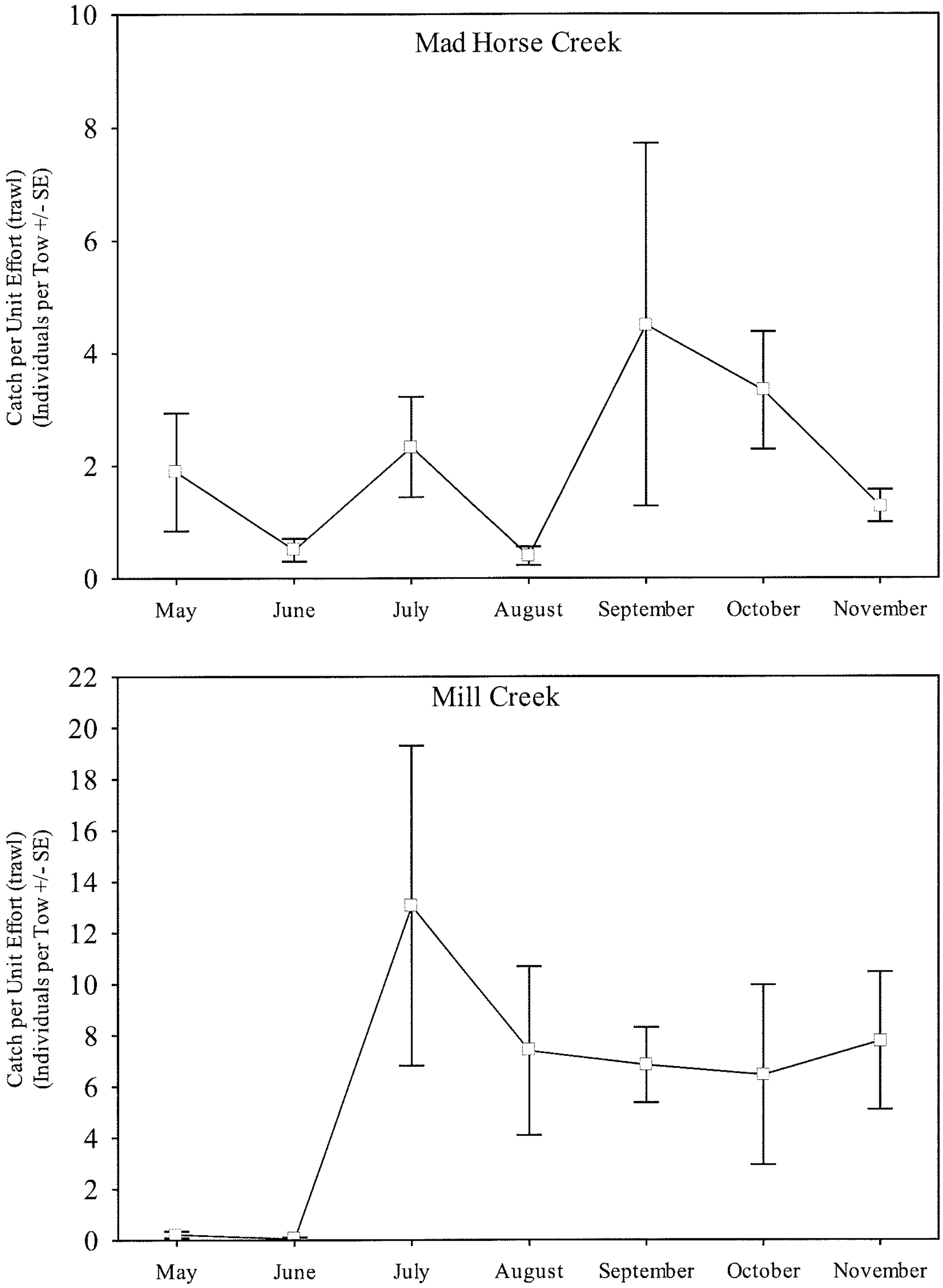


Figure 7-35. Monthly abundance for bay anchovy caught, in large marsh creeks with otter trawls, in the Upper Bay Region during 2008.

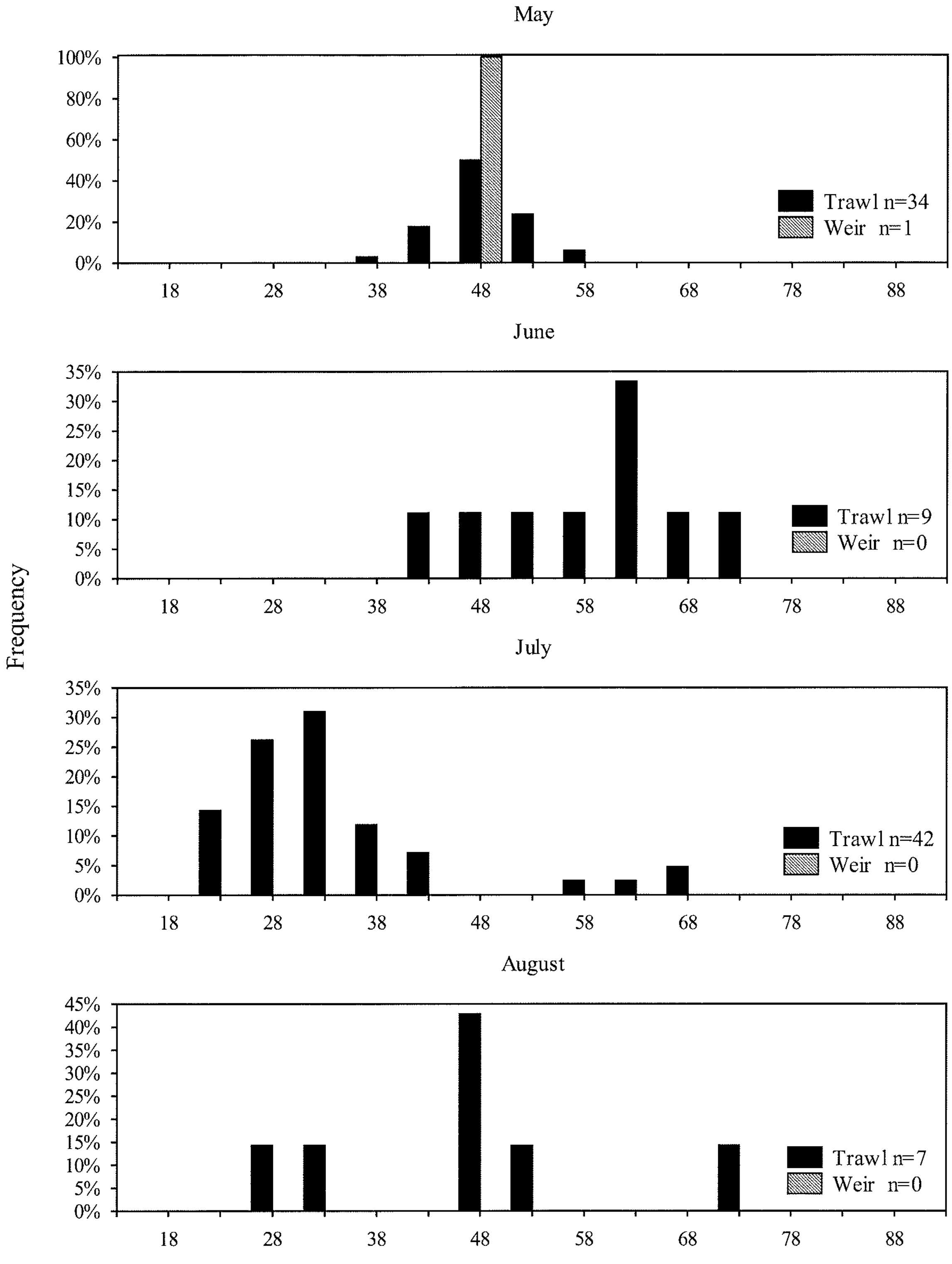
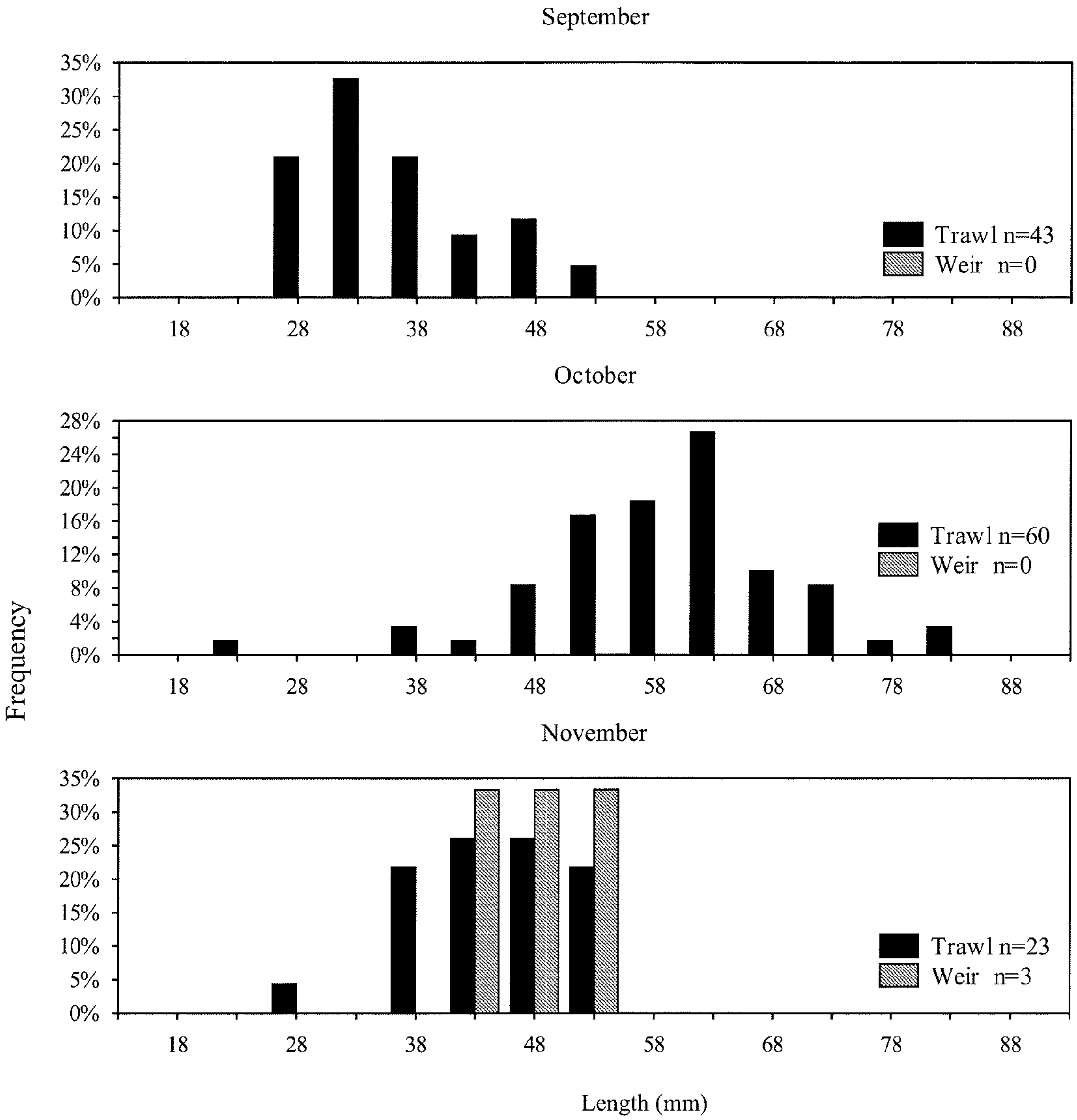


Figure 7-36. Size distribution of bay anchovy, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mad Horse Creek during 2008.



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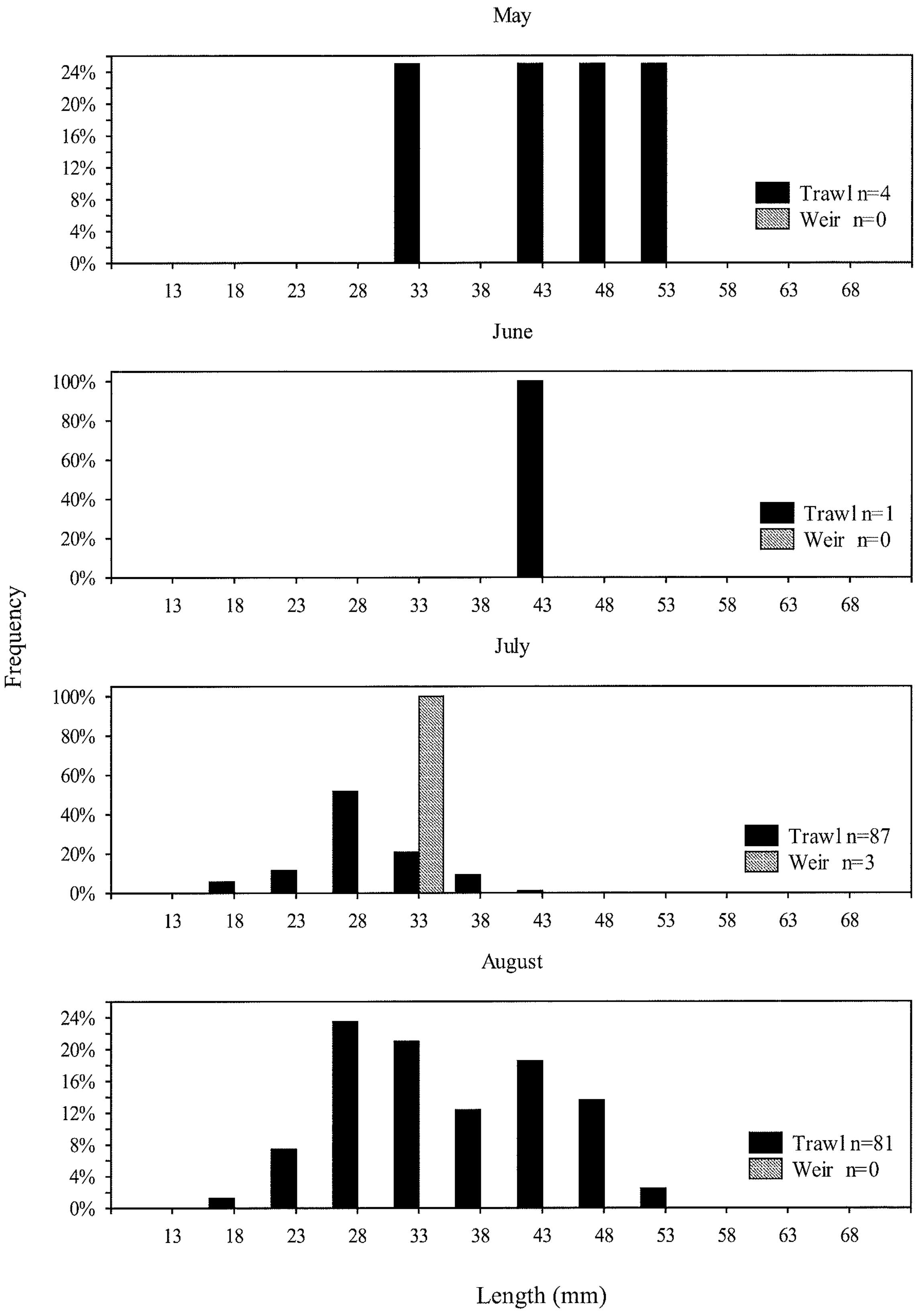
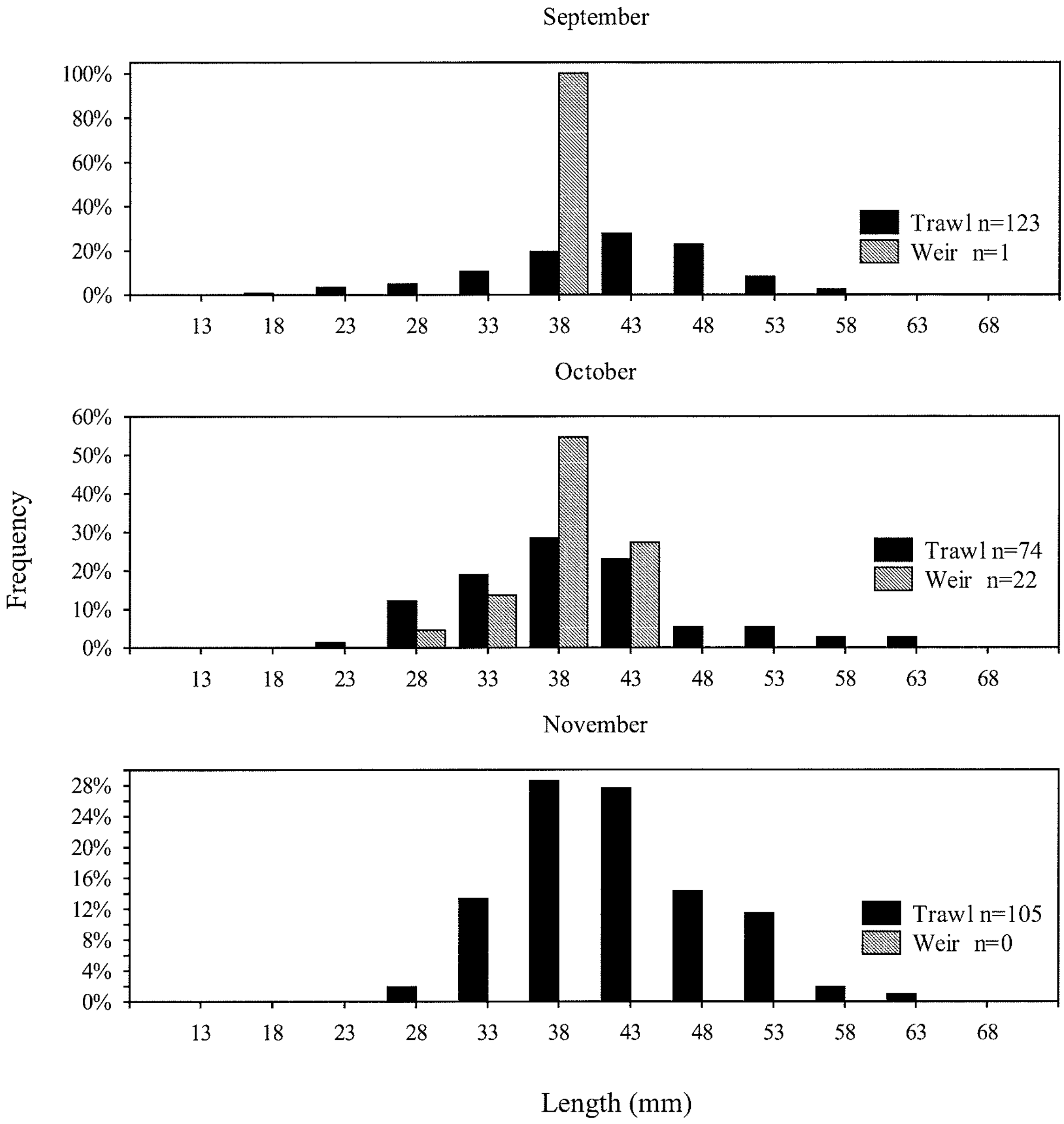


Figure 7-37. Size distribution of bay anchovy, collected in large marsh creeks (otter trawl) and small marsh creeks (weirs), at Mill Creek in 2008.



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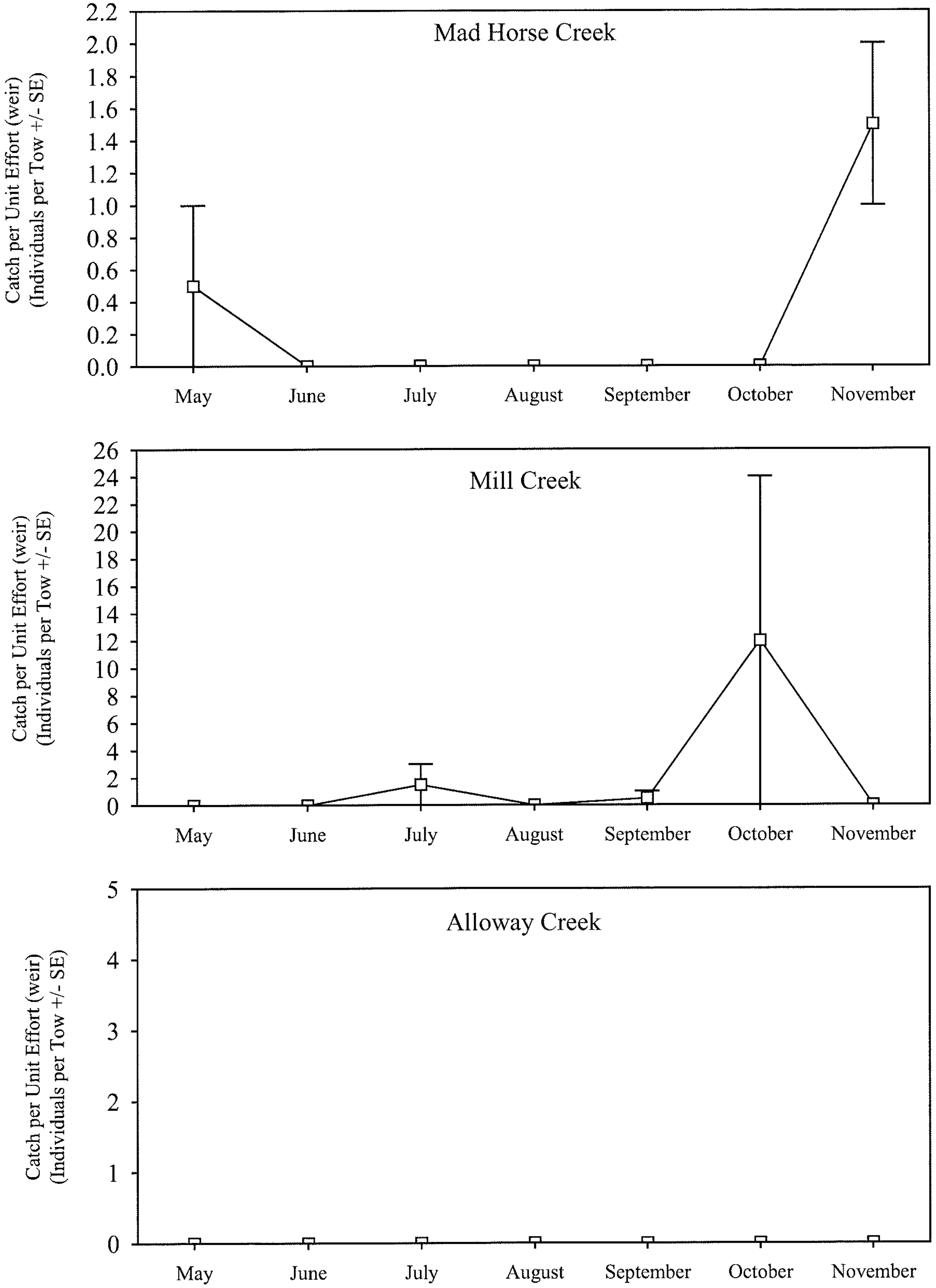


Figure 7-38. Monthly abundance for bay anchovy caught, in small marsh creeks with weirs, in the Upper Bay Region in 2008.

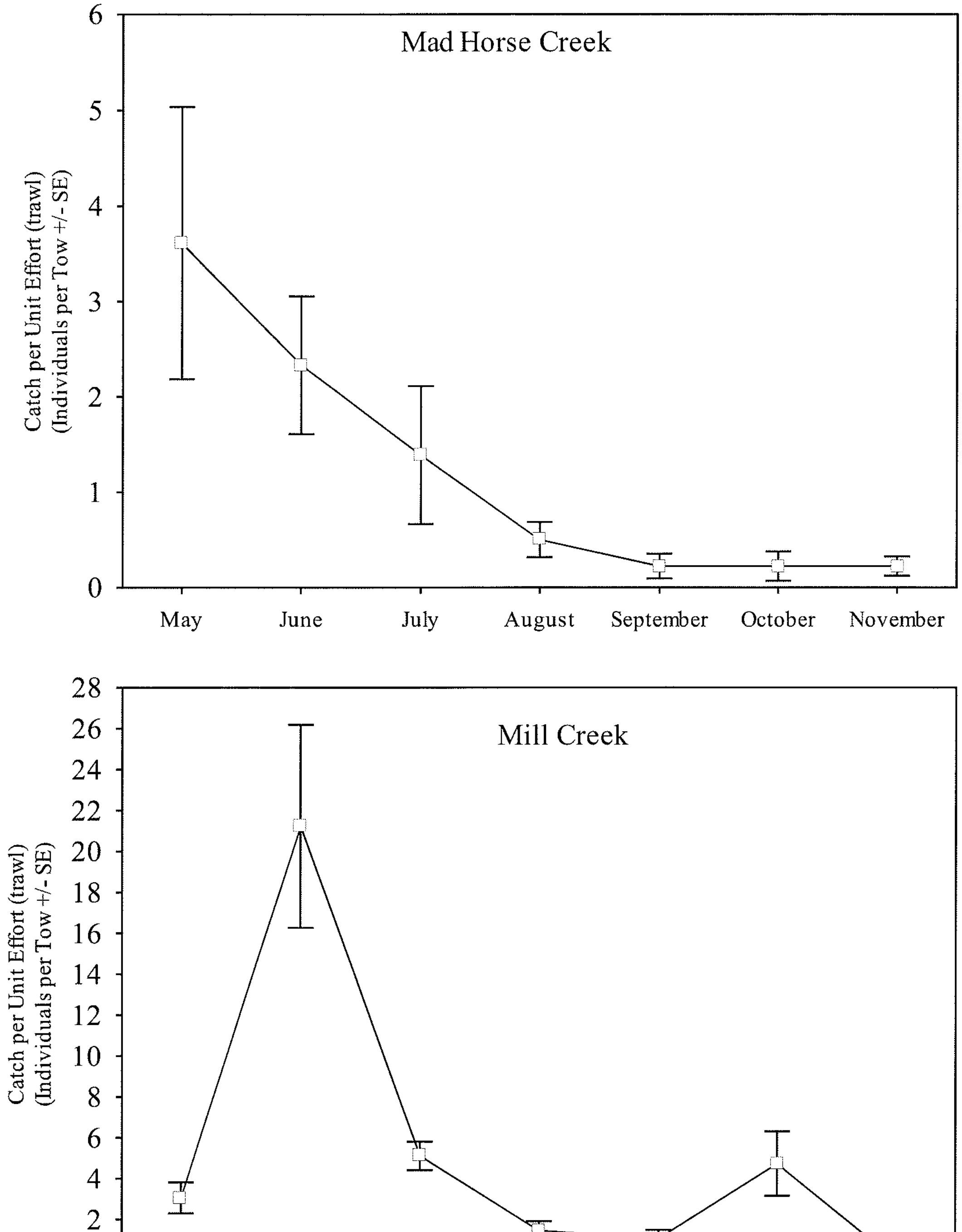


Figure 7-39. Monthly abundance for spot, collected in large marsh creeks with otter trawls, in the Upper Bay Region during 2008.

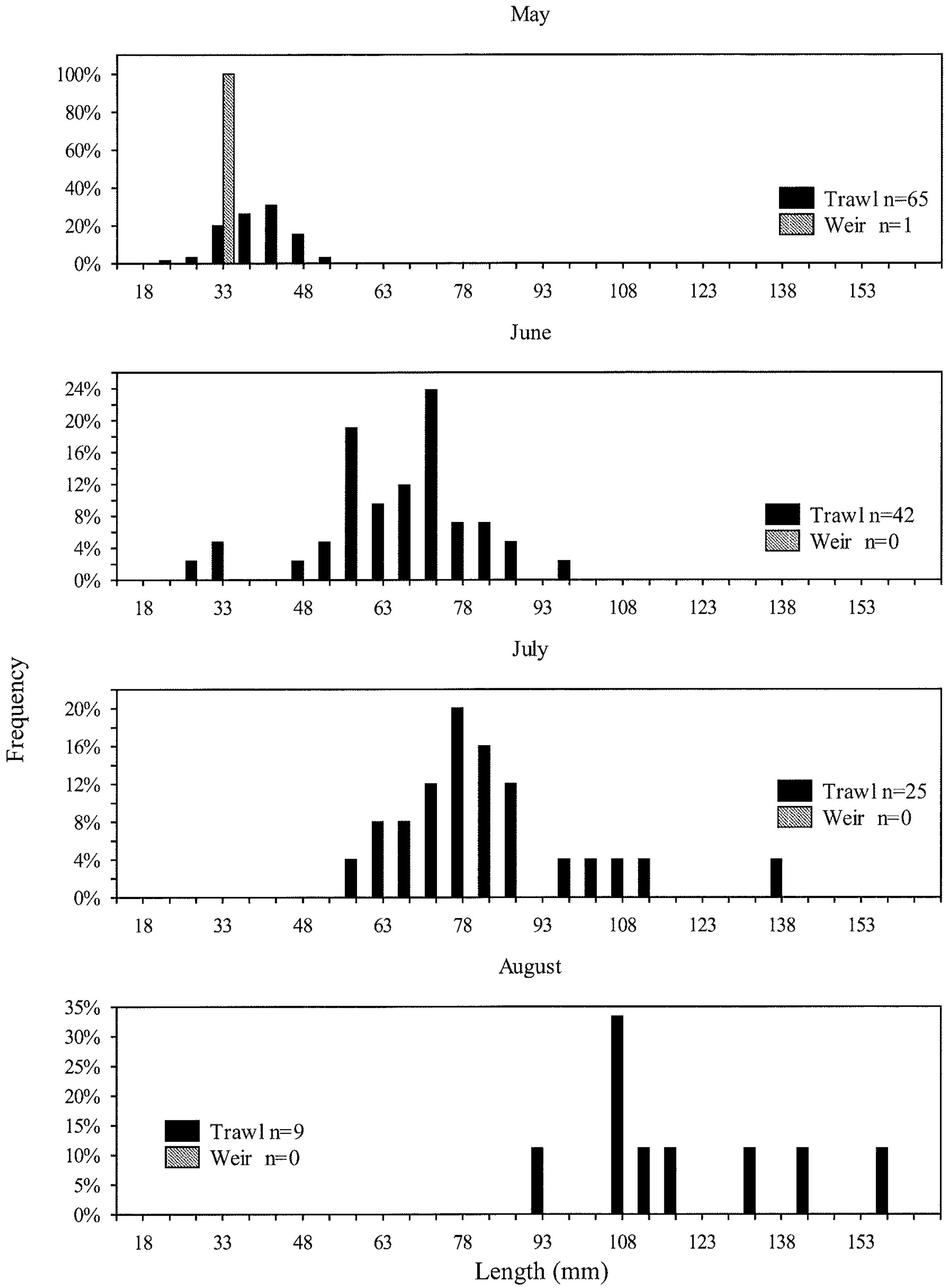
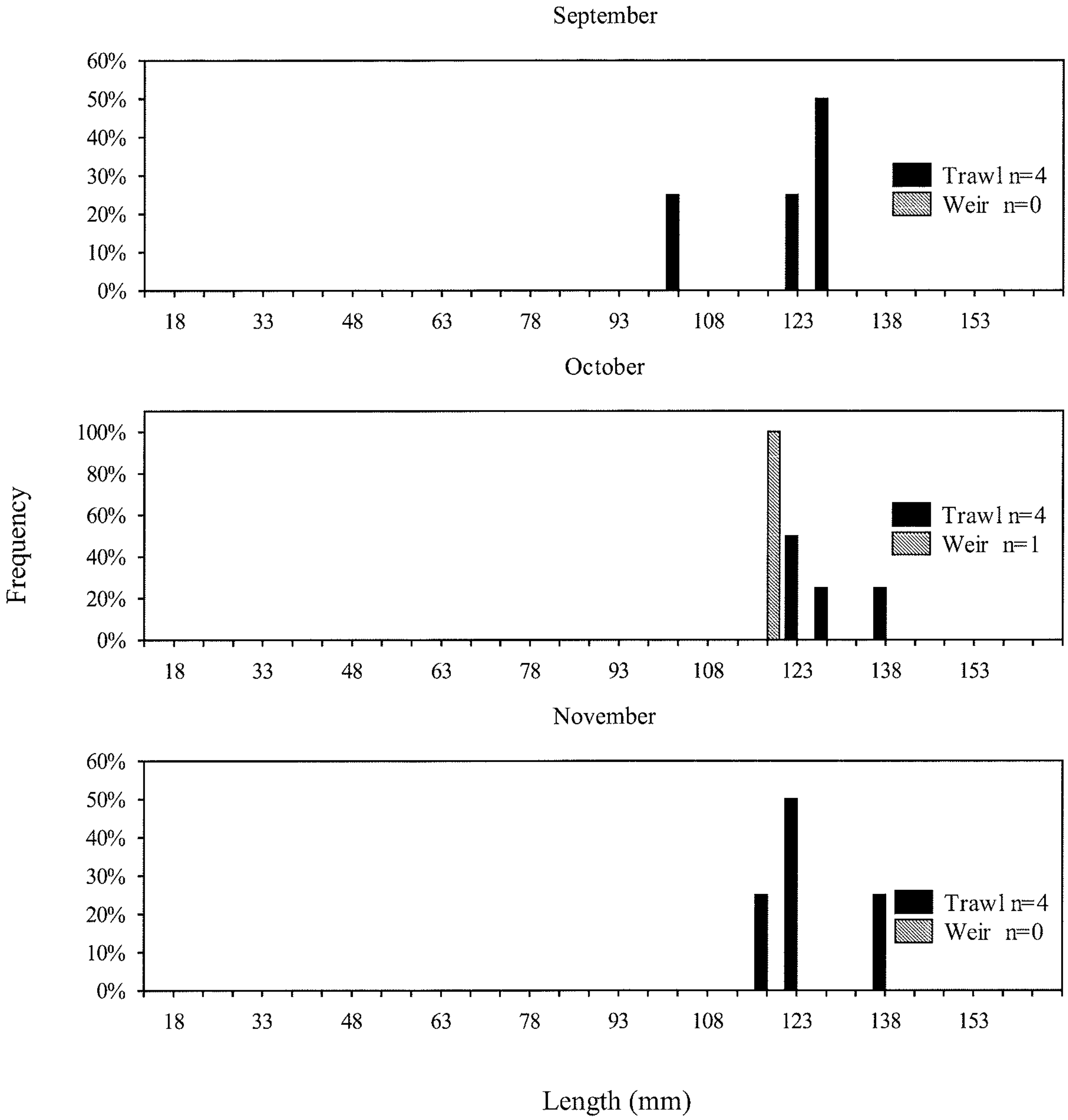


Figure 7-40. Size distribution of spot, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mad Horse Creek during 2008.



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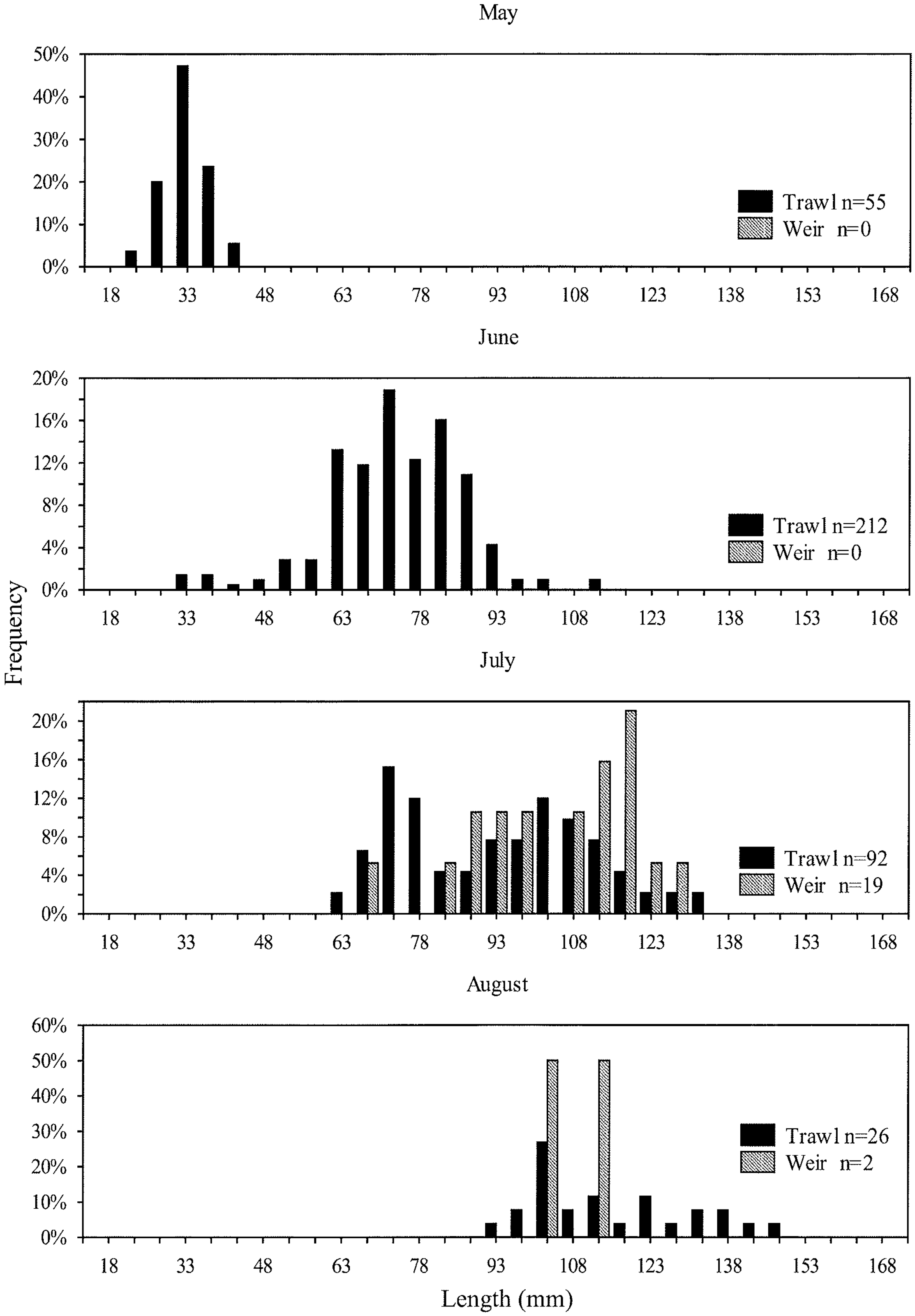
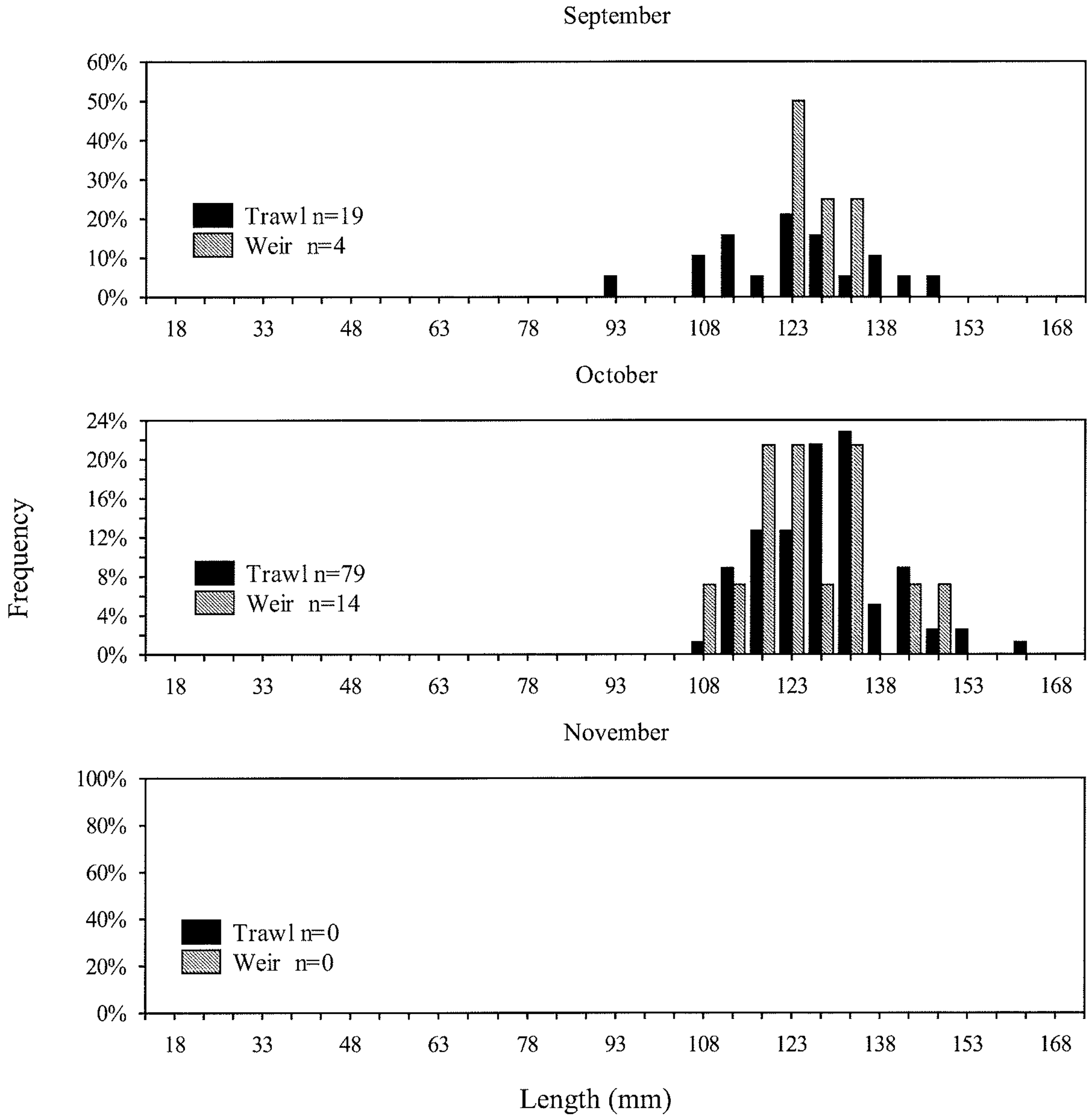


Figure 7-41. Size distribution of spot, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mill Creek during 2008.



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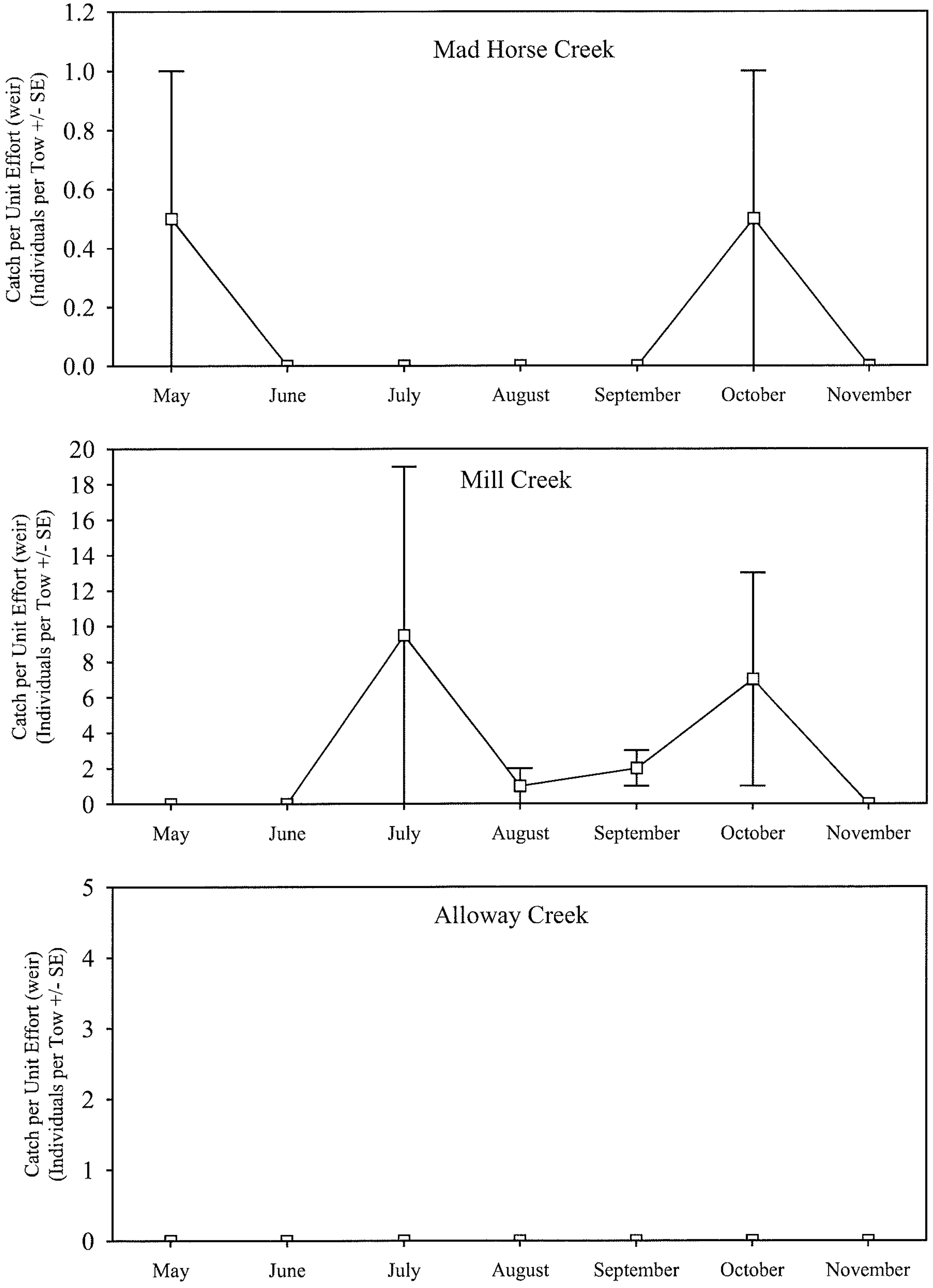


Figure 7-42. Monthly abundance for spot, collected in small marsh creeks (weir), in the Upper Bay Region during 2008.

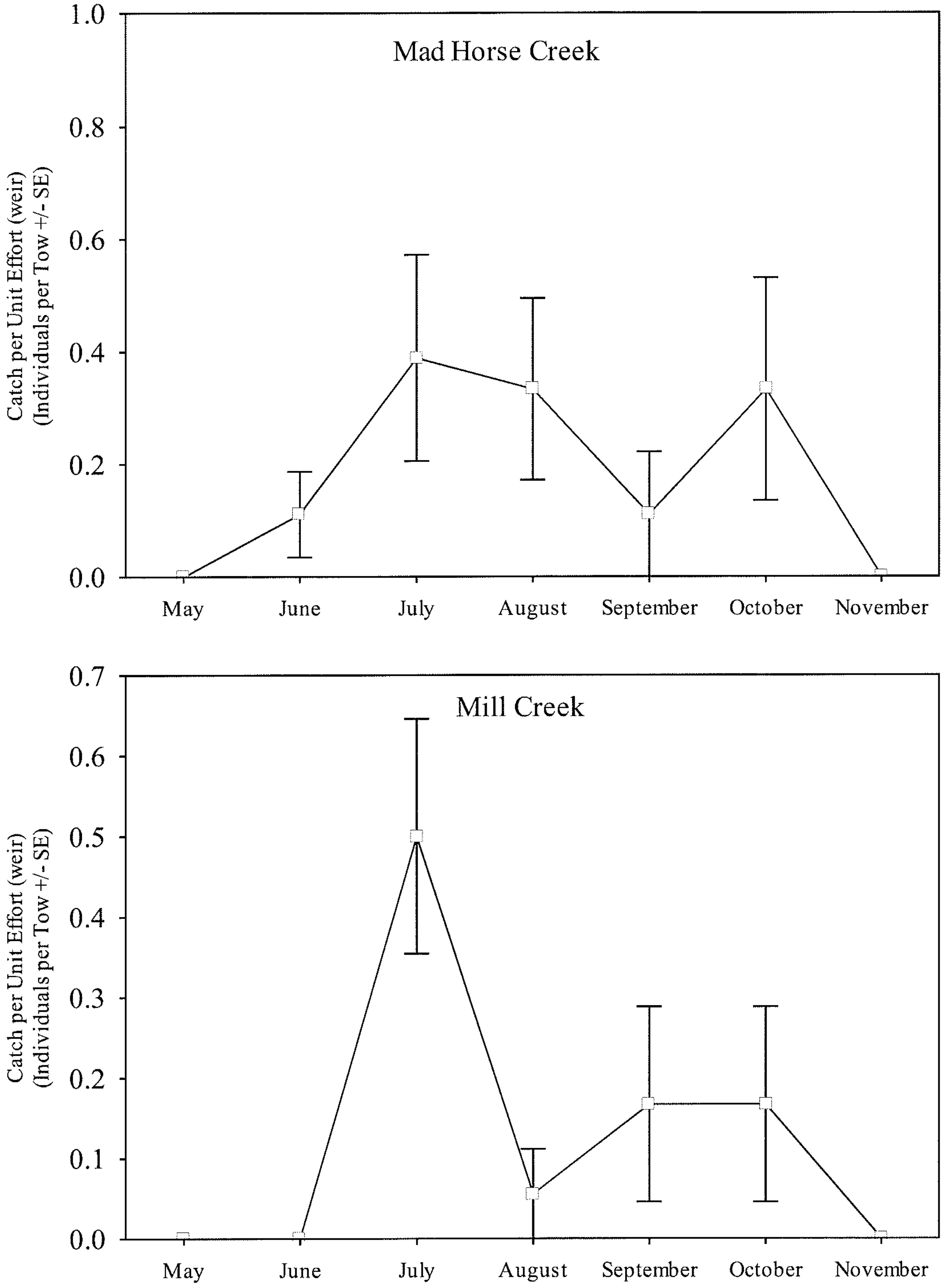


Figure 7-43. Monthly abundance for weakfish, collected in large marsh creeks with otter trawls, in the Upper Bay Region during 2008.

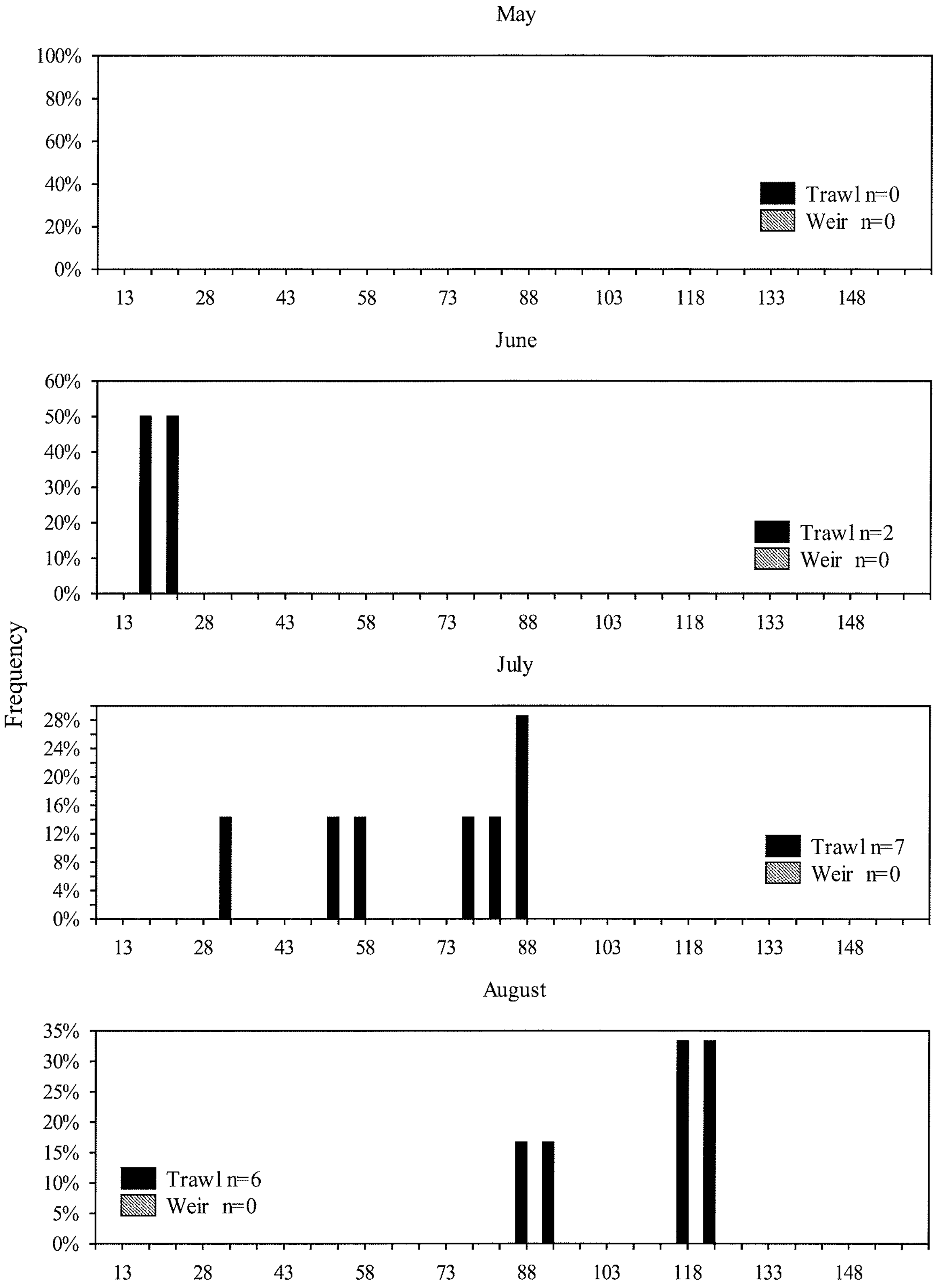
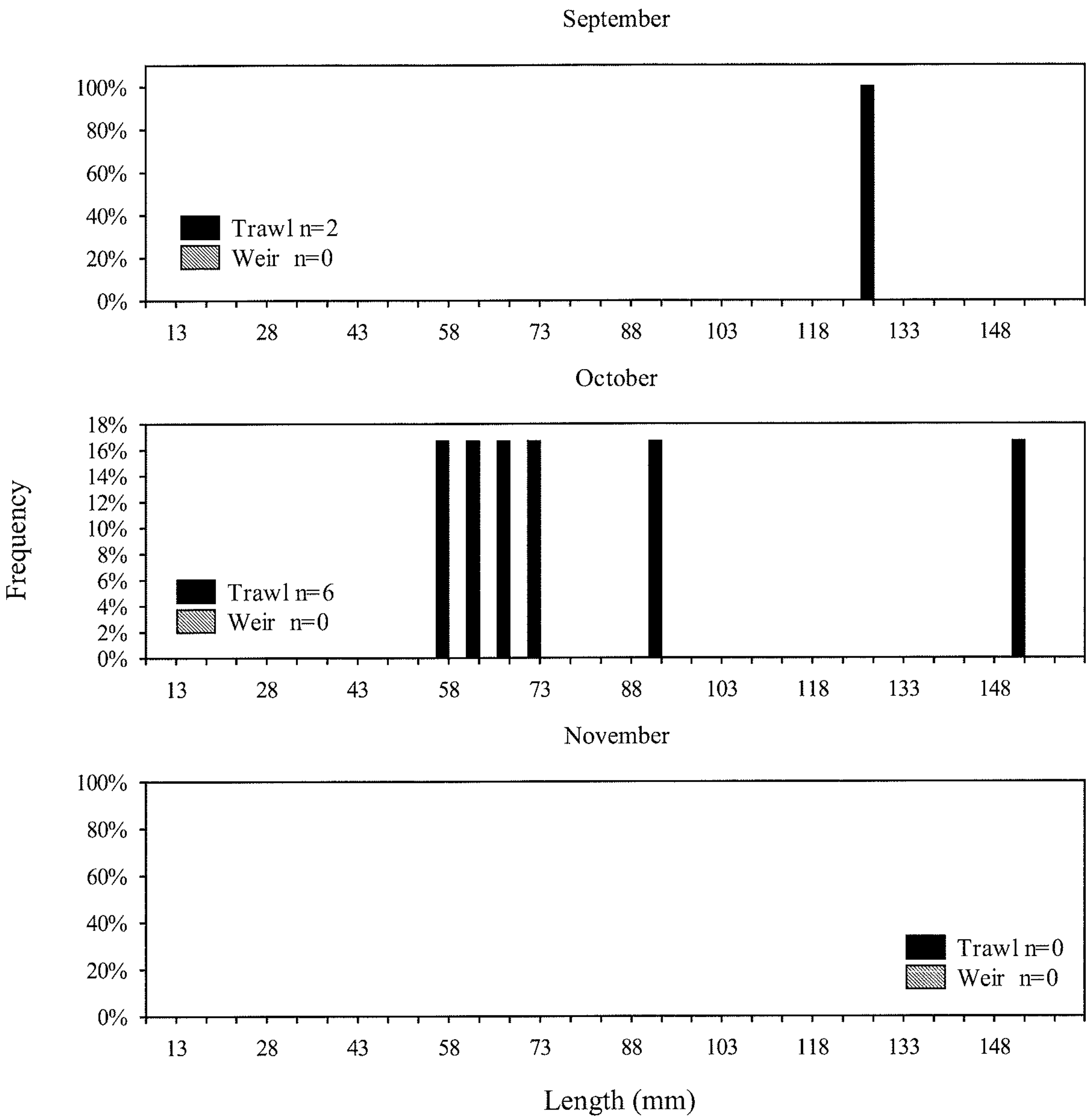


Figure 7-44. Size distribution of weakfish, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mad Horse Creek during 2008.



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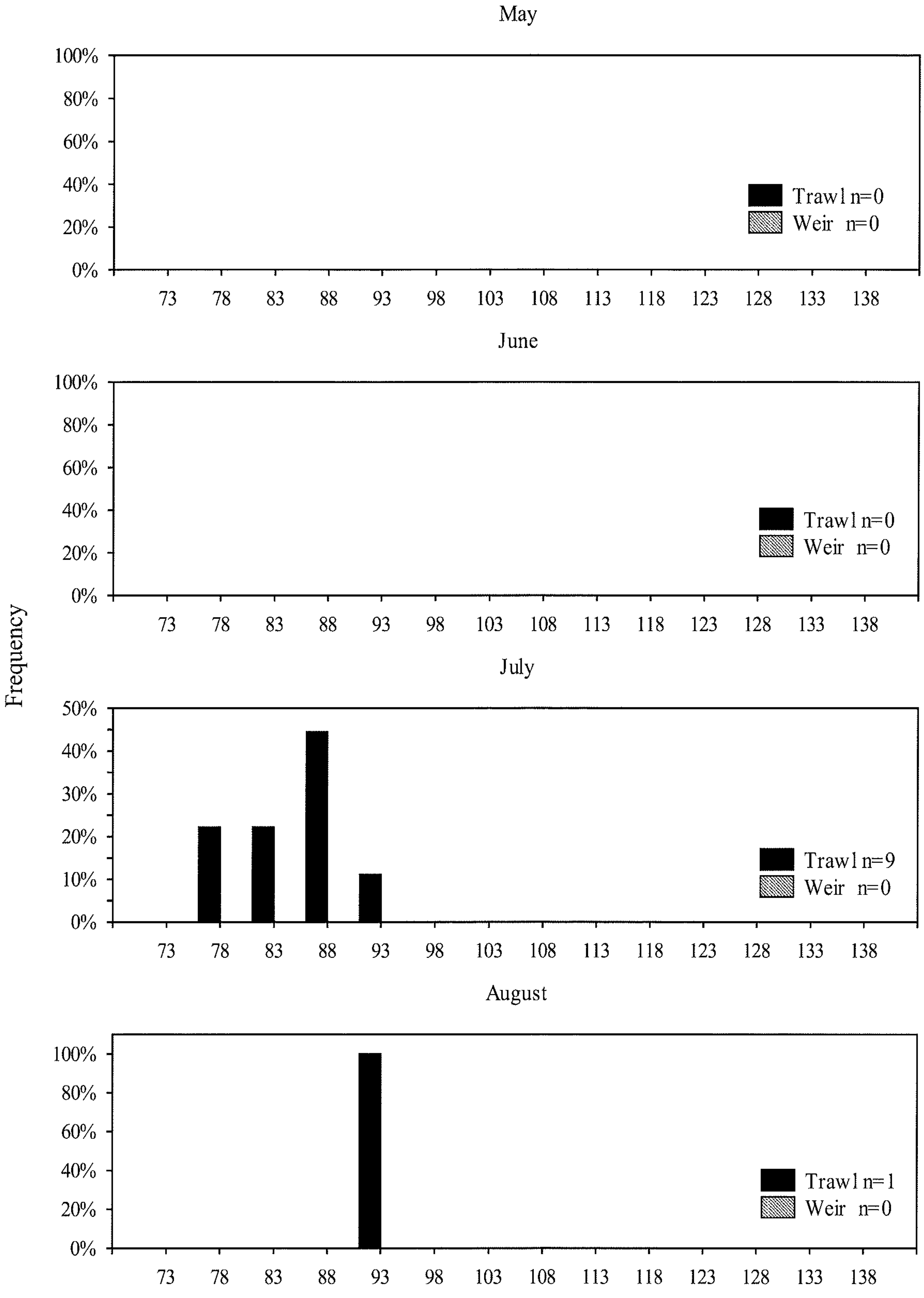
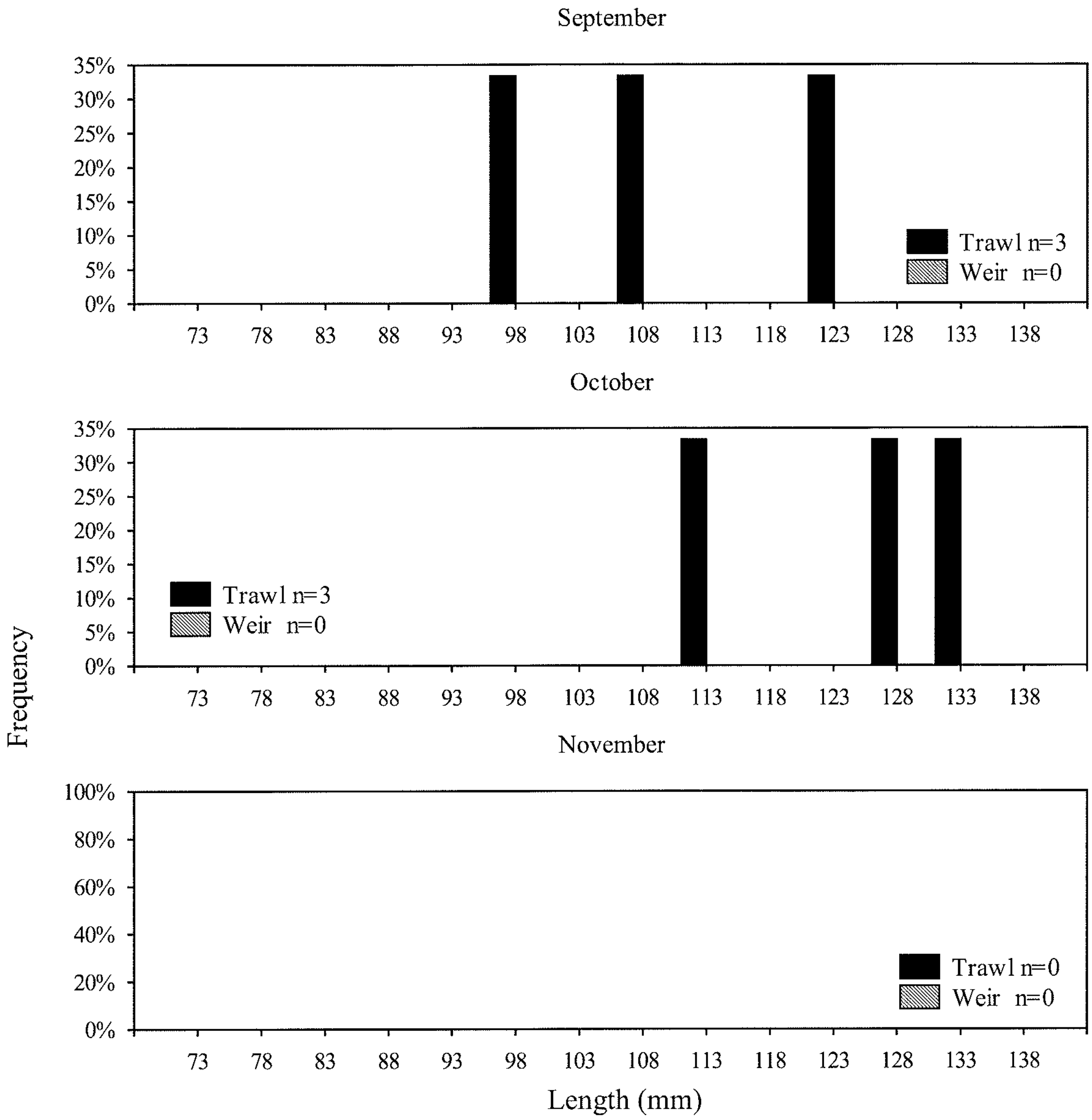


Figure 7-45. Size distribution of weakfish, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mill Creek during 2008.



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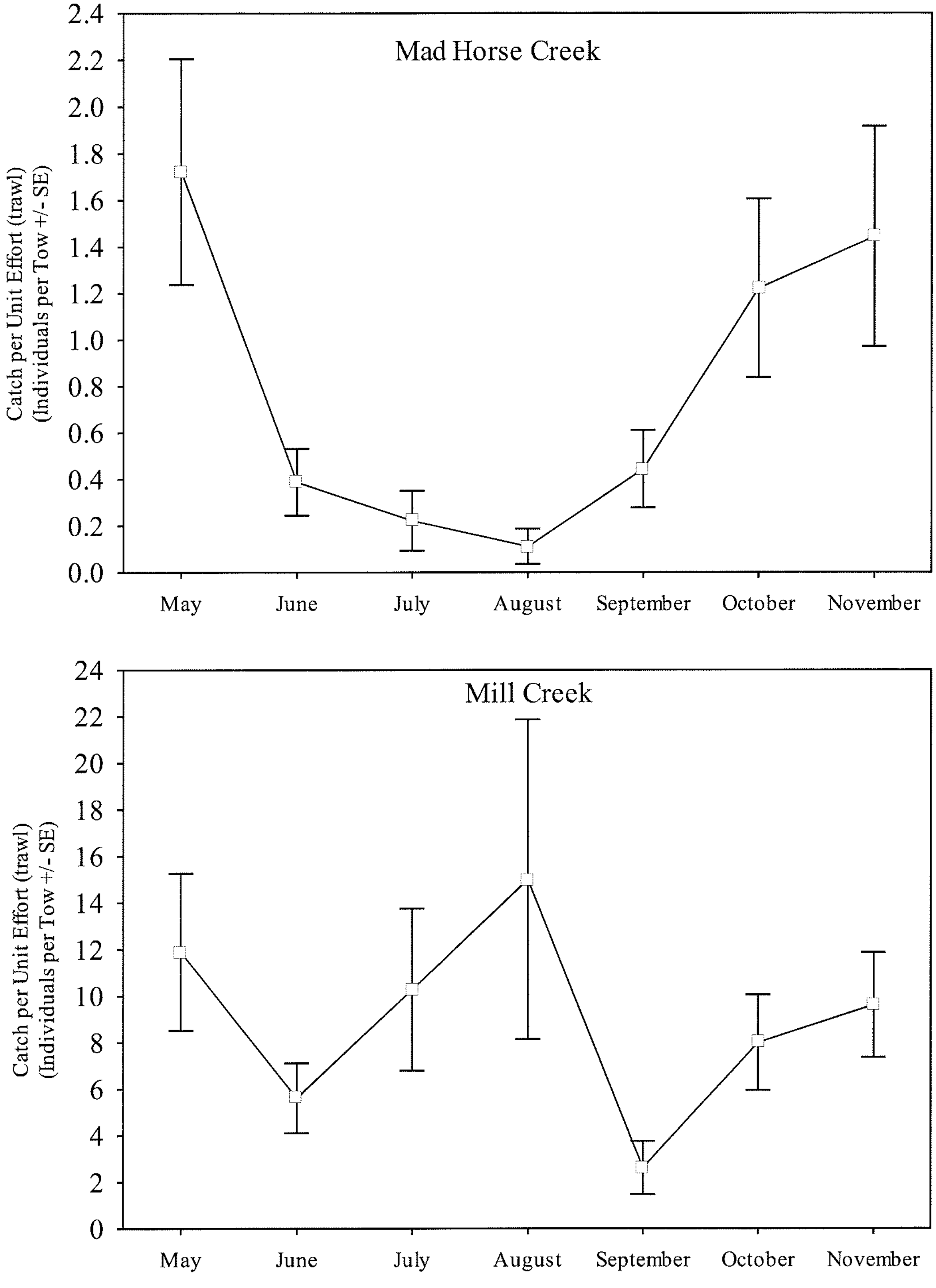


Figure 7-46. Monthly abundance for white perch, collected in large marsh creeks (otter trawl), in the Upper Bay Region during 2008.

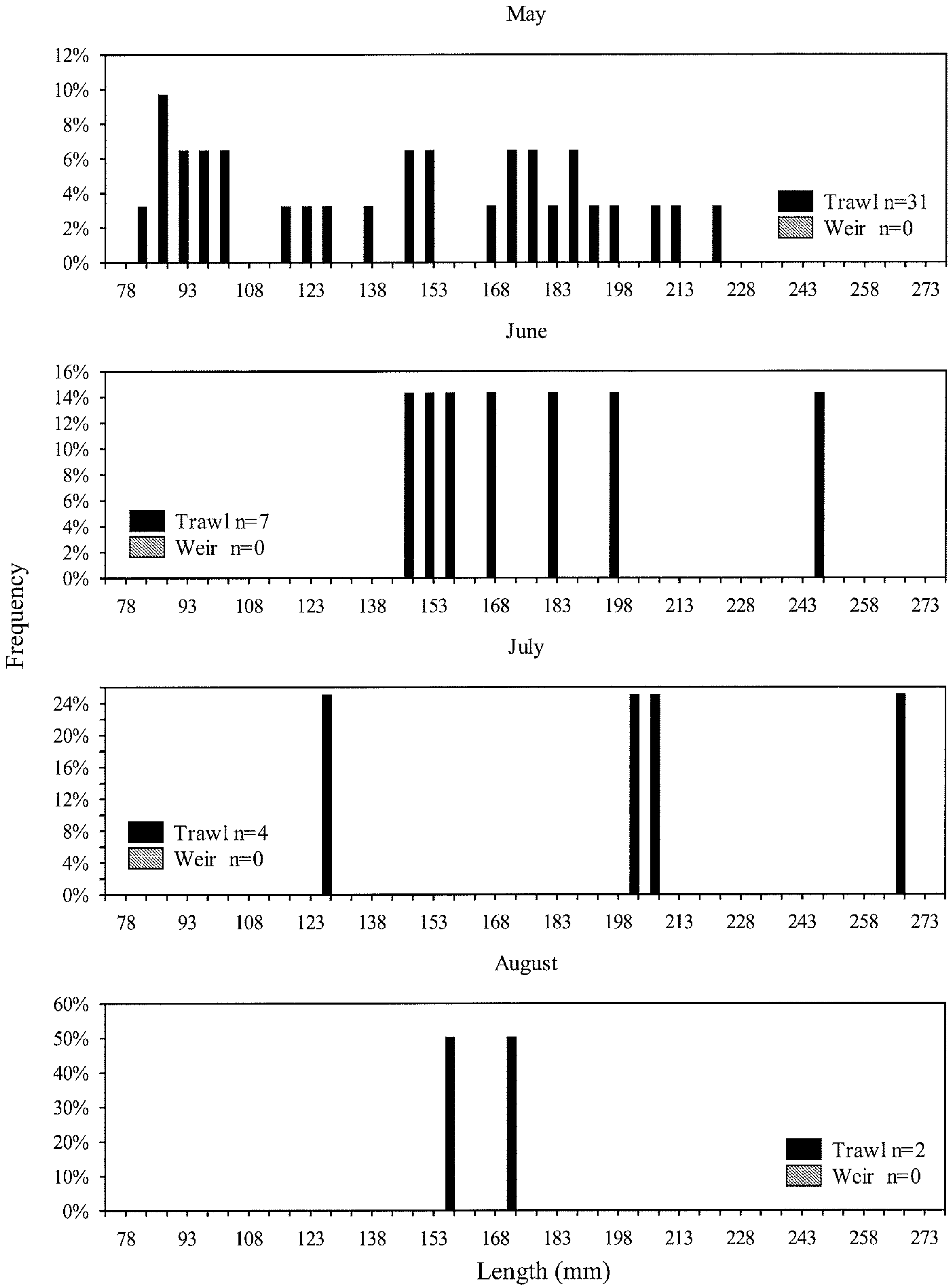
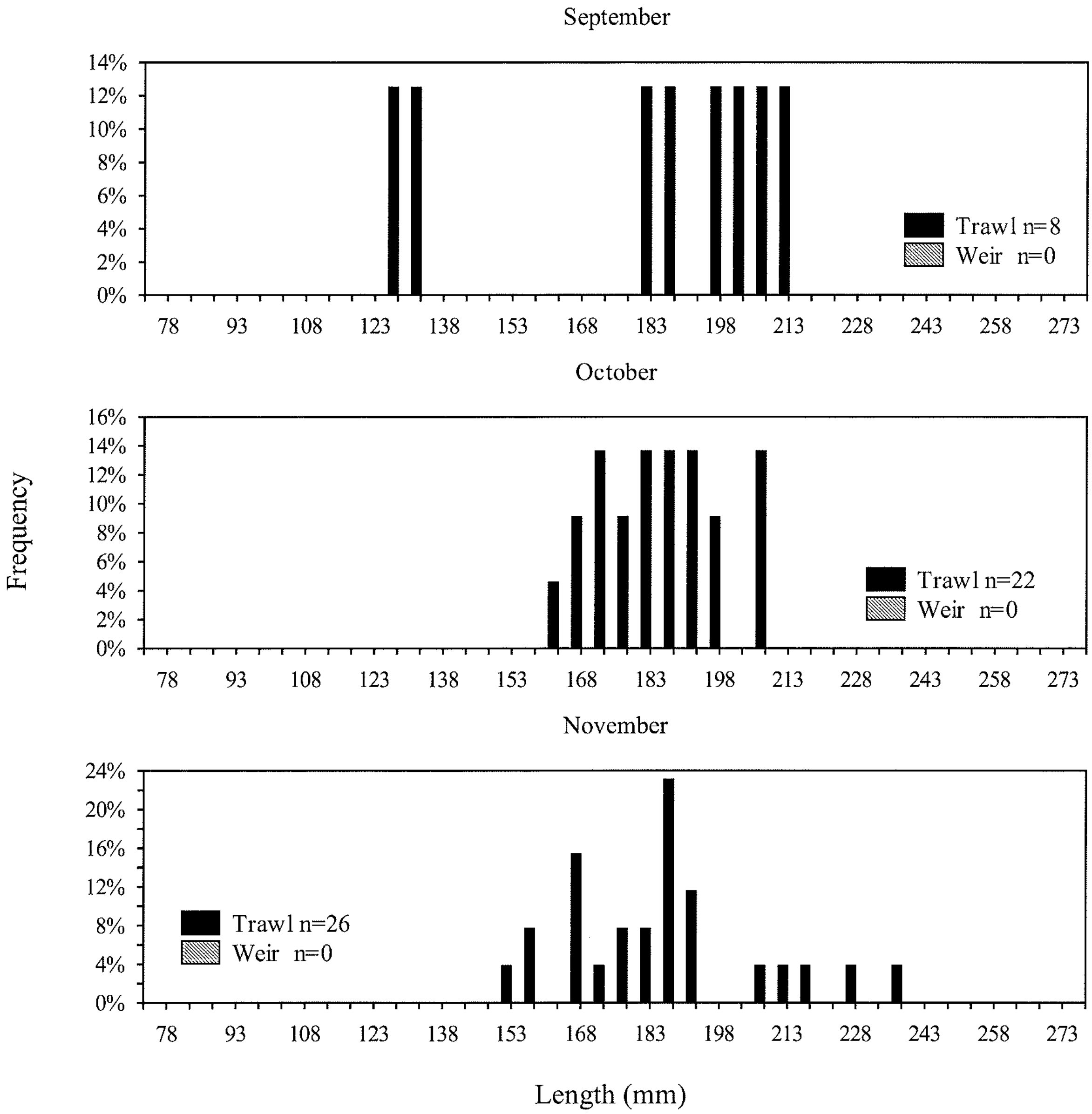


Figure 7-47. Size distribution of white perch, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mad Horse Creek during 2008.



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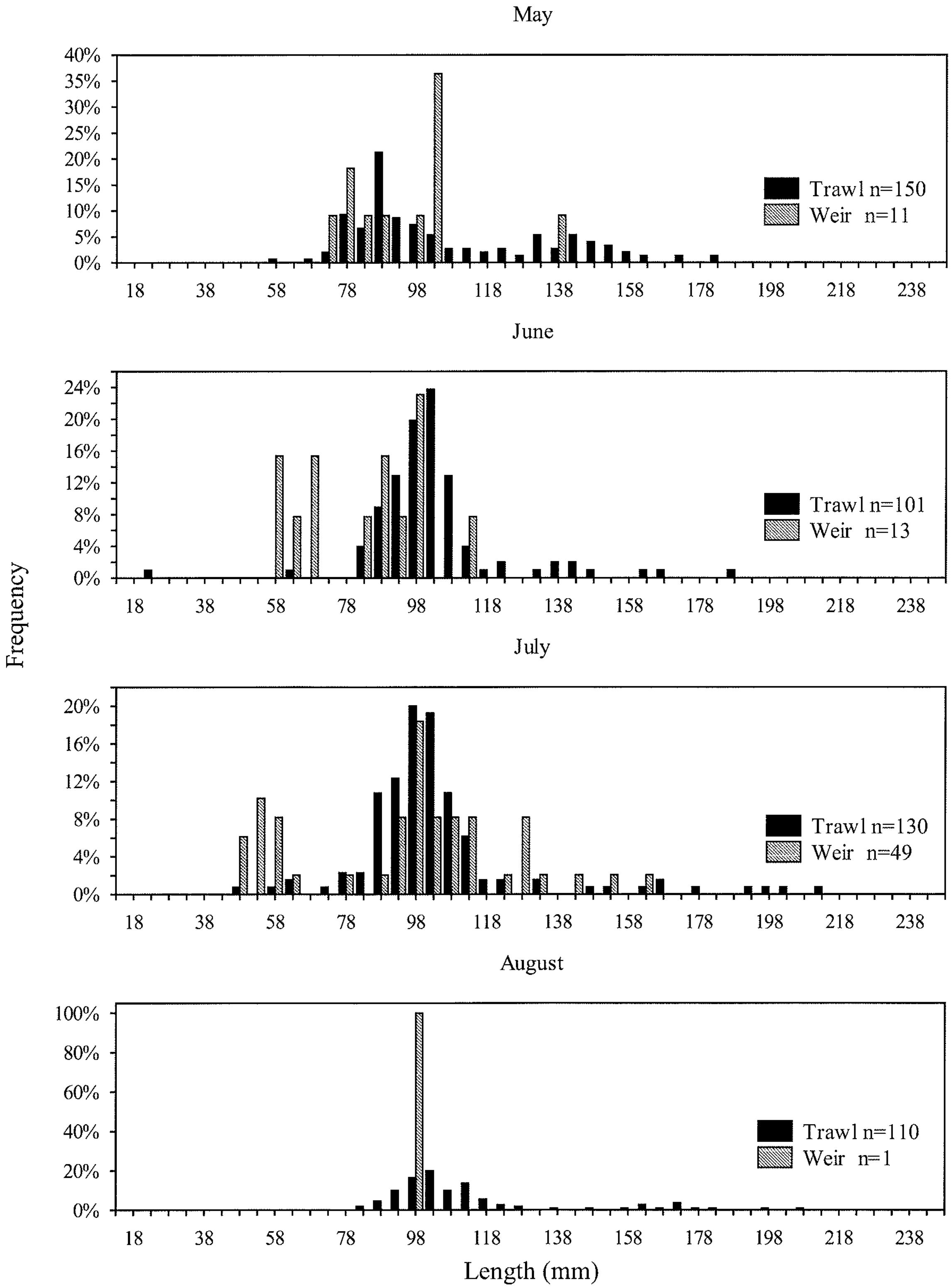
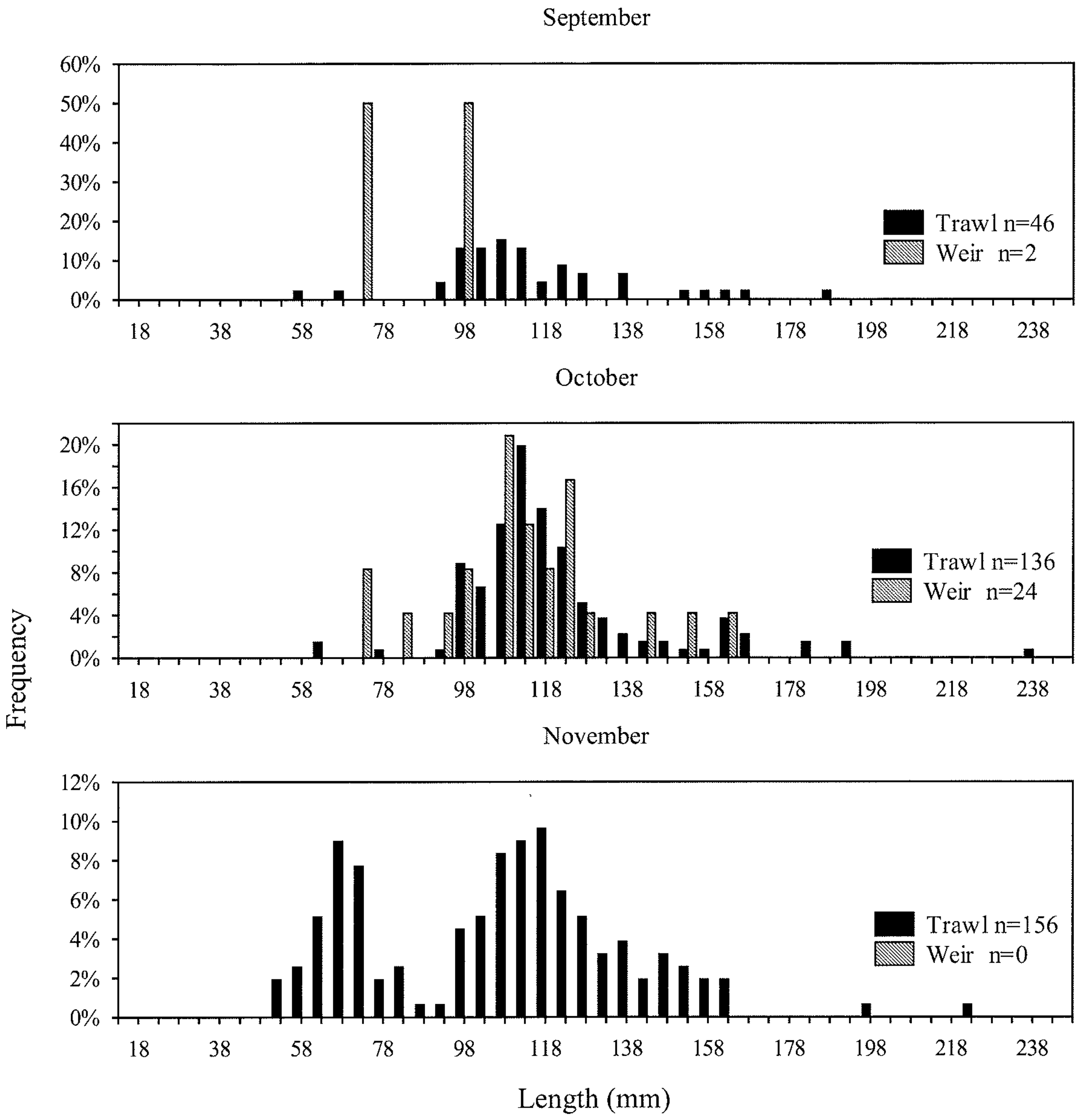


Figure 7-48. Size distribution of white perch, collected in large marsh creeks (otter trawl) and small marsh creeks (weir), at Mill Creek during 2008.



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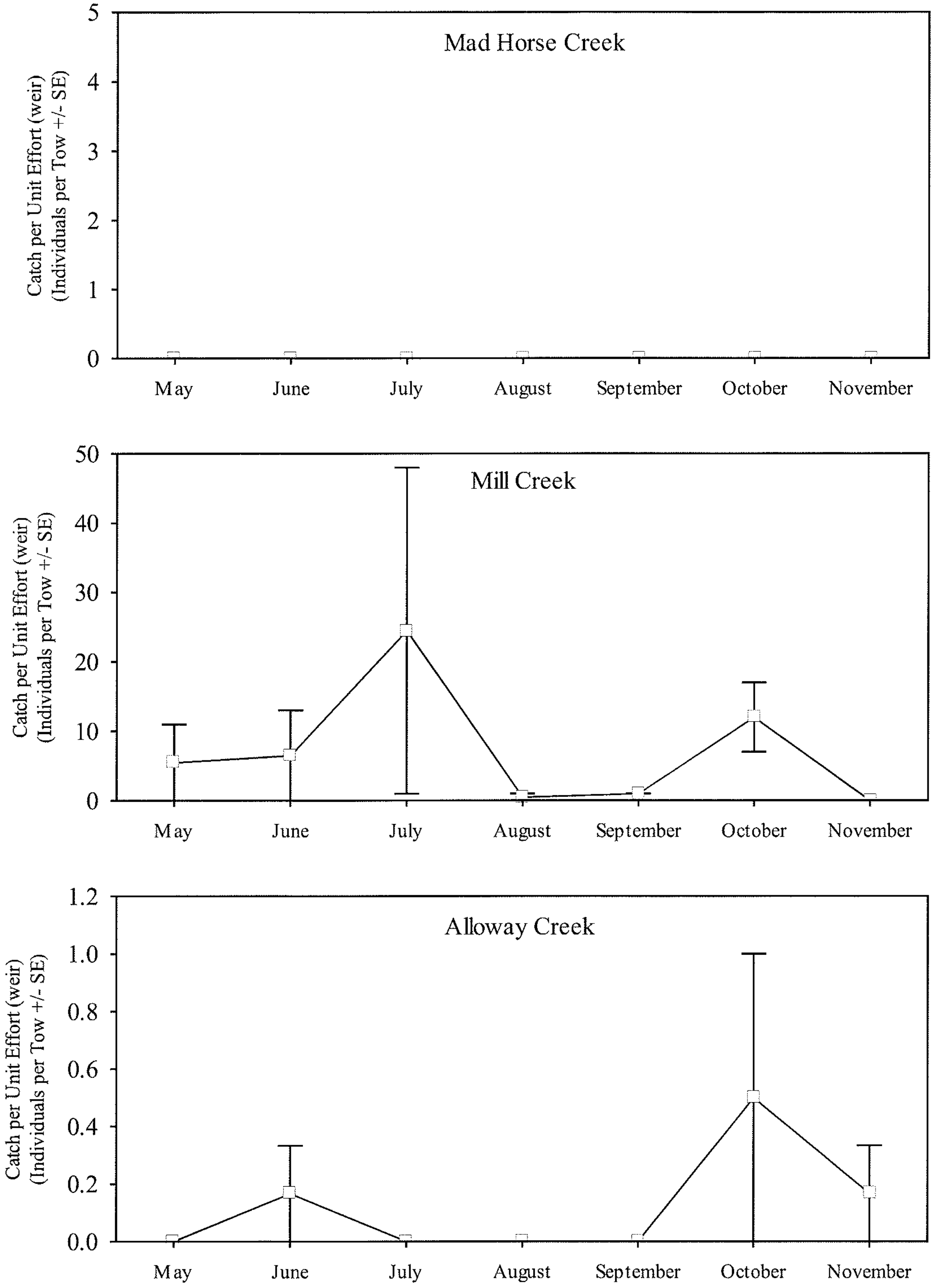


Figure 7-49. Monthly abundance for white perch, collected in small marsh creeks (weir), in the Upper Bay Region during 2008.

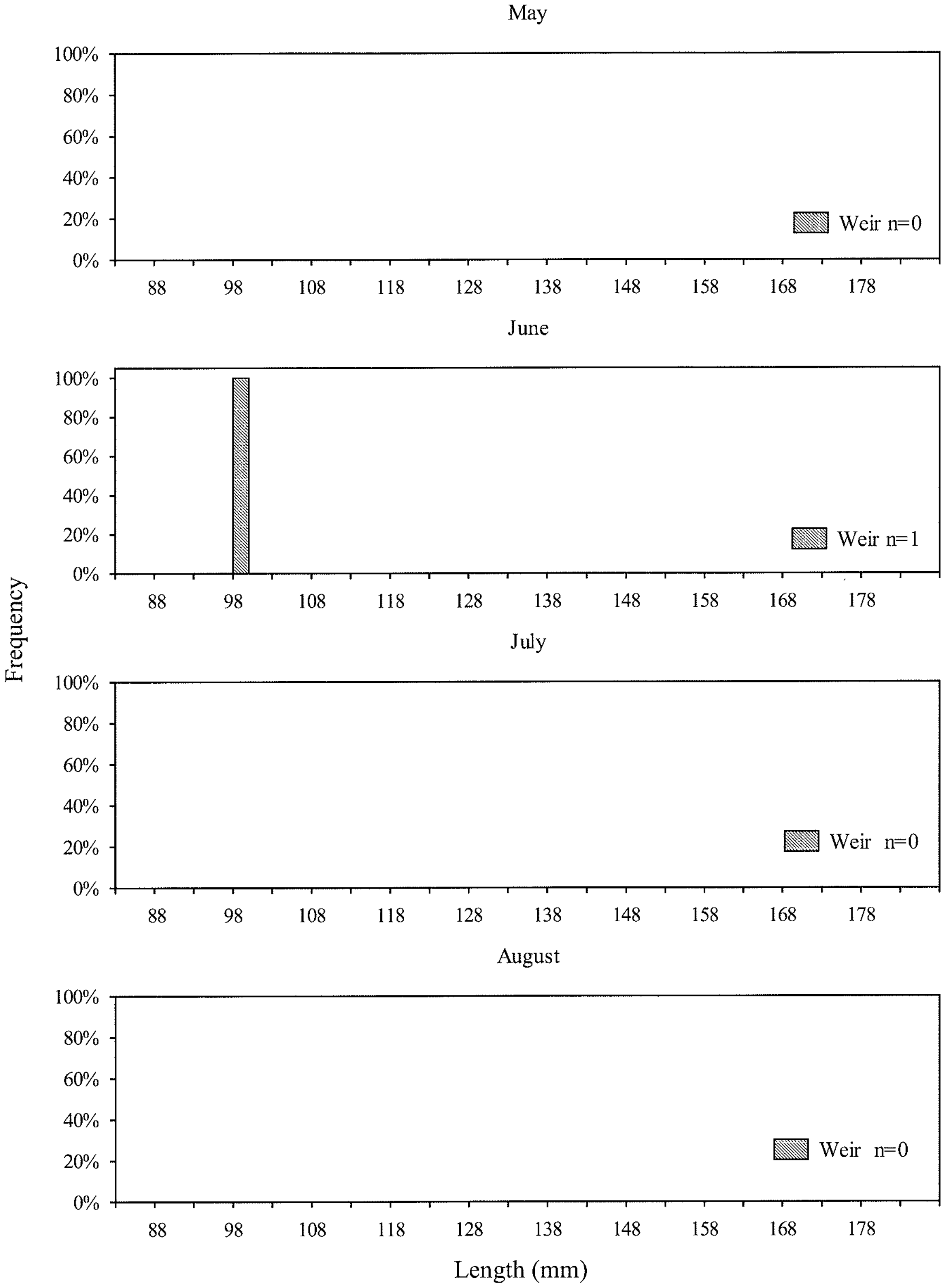
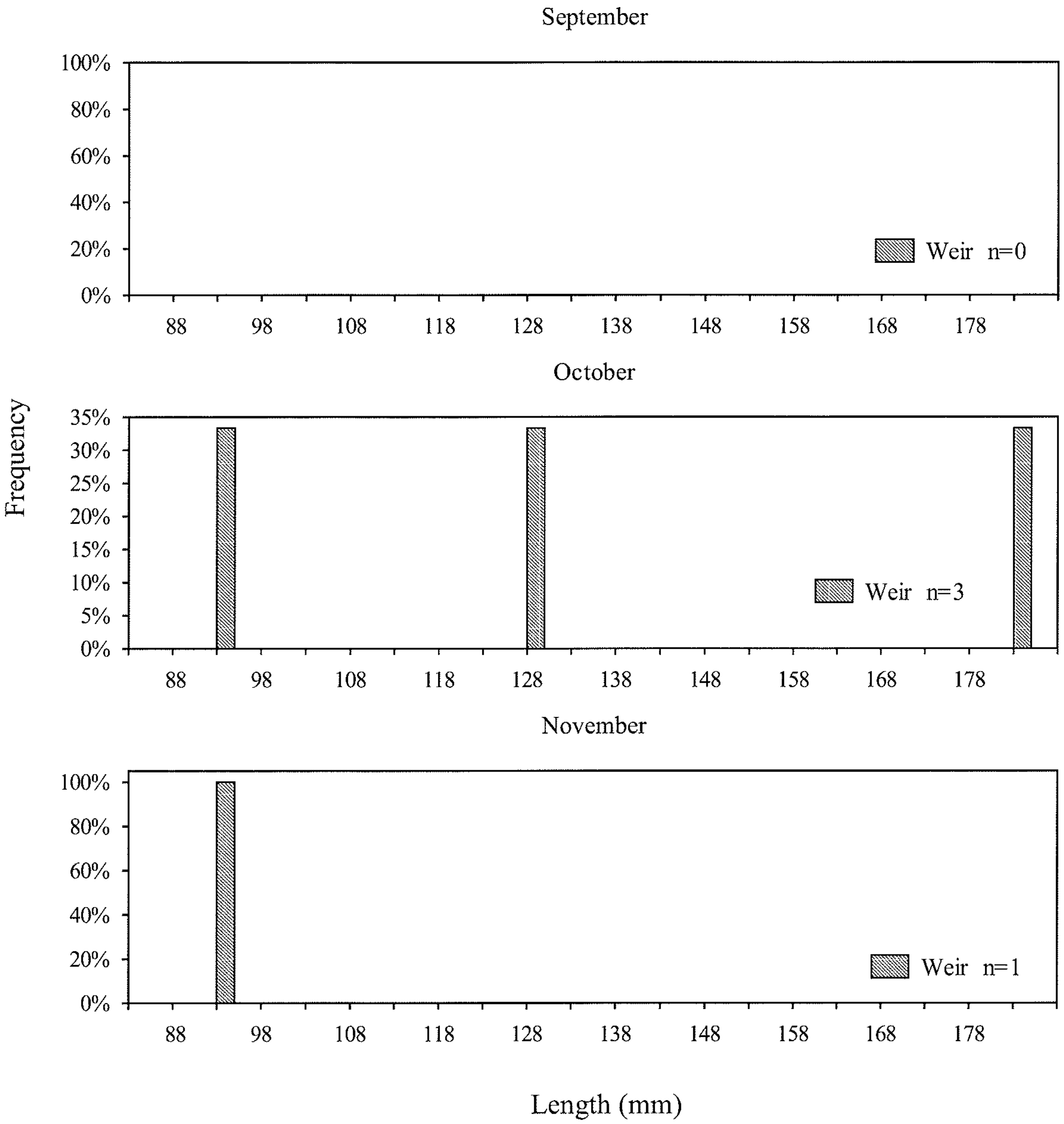


Figure 7-50. Size distribution of white perch, collected in small marsh creeks (weir) at Alloway Creek during 2008.



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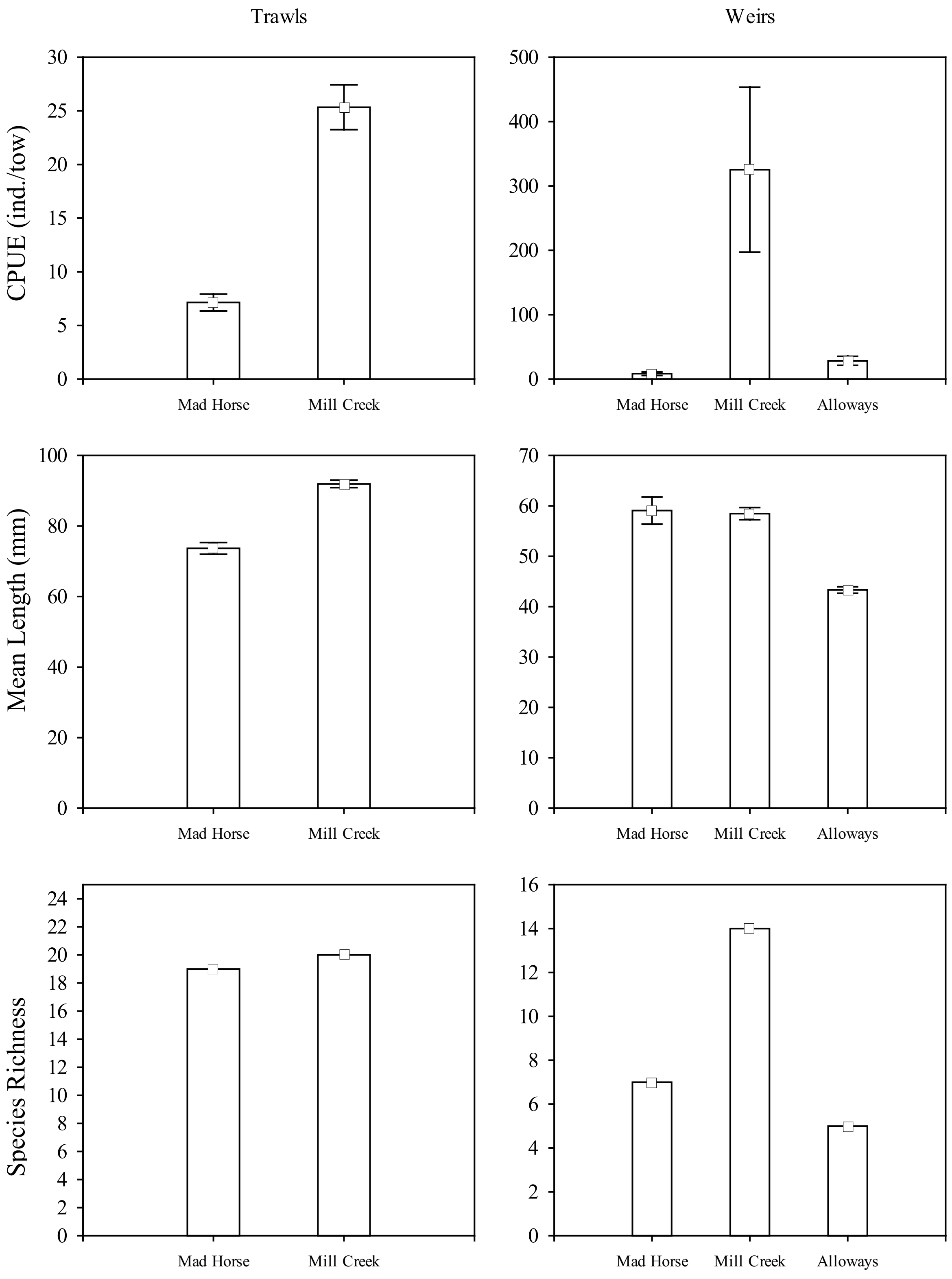

Figure 7-51. Comparisons of abundance, fish length, and species richness among restored (Alloway Creek and Mill Creek) and reference (Mad Horse Creek) marshes from large and small marsh creeks during 2008.

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INTRODUCTION

As a component of its Estuary Enhancement Program (EEP), Public Service Enterprise Group (PSEG) has initiated an Improved Biological Monitoring Program (IBMWP) for the Delaware Estuary pursuant to Special Condition Section G.6 of the 2001 NJPDES Permit (No. NJ0005622) for the Salem Generating Station. The IBMWP was prepared and amended by PSEG, reviewed by the Estuary Enhancement Program Advisory Committee and approved by the New Jersey Department of Environmental Protection (NJDEP).

In accordance with the IBMWP, vegetative and hydrogeomorphic monitoring was conducted in 2008 by PSEG. This monitoring included peak growing season (August) sampling at two reference marshes in New Jersey and four wetland restoration sites in New Jersey and Delaware. False color infrared (CIR) and true color aerial photographs were also acquired of the reference marshes and wetland restoration sites on September 8, 2008. These photographs were utilized to map the extent of the various vegetation cover types present on each of these sites.

MATERIALS AND METHODS

This section describes the materials and methods used in the collection of detrital production data in 2008 and subsequent data analysis. Elements of the 2008 work scope included:

- Collection of percent coverage, height and flowering status data within quadrats located along transects and within plots;

- Collection of macrophyte and litter samples;

- Processing (i.e., weighing) of macrophyte samples in the laboratory;

- Data analysis (e.g., mean, standard deviation, standard error) of percent cover, height and biomass data;

- Acquisition and interpretation of CIR and true color aerial photography.

SITE LOCATIONS

The locations of the EEP restoration sites and reference marshes are shown in Figure 8-1. CIR or true color aerial photography was acquired at all sites for the purpose of mapping the extent of the vegetation communities present. Field data collection in 2008 occurred in New Jersey at four sites: the Mad Horse Creek (MHC Reference Marsh) and Moores Beach West (MBW Reference Marsh) reference marshes; the Commercial Township Salt Hay Farm Wetland Restoration Site (CT Site); and the Alloway Creek Wetland Restoration Site (ACW Site). Field data collection also occurred at two wetland restoration sites in Delaware: The Rocks and Cedar Swamp. A brief description of each site is provided in the following paragraphs.

Reference Marshes

The two reference marshes selected in accordance with the IBMWP were MHC Reference Marsh and MBW Reference Marsh. MHC Reference Marsh is an oligohaline (salinity 0-5 ppt) marsh, most of which had not been previously used for salt hay farming operations. The 3,942-acre portion of the marsh selected as a reference site is considered to represent a good example of natural hydrology and drainage patterns, and represents a mature vegetative marsh community.

MBW Reference Marsh is a mesohaline (salinity 5-18 ppt) marsh that “naturally restored” following storm damage to its berms in 1972. By 1992, most of the areas that were in salt hay production in 1960 had been converted to low marsh dominated by *Spartina alterniflora.* The low marsh succession was accomplished by natural processes. The marsh area designated as the reference site encompasses approximately 1,264 acres.

Salt Hay Farm Wetland Restoration Sites

Three New Jersey salt hay farms, located in Commercial Township, Maurice River Township and Dennis Township, have been restored to normal daily tidal flow by PSEG under the EEP. The Dennis Township and Maurice River Township salt hay farm sites have reached their targeted coverage of *Spartina alterniflora* and other desirable marsh species, and are not included in this chapter of the 2008 Annual Report. Detrital production monitoring has continued at the CT Site, which is located in Cumberland County and contains 2,894 acres within the restoration boundary.

The CT Site is bounded to the east by the Village of Bivalve and the Maurice River, to the south by the Delaware Estuary, to the west by Dividing, Indian, and Hansey Creeks and to the north by rural properties and the Village of Port Norris. The restoration site is situated along the southern New Jersey shoreline of the Delaware Estuary at the northern margin of the Maurice River Cove, approximately 18 miles northwest of Cape May Point. For at least three generations, the area between Dividing Creek and the Maurice River had been farmed commercially; earthen dikes had been constructed to enhance the production of salt hay *(Spartina patens* and *Distichlis spicata).* As a result of storms during early 1996, a number of breaches in the perimeter dike occurred; despite attempts to repair these, much of the salt hay farming area was inundated during the 1996 growing season. However, salt hay farming was continued on some areas in the western portion of the site. The construction phase (dredging, dike breaching, etc.) of the wetland restoration was completed in the fall of 1997, returning daily tidal flows to the wetland restoration area of the site.

New Jersey *Phragmites* Dominated Sites

Two *Phragmites*-dominated sites in New Jersey, the ACW Site and the Cohansey River Watershed Wetland Restoration Site (CRW Site), have undergone restoration by PSEG under the EEP. The CRW Site has reached its targeted coverage of *Spartina alterniflora* and other desirable marsh species, and is not included in this chapter of the 2008 Annual Report. The ACW Site is a *Phragmites*-dominated site that had been historically diked and farmed. Based on a review of historical aerial photography, *Phragmites* originally became established on dike areas and then spread to the adjacent marshes. The ACW Site is located in Elsinboro and Lower Alloways Creek Townships, Salem County, NJ. The ACW Site encompasses approximately 3,096 acres that include the wetland restoration area and adjacent buffer. The wetland restoration area is comprised of approximately 1600 acres; *Phragmites* covered approximately 58.7 percent of the wetland restoration area in 1996, prior to initial restoration activities. The wetland restoration area is subject to tidal influence from the Delaware River, via Alloways Creek, Straight Ditch and Mill Creek. The ACW Site is bounded to the east by the Salem-Hancocks Bridge Road, to the north by the Fort Elfsborg-Hancocks Bridge Rd, tidal marsh and agricultural fields, to the west by the Delaware River, and to the south primarily by the Alloways Creek.

Delaware *Phragmites* Dominated Sites

Prior to 1999, five restoration sites were monitored in Delaware. PSEG selected to continue restoration activities at two of these sites, The Rocks and Cedar Swamp. Wetland restoration activities were initiated at these two Delaware *Phragmites*-dominated sites by the Delaware Department of Natural Resources and Environmental Control (DNREC) in 1995. A brief description of the pre-restoration conditions at each site based on interpretations of 1993 aerial photography is provided in the following paragraphs.

The restoration area at The Rocks is comprised of 736 acres and is located approximately 2.3 miles south of Silver Run and 4.0 miles southeast of Odessa in Appoquinimink Hundred, New Castle County, Delaware. This site is part of a continuous tidal marsh community, referred to as the Appoquinimink River-Blackbird Creek System, which extends north and south for several miles. The site is bounded to the east by the Delaware River, to the north by Appoquinimink River, to the west by Stave Landing Road and to the south by Blackbird Creek. Stave Landing Road provides access to The Rocks from the west. *Phragmites* covered 86.9 percent of the vegetated marsh plain in 1993 prior to the initiation of restoration activities by DNREC.

The restoration area at Cedar Swamp is comprised of 1,863 acres and is located approximately 2.6 miles south of The Rocks in Blackbird Hundred, New Castle County, Delaware. This site is bounded to the east by the Delaware Bay. To the north, the site is bounded by farmland and Cedar Swamp Road, and to the west and south the site is bounded by farmland, woodland, and contiguous tidal marsh. The boundary between the Delaware River and the Delaware Bay is located at the northeast side of the site, at Liston Point. Collins Beach Road provides access to a public boat ramp and parking area in the southeast corner of the site. Public access to the northern side of the site is available via Cedar Swamp Road. In addition to public hunting and wildlife observation, Cedar Swamp is used as an anchorage for commercial and recreational crabbing and fishing boats. Historically, the site was used for hunting and included a coastal recreation resort. *Phragmites* covered 71.3 percent of the wetland restoration area prior to the initiation of wetland restoration activities by DNREC.

AERIAL MAPPING

Aerial photography was acquired for all reference and restoration sites in New Jersey and Delaware on September 8, 2008. True color photographs were acquired of the MHC Reference Marsh, ACW Site, Cedar Swamp and The Rocks. CIR photographs were acquired of the MBW Reference Marsh and the CT Site. This photography was acquired at a nominal scale of 1:9600 (i.e., 1 in = 800 ft). The time of acquisition was selected to provide images of the sites at the end of the growing season during the mid-day period and at low tide.

Camera, Aircraft, and Film Type

To obtain the aerial photography, a Wild-RC30 camera with a Wild Universal Aviogon/4-S lens and a nominal focal length of 153 mm was flown in a Cessna Piper aircraft. Kodak Aerochrome III Infrared Film 1443, an infrared-sensitive, false color reversal film, was used for the CIR aerial photography. CIR photographic film is comprised of three layers (cyan, yellow and magenta) that are exposed in response to the characteristics of the light reflected from the earth's surface. Plant leaves reflect a significant amount of green energy and partially expose the yellow layer in addition to almost complete exposure of the cyan layer by the infrared - leaving the magenta layer and varying parts of the yellow layer with an image color ranging from magenta to red. The more green energy that is reflected by a given vegetation cover, the less yellow layer remains and the more magenta the images of that type appears. Because of species differences in leaf structure and chlorophyll content, separation of species dominated areas on CIR photography often can be based on this variation in red to magenta color. Since wet soil and water reflect little in the wavelengths that CIR film is sensitive to, these areas appear dark (unexposed) on the image. As a result, CIR aerial photography is particularly useful in mapping vegetative coverage on sites that are not fully vegetated.

Agfa AVIPHOT Color X100 PEI, a color negative film without color mask that is suitable for electronic image scanning for the reproduction of clean and saturated colors without additional color correction, was used for the true color aerial photography. This film is particularly useful for mapping vegetation types that are visually different during the peak growing season (e.g., *Spartina alterniflora* and *Phragmites australis*).

The aerial photography was acquired following standard specifications for stereo coverage. The forward overlap (overlap in the direction of flight) was 60 percent. The sidelap between overlapping parallel flight lines of vertical photography was 30 percent. Any series of two or more consecutive photographs within a flight line were not to be crabbed in excess of three (3) degrees relative to the plotted line of flight, and the differential crab between any two consecutive exposures within a flight line did not exceed three (3) degrees. The tilt within a single frame did not exceed three (3) degrees nor did the difference in tilt between two consecutive frames within flight lines exceed four (4) degrees. The average tilt for all negatives of the same nominal scale did not exceed one (1) degree.

Once the aerial photography was secured, the original photographic negatives were developed through automated processing equipment and RC paper contact prints (9in x 9in) and diapositives of each negative were produced. One set of film diapositives was printed from the original aerial photography using an automatic dodging printer having a flat platen on cut sheets of Kodak Aerographic Duplicating (ESTAR Thick Base) Film No. 4421. This set was used for the vegetation mapping photo interpretation process.

To allow for quick referencing of the aerial flight, an aerial photographic line index of the photography was produced utilizing minifications of each exposure and referencing photographs to each other using Adobe® Photoshop® software. The index references each flight line and exposure on the index map by site.

Geodetic Control

Available existing horizontal and vertical controls, as well as controls acquired in 1996, were used to establish geodetic control for the mapping. All external control (used to control the final network adjustment) was based entirely on first order stations as published by the National Geodetic Survey. Stations were located for photo-identifiability (e.g., targets were painted, where surfaces allow, with high visibility traffic paint). Where surfaces did not permit painting, targets consisted of weather-proof plastic material. Target legs measured 12 inches in width and seven feet in length.

GPS survey techniques were used for establishing photo control at these sites using ground-based rapid static procedures. Rapid static GPS uses dual-frequency receivers to occupy the stations for 8-15 minutes compared to 30-45 minutes using dual frequency receivers in a static mode and 60-75 minutes using single-frequency static methods. The accuracy of the GPS-derived orthometric heights is enhanced by occupying a number of existing benchmarks throughout the project area, and using *Geoid93*—geoidal height interpolation and modeling software from the National Geodetic Survey (NGS)—to model the undulations, or the separation of the modeled sea level surface (the geoid) from the idealized mathematical representation of the earth as an ellipsoid of revolution.

All GPS surveys were performed to exceed the first order horizontal specification (0.01 m + 10 ppm). A sufficient number of existing National Geodetic Reference System (NGRS) stations was used as external control. When the vertical control was done using static mode GPS, a sufficient number (at least 6) of well-distributed benchmarks was included in the network. These known orthometric heights were used along with geoid heights derived from *Geoid93* to obtain orthometric heights of all stations in the network. The network was designed so that loop closures may be analyzed for verification.

GPS data collected in the field were downloaded from the receivers to a computer and processed using the GP Survey® software package from Trimble Navigation, Ltd. The baseline processor is known as WAVE (Weighted Ambiguity and Vector Estimation), which is optimized for dual frequency data. This program checks the data as it is downloaded, allowing editing of items such as station name, height of instrument, and so forth. The data was processed in batch mode, with no operator interaction required. Only integer biased fixed solutions were used. The results were examined to identify suspect lines. When a baseline had a low ratio and/or a high reference variance, it was checked by loop closures. The network was designed to enable the verification of all lines. The results were sent by high-speed modem link for analysis by an experienced geodetic engineer. If any re-observations were required, theses were performed before the GPS crew left the site. Office processing consisted of analyzing the results to determine if any manual reprocessing was necessary. Results deemed acceptable were combined to form a network. This network was then adjusted by TRIMNET, a least squares adjustment package from Trimble Navigation, Ltd.

Aerotriangulation

Analytical aerotriangulation was performed for the CIR and true color aerial photography obtained in September 2008. The aerial film negatives were digitally scanned at 22.5 microns and the scanned images were used in the analytical aerotriangulation process on Socet Set® softcopy workstations utilizing Socet Set® Multi-Sensor Triangulation System (MST) software. Data capture was performed with the Automation Point Measurement program (APM). The identification and numbering of pass points and tie points between contiguous strips, was performed by the APM program. This data was then edited with the Interactive Point Measurement program (IPM). The editing process reduces the point residual error, point placement and the addition of ground control. The data was corrected for radial lens distortion and film deformation, and a non-airborne simultaneous adjustment was performed. The data was then exported into the program system BLUH to perform the data reduction and final adjustment. BLUH performs the automatic elimination of systematic image effects through the use of additional parameters. Simultaneous Adjustment was carried out and the data was exported into Socet Set® software for the stereo compilation process.

Stereo compilation

Stereo compilation was accomplished by the stereo digitizing of map elements, extracted from the 2008 CIR and true color aerial photography using precision analytical stereo plotting instruments. The aerial photographs were arranged in overlapping pairs, (commonly referred to as a stereo model) and were then mounted in a stereoplotter for compilation. The analytical solutions, aerial calibration, and geodetic control data, developed in the previous steps of the mapping process, were downloaded into the photogrammetric device and accurately registered to the photography. This process involves mathematically orienting the stereo model with the instrument to create a stereoscopic three dimensional image that the photogrammetrist interprets and compiles to build a vector land base of the mapping features as seen through the optics of the instrument. Such map features include:

- Center lines of channels between one and five feet in width;
- Edges of channels greater than five feet in width;
- Ponded areas;
- Dikes, dike breaches and internal berms; and
- Miscellaneous roadways.

Digital Elevation Models (DEM) were also developed to support the production of digital orthophotographs by taking a file containing break lines (digitized points that are connected by a line) which have been placed at all breaks in terrain, and mass points placed at strategic locations (tops, depressions, road intersections, and so forth) and linking them together to form the triangulated irregular network, or TIN. Generally, break lines will be shown at all terrain breaks, drains, tops of banks, ridges, valleys, bases of hills, edges of plateaus, road edges, and so forth. All vector information (map data) was tiled to match PSEG’s existing tiling scheme (4,000 ft x 8,000 ft).

Digital Orthophotography

An Intergraph Digital Ortho Production System was used for generating digital orthophotography of the reference and restoration sites. The system includes the Zeiss/Intergraph PhotoScan PS1 digital transmissive scanner, six Intergraph workstations with JPEG Compression boards, and more than 40 gigabytes of disk storage capacity. The following steps comprise the general digital orthophoto workflow:

Scanning. Each diapositive was scanned three times using red, green, and blue filters. Each scan pass detects the film’s emulsion layers that are sensitive to a corresponding spectral bandwidth. Scanning is performed in a manner that duplicates the film as it is exposed to maintain the relationships between the individual colors in the film.

DEM Production. Mass point and break lines were merged into blocks and the coordinate system, global origin and working units were set using Intergraph's MGE Terrain Modeler software package. A TIN surface model was developed for each site and, from that surface representation, a grid model was created at an appropriate interval to support orthorectification.

Image Orientations. After an exposure was scanned, the fiducial marks were measured using

Image Station Digital Orientation (ISDO) software to determine the Interior Orientation (IO) of the image. This step relates the scanned image to the USGS camera calibration report and determines the geometric relationship between the two. Residual errors are normally less than 10 microns for a diapositive. If the Root Mean Square Error (RMSE) was excessive, the exposure was re-scanned. If the error was repeated, the diapositive was rejected and remade.

The Exterior Orientation (EO) was performed by relating measured pug mark positions with the corresponding ground coordinates to determine the exact location of the camera at the time of exposure. Known as the space resection, this position consists of the X, Y, and Z coordinates of the camera and the three rotation angles that describe the tip, tilt, and yaw of the aircraft. Convergence statistics should not exceed National Map Accuracy Standards (NMAS) standards for the scale of photography.

Digital Orthorectification. Digital orthophoto processing is a reiterative process that combines input from photography, analytics, and a DEM. The Intergraph Image Station Rectifier (IISR) software mathematically calculates the true orthogonal position and brightness value for each pixel within the digital orthophoto. This is accomplished by differentially resampling the input data both spatially and radiometrically to calculate a new rectified pixel.

The central portion of every exposure from the stereo model was scanned and rectified. Using only the central portion of each exposure reduces the effect of vignetting (uneven exposure that results in darker margins around the diapositives). This is especially important with color infrared photography as it is very susceptible to change in exposure level. Following rectification, the coordinates of photo-identifiable points within the rectified image were compared to the actual ground coordinate of that point. The distance between the observed point and the true coordinate is used to quantify the accuracy of the orthophoto in terms of the NMAS for the mapping scale. These values were included with the result of the interior and exterior orientation analysis. The ortho image was also viewed against the vectorized break lines and other planimetric features to ensure correlation with the DEM file. Compiled features such as stream edges and road center lines are readily identifiable and were used to assess the overall accuracy of the orthophoto.

Mapsheet Generation and Output

Automated procedures were used to merge two or more overlapping images together and generate a specified mapsheet (4,000 ft in a north-south direction and 8,000ft in an east-west direction). Using the AutoOrtho (ISAO) software developed by Intergraph and TRIFID Corporation, digital imagery can be mosaiced, tone-matched, and feathered into a single continuous seam-free image that can be edge matched against the adjacent sheets to check for continuity of features and contrast. All digital orthophoto files were produced as Intergraph type 28 RGB 24-bit files with a standard color table attached to it so that plotting and display characteristics are consistent among the files.

Vegetation Mapping

Mapping of marsh vegetation types on the wetland restoration and reference sites utilized the 2008 CIR and true color aerial photography acquired for vector mapping and digital orthophotograph production. CIR photography is a three layer (cyan, yellow and magenta) film that has been widely used for crop and natural vegetation studies because image color formation is dependent upon reflected energy in the red and green portion of the visible spectrum as well as the near-infrared. An object that reflects only infrared energy will expose the cyan layer of the film, leaving the yellow and magenta layers that combine in a subtractive mixture to form a red image when viewed by transmitted light.

A team of scientists familiar with the vegetation and physical features of the reference and restoration sites interpreted the CIR and true color aerial photography by identifying color/texture characteristics (i.e., signatures) of the various cover types present. The various areas of species-dominated polygons or other site features (e.g., mud flats) identified on the CIR aerial photography were delineated digitally while viewing the orthophotograph on the computer monitor. On-screen digitizing of cover type boundaries was performed using AutoCAD LT 2005™. Each polygon mapped in this way was assigned an identifying code consisting of the year, cover type designation, and a sequential polygon number for that cover type. Thus, each polygon was given a unique alphanumeric identification that linked the polygon to an external Microsoft Access™ database. AutoCAD Map 2® Release 14.0 software was utilized to further process the data. The minimum mapping unit (MMU) employed for the digitizing effort was one acre. In order to be identified as a given cover type, it is generally necessary that the vegetative cover of the polygon exceed 30 percent. Thus areas mapped as "mud flat" may support vegetation below the 30 percent mapping threshold. This is consistent with the approach utilized by the USFWS in the preparation of NWI maps, where areas supporting less than 30 percent cover are identified as unvegetated (Tiner 1998).

Quantitative Geomorphologic Evaluation

A quantitative evaluation of the geomorphologic features was conducted based on the geomorphological mapping compiled from the September 2008 CIR and true color photography. The following parameters were determined as part of the quantitative geomorphologic evaluation:

- Channel classification (order)
- Determination of the total number of channels in each order
- Calculation of bifurcation ratio
- Channel frequency
- Total length (sinuous length)
- Total linear length
- Average channel length
- Channel length ratio
- Percent of total channel length
- Average channel sinuosity
- Drainage density

An approach to geomorphological classification of stream channels was developed by Horton (1945), who emphasized topographic characteristics of the drainage area and gave a hierarchical order to every channel in the drainage basin in his stream-ordering technique. The Horton method utilizes a "top-down" approach to determine the order of the drainage channels, where the smaller streams have lower-order numbers and the central channel is assigned the highest-order number.

Strahler (1957) modified the Horton system by starting the next highest order at the confluence of two tributaries of lower order. Strahler's method is based on the premise that, for a sufficiently large sample size, order number is directly proportional to relative watershed dimensions, channel size, and volume of stream discharge. Also, because the order number is a dimensionless value, two drainage basins of different sizes can be compared at corresponding points through the use of order numbers.

The analytical channel geomorphology tools of Horton (1945) and Strahler (1957), as referenced in Chow (1964, 1988) (order analysis) were developed for evaluating mature stream systems and to aid in the design of stream restoration projects. An implicit assumption of order analysis is that the evaluation is done for sites with comparable channel orders. While this technique is appropriate for mature stream systems, it is not as effective for rapidly developing (i.e., recently restored) salt marsh tidal channel systems in which the number and order of channels can change dramatically over a short time period.

The development of small channels through natural restoration processes dramatically changes the order number of the largest channels. The change in order number with channel development makes it extremely difficult to relate channel dimension with channel order. Because the number of small channels at a restoration site increases as the site matures, the classical channel ordering method makes it appear as if the number of large inlet channels also varies over time. This is because the increase in small channels causes the order number assigned to the largest channels to increase as well.

This increase in order number for the largest channels made comparison between years and among sites extremely difficult at the PSEG restoration sites. In some instances it was not possible to match channel size (dimensions) with channel order, since each channel system changed independently of other systems at a site, and among sites. As a result, it was impossible to track what was happening over time in the smaller channels. Knowing what was happening in the smaller channels was critical, since these small marsh channels provide pathways for tidal waters to access the marsh plain. Additionally, these small marsh channels provide conduits for fish access and detrital export. Therefore, analyzing changes of these small tidal channels is one of the most critical aspects for assessing restoration success.

To address the difficulties associated with application of the "top-down" channel order approach, the hydrogeomorphic analysis technique utilized for this project was modified to be more useful with a dynamic system. Using this hydrogeomorphic class technique ensures that the largest channels are always the lowest number (first class), and that increasing order numbers are assigned to the rapidly changing smaller channels.

Using the "bottom-up" approach, the main inlet from the Delaware Bay or other major water body (e.g. West Creek, Riggins Ditch) was designated a first-class channel. The procedures outlined below were then followed to determine the class designations of channels to be analyzed at each site.

(1) A second-class channel begins where a first-class channel splits into two separate, comparably sized double-lined channels (double-lined channels are greater than five ft wide). If one of these two channels is less than half the size of the other channel, the smaller channel becomes a second-class channel and the other remains a first-class channel.

(2) When a second-class channel splits, the above-stated procedure is applied to identify these branches as third class, fourth class, etc. This rule is only applicable to double-lined channels (i.e., greater than 5 ft wide).

(3) Any single-lined channel (i.e., less than 5 ft wide) coming off a double-lined channel is a third-class channel. However, if that double-lined channel is already a third-class channel or greater, then that single-lined channel will be one class higher than the double-lined channel it branches from.

(4) With any split of a single-lined channel, those two channels will be one class higher than the channel they are splitting from.

The method used to derive the geomorphological analysis of the reference marshes and wetland restoration sites utilizes the attributes of both AutoCAD® and Arc View® software. This software quantifies the number of channels of each order that occur on a site as well as derive the various length measurements that are utilized to characterize the channel systems on the sites, as described below:

Bifurcation Ratio (R_B). The bifurcation ratio, or R_B, is the ratio of the number of channels of one class to the number of channels of the next lower class.

$$R_B = N_n \ / N_{n-1}$$

Channel Frequency (F_C). The channel frequency, or F_C, is the number of channels for all classes (N_T) per unit area.

Total length (sinuous length) (L). The total sinuous length, or L, for channels in each class is the centerline length along the channel course from the start of a channel of one class to the beginning of the channel of next lower class.

Total linear length (straight line length) (SL). The straight line length, or SL, is the length for channels in each class measured as the straight line distance from the start of the channel of one class to the beginning of the channel of next lower class.

Average channel length ($L_{n\ avg}$). The average channel length, or $\mathbf{L_{n\ avg}}$, is the total length of channels of a given class divided by the number of channels in that class.

$$L_{n\ avg} = L_n / N_n$$

Channel length ratio (R_L). The channel length ratio, or R_L, is the ratio of the average length of channels in one class to the average length of channels in the next higher class.

$$R_L = L_n / L_{n+1}$$

Percent of total channel length (%CL). The percent of total channel length, or %CL, provides information on the proportion of each channel class in the site. This value is calculated by dividing the total length of channels in one class (Ln) by the total length of channels of all classes (LT) and multiplying by 100%.

$$\%CL = L_n / L_T \text{ x } 100\%$$

Average channel sinuosity (S_{avg}). The average channel sinuosity, or S_{avg}, is the ratio of the average length of channels of a given class to the average straight line length for channels in that class.

$$S_{avg} = L_{n\ avg} / SL_{n\ avg}$$

Drainage density (D). The drainage density, or D, is the total length of channels of all classes divided by the area of the site.

VEGETATION TRANSECTS

Detrital production data were collected in August 2008 along transects located in New Jersey at the MHC Reference Marsh and MBW Reference Marsh (Figures 8-2 and 8-3, respectively); the CT Site (Figure 8-4); the ACW Site (Figure 8-5); and The Rocks and Cedar Swamp Sites in Delaware (Figures 8-6 and 8-7). Random quadrats (0.25 m^2) were located as described below along each of the transect alignments shown in these figures. Macrophyte production data were collected within these quadrats as described in the following sections. The original transects at the restoration sites and the reference marshes were established as part of the 1995 detrital production monitoring effort. Two of the reference site transects were relocated in 1996, MHC Reference Marsh Transect 3 (shown as MHT3A in Figure 8-2) and MBW Reference Marsh Transect 1 (shown as MBT1A in Figure 8-3). The former was relocated for a property access purpose; the latter to eliminate the excessive edge habitat that the original alignment traversed. The Rocks and Cedar Swamp transects were established for the 1999 sampling effort.

Each transect sampled in 2008 was divided into community segments, with each segment traversing a portion of the total transect length dominated by a given species. In the event that two or more species were determined to be co-dominants, the community segment was identified as such. This method is further discussed in the following section.

The collection of field data (e.g., percent aerial cover) and clipping of samples of macrophytes for laboratory processing occurred within the randomly selected quadrats located along the community segments of each transect. Each quadrat was identified by an alpha-numeric code designating its associated transect and sampling event, the type of data collected at the quadrat and its position along the transect. As an example, MHT1-08-OQ18 indicates that the quadrat was sampled along MHC Reference Marsh Transect 1 during 2008 (MHT1-08). The data collected was an ocular estimate of percent cover within the quadrat area (O), and the quadrat was the eighteenth sampled along the transect (Q18). Similarly, MHT1-08-CQ1 indicates that the quadrat was sampled along MHC Reference Marsh Transect 1 during 2008 (MHT1-08). In this instance, percent cover data were collected and the quadrat area was clipped for standing crop determinations (C). The quadrat was the first sampled along the transect (Q1).

The method for establishing the random location of the quadrats is as follows:

The transects at the wetland restoration sites were walked, recording the type, length and number of plant communities (i.e., community segments) and open water and mudflat areas crossed on an appropriate data sheet (Appendix A, Exhibit A-1). A Magellan Meridian® global position system (GPS) unit was utilized to determine the lengths of each plant community traversed and the locations of channels and other geomorphic features. The community designations determined as a result of this effort served as the basis for the selection of quadrat locations.

The appropriate number and location of quadrats sampled utilizing the appropriate data form (Appendix A, Exhibits A-2 and A-3) was determined as follows:

1. Two quadrats per dominant species type traversed along the transect (e.g., *Spartina patens* dominated, *Spartina alterniflora* dominated) were randomly located. Within these quadrats, standing crop collections (“clips”) were made. To locate these clip quadrat locations, two community segments of the transect dominated by the same species were randomly selected from the total number of similarly dominated segments[1]. A quadrat location was then randomly selected within each segment.

2. Additional quadrats were randomly located along the transect length within which only ocular estimates of percent cover were made (i.e., “ocular” quadrats). The number of ocular quadrats was determined by multiplying three by the total number of biomass clip quadrats (maximum 22).

Clip and/or ocular quadrats were located one meter to the side of the transect alignment so as to avoid sampling areas that were previously walked over. The side (right/left) of the transect to which the quadrat was placed was alternated between sample points.

At the reference marshes, community data collected during the 1996 sampling effort were used to determine the appropriate number and location of quadrats to be sampled (according to the procedures outlined above) during the 2008 effort.

QUADRAT SAMPLING

Sampling within the 0.25 m^2 quadrats located along the transects as described above was

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[1] In the event that only one transect segment was dominated by a given species, both clip quadrats were randomly located within that segment.

conducted utilizing the field procedures described below:

Percent Aerial Coverage

Within each 0.25 m^2 quadrat, the percent of plant foliar and stem aerial coverage (as viewed from above by an observer standing at a point adjacent to the quadrat) was visually estimated using the following percent coverage categories:

0% = open water or bare sediment
<1% = plants sparsely or very sparsely present
5% = plants covering from 1 to 10% of the area
15% = plants covering from 11 to 20% of the area
25% = plants covering from 21 to 30% of the area
35% = plants covering from 31 to 40% of the area
45% = plants covering from 41 to 50% of the area
55% = plants covering from 51 to 60% of the area
65% = plants covering from 61 to 70% of the area
75% = plants covering from 71 to 80% of the area
85% = plants covering from 81 to 90% of the area
95% = plants covering from 91 to 100% of the area

The process of determining the percent coverage for each species occurring in a quadrat first involved estimating of the total percent coverage of all plants within the 0.25 m^2 quadrat area. This total was then subdivided into individual percentages for each species within the quadrat and entered onto an appropriate data sheet (Appendix A - Exhibit 2 for clip quadrats; Exhibit 3 for ocular quadrats).

Canopy Height

Canopy height was determined for each species by measuring the height of a mid-sized plant occurring within the quadrat. These data were entered onto an appropriate data sheet (Appendix A - Exhibit 2 for clip quadrats; Exhibit 3 for ocular quadrats).

Flowering status

During each sampling event, plant species occurring within each quadrat were noted as being either flowering or non-flowering at the time of sampling. The flowering status was recorded on the appropriate data sheet (Appendix A - Exhibit 2 for clip quadrats; Exhibit 3 for ocular quadrats).

Above-ground Biomass Collection

A vertical photograph was taken of each clip quadrat area and all living and standing non-living vegetation within the quadrat was cut within 1 cm of the sediment, separated by species and placed in labeled paper bags. Unattached surface litter from within the quadrat area was also collected and placed in labeled paper bags. Samples were then transported to and processed in the laboratory as described below.

VEGETATION PLOTS

To supplement the collection of field data within quadrats along transects in 2008, additional 0.25 m^2 quadrat sampling was conducted within previously established 60 m x 60 m (3,600 m^2) "plots". These plots were located at each site during the initial years of restoration to collect macrophyte productivity data from areas appearing to be of relatively uniform species composition, coverage and height at the time of selection. The primary purpose of this supplemental sampling was to determine the peak live standing crop in areas that could be located on the peak growing season CIR and true color photography, since a 3,600 m^2 area appears as an approximately 0.2 cm^2 area (0.4 cm x 0.4 cm) on a 2X enlargement (1:4,800) of the 1:9,600 scale aerial photography. The number of plots located at each site and the dates these plots were established are as follows:

Site	Number of Plots	Date Established
MHC Reference Marsh	3	1996
MBW Reference Marsh	3	1996
Cedar Swamp Site	1	1997
The Rocks Site	1	1997
ACW Site	3	1999
CT Site	4	1999

The corners of these plots were marked with PVC pipes and located using Global Positioning System (GPS) methods to provide a permanent record of the sampling location. The locations of these plots at each site are shown in Figures 8-2 (MHC Reference Marsh), 8-3 (MBW Reference Marsh), 8-4 (CT Site), 8-5 (ACW Site), 8-6 (The Rocks Site), and 8-7 (Cedar Swamp Site).

Quadrat Locations

Each of the fifteen 3,600 m^2 plots listed above was stratified into nine 20 m x 20 m (400 m^2) sub-areas. One 0.25 m^2 quadrat was randomly located within each sub-area, for a total of 9 quadrats per plot. Each quadrat was identified by an alpha-numeric code designating the site, plot number and quadrat number. As an example, MHP1-08-CQ5 indicates that the quadrat was sampled within MHC Reference Marsh Plot 1 (MHP1) during 2008 (08). The quadrat area was clipped for standing crop determination (CQ) and it was the fifth sampled within the plot (5).

Quadrat Sampling

Percent coverage, height and flowering status data were collected in each quadrat as described previously and recorded on the appropriate data sheet (Appendix A – Exhibit A-4). Above ground biomass collection was performed as described previously. Samples were then transported to and processed in the laboratory as described below.

MACROPHYTE LABORATORY PROCESSING

In the laboratory, each sample was dried to a constant weight at 60^o C. Following drying, the plant materials collected from each quadrat were weighed to the nearest 0.01g and entered onto the laboratory data sheet (Appendix A – Exhibit A-5). The data was then entered into a Microsoft ® EXCEL spreadsheet for subsequent statistical analysis.

RESULTS

COVER TYPE MAPPING

Cover Type Descriptions

The CIR and true color aerial photography acquired on September 8, 2008 was interpreted to map the extent of the various cover types present on the wetland restoration and reference sites at the time of peak standing crop. The cover types identified at the various sites were delineated by mapped polygons[2] representing areas of each site that are either dominated by listed species (i.e., vegetation community types) or represent identifiable land/water features (e.g., developed land, agricultural land, open water, mud flat). In areas where two or more species dominate a vegetation community, multiple species were listed.

The acreage and percent coverage of each individual cover type (e.g., species or group of species) for the reference marshes and the "wetland restoration area" of each wetland restoration site is provided in Tables 8-1 through 8-4. The wetland restoration area generally occurs within the overall "site boundary" and was determined based on the mapping of the tidal wetland/upland edges. These tables group the cover types under the following categories:

- *Spartina*/other desirable marsh vegetation;
- *Phragmites*-dominated vegetation;
- Non-vegetated marsh plain;
- Internal water areas;
- Open water; and
- Upland vegetation/miscellaneous cover categories

The extent of each cover category at each of the reference marshes and wetland restoration sites is shown in Appendix B, Figures B-1 to B-6. These figures also show the wetland restoration area boundaries for each site. General descriptions of the various cover categories that appear on these figures and the individual cover types that they represent are provided in the following paragraphs.

***Spartina spp*. and Other Desirable Marsh Vegetation**

While restoration of *Spartina alterniflora* as a dominant species is desirable, there are numerous other species that contribute to estuarine productivity and are indicative of a fully functional marsh ecosystem. Such species include, but are not limited to: *Spartina cynosuroides, Spartina patens, Distichlis spicata, Scirpus robustus*, *Scirpus olneyi, Typha latifolia, Pluchea purpurascens, Acorus calamus, Eleocharis parvula,* and *Echinochloa walteri*. Areas that are predominated by *Spartina alterniflora* or another desirable marsh species are included in this category. Where other species are co-dominants with *Spartina alterniflora*, these species are also indicated in the type designation (e.g., *Spartina alterniflora*/*Amaranthus cannabinus*).

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[2] The minimum polygon area for vegetation stands is approximately 1 acre.

Where sparse clumps of *Spartina alterniflora* occur in mud flat areas, these areas are designated in a similar manner (e.g., *Spartina alterniflora*/Mud flat). In the event that mud flat predominates an area, the order of the type name is reversed (i.e., Mud flat/*Spartina alterniflora*).

Spartina alterniflora

The *Spartina alterniflora* cover type represents areas that have developed "complete" coverage by this species. The percent coverage of the marsh plain by *Spartina alterniflora* in these areas generally ranges between 80 and 90 percent. This cover type represents both tall and short forms. The tall form reaches heights of between 120 and 200 cm and occurs along the margins of creeks, guts, channels, and in other areas that are subject to daily tidal inundation. Short form plants are generally 30 to 60 cm high and occur either in areas of higher marsh surface elevation or on the normally flooded marsh plain inland from the creek channels. In some cases other species, including *Spartina cynosuroides, Scirpus robustus*, and *Amaranthus cannabinus*, also occur as co-dominants in this community.

Salt Hay

The salt hay cover type represents areas of the Commercial Township Site vegetated with *Spartina patens, Distichlis spicata*, and *Juncus gerardii.* This cover type was present prior to the restoration of tidal flows to this site. These areas were actively managed for salt hay production, which involved, among other things, periodic inundation and mowing.

Spartina patens

The *Spartina patens* cover type is typically found in natural high-marsh areas that are at an elevation between mean high and mean higher high water (MHW and MHHW, respectively). These areas are usually dominated by *Spartina patens*.

High Marsh

The high marsh cover type includes a variety of coastal species that are generally found at an elevation above MHW. Depending on the particular location, it may contain *Spartina patens, Distichlis spicata*, *Iva frutescens*, *Baccharis halimifolia*, *Panicum virgatum*, and *Phragmites australis*.

Typha spp.

The *Typha* spp. cover type includes areas dominated by *Typha latifolia* and *Typha angustifolia*. These species generally occur in the lower-salinity areas of the estuary and have become established over large areas of the *Phragmites*-dominated sites following the application of a glyphosate-based herbicide with a surfactant.

Recovering Desirable Species Area

These areas, historically, were dominated by desirable marsh vegetation, (i.e., *Spartina alterniflora, Spartina cynosuroides*). In recent years, these areas have been severely damaged by foraging snow geese and muskrats, turning them primarily to mud flat.

Desirable Marsh Vegetation and *Phragmites*

Desirable Marsh Vegetation/*Phragmites* represents portions of each site that are dominated by a variety of desirable marsh species, and include *Phragmites* as a subdominant species. *Phragmites* may occur sparsely throughout the mapped area (Mixed Marsh) or as small isolated colonies that are below the mapping threshold. These areas are primarily within the *Phragmites*-dominated wetland restoration sites and usually represent areas that, prior to initial restoration activities, were monotypic stands of *Phragmites*.

***Phragmites*-Dominated Vegetation**

This cover category includes larger areas (>1 acre) dominated by living monotypic stands of *Phragmites* and areas treated with a glyphosate-based herbicide with a surfactant that have remaining dead culms present (e.g., areas that have not been burned).

Phragmites australis

Stands of *Phragmites* occur at both the reference marshes and the wetland restoration sites. At the reference marshes and salt hay farm restoration sites, this community is usually found as an isolated cover type in disturbed areas such as dikes, ditch and road edges, and on natural creek levees. At the *Phragmites*-dominated sites, the cover type had occurred over large areas of the marsh plain prior to the initiation of the restoration activities. Although *Phragmites* usually forms monotypic stands, species such as *Iva frutescens*, *Baccharis halimifolia*, and *Atriplex patula* may also be present in this community, especially along the upland edge.

Dead *Phragmites australis*

Monotypic stands of *Phragmites* that have been either treated with a glyphosate-based herbicide with a surfactant or subjected to salt water inundation are delineated as the dead *Phragmites australis* cover type. This type is included in the *Phragmites*-dominated vegetation category because the dead culms mask the underlying vegetation; therefore, the establishment of desirable marsh vegetation cannot be interpreted from the aerial photography. As these culms are removed by natural processes (e.g., storm tides, ice flows) or by mechanical means through continued restoration activities, the marsh plain will be exposed and these areas will likely become vegetated with *Spartina alterniflora* or other desirable naturally occurring marsh vegetation.

Non-Vegetated Marsh Plain

Various cover types within the marsh plain that are not vegetated[3] by macrophytes are included in this category.

Mud Flat

At the restoration sites, mud flat is primarily a transitional cover type that precedes the establishment of desirable vegetation. Mud flat areas that were exposed (i.e., not covered by water) at the time of the CIR and true color aerial photography were delineated as this cover type. During many high tides these areas are inundated. Sparse (< 30 percent cover) vegetation may be present that cannot be detected on the CIR or true color aerial photography. This vegetation may be dominated by *Phragmites* or *Spartina* spp. and other desirable naturally occurring marsh vegetation. Algal mats may also be present over much of the mud flat areas.

Algal Mat

Mud flats covered by cohesive mats of filamentous algae or a filamentous or gelatinous mat of cyanobacteria have been categorized as algal mat. This cover type is present over many areas, but is not always identifiable on the CIR or true color aerial photography because of differences in the sun's reflection off the marsh surface and sediment deposition onto the algal mat.

Wrack

In some areas, the marsh plain is covered by accumulated dead stems of marsh vegetation that that have been deposited by the tides, obscuring the marsh surface. These areas are delineated as the wrack cover type.

Internal Water Areas

Areas that were covered by surface water at the time of the aerial photography (low tide) were designated as open water. Open water includes the subtidal areas of tidal creeks, guts, channels, ditches, and areas of ponded water within the marsh. These areas generally do not support any significant vegetation.

Interior Channels

This cover type consists of interior channels greater than five feet wide and includes water areas within channels at the time of the aerial photography (low tide) as well as exposed channel mudflat areas between the low tide water line and the adjacent marsh plain.

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[3] Areas considered to be non-vegetated may support sparse vegetative cover. To be mapped as vegetated, it is generally necessary that greater than 30 percent of the marsh surface be covered by macrophytes.

Ponded Water

The ponded water cover type represents areas within the reference marsh and wetland restoration sites that are hydrologically isolated and remain inundated at low tide.

Open Water

The open water category includes small portions of major water bodies (e.g., Delaware Bay, Alloways Creek) adjacent to the various restoration sites or reference marshes that occur within the site boundaries.

Upland Vegetation/Miscellaneous Cover Categories

Relatively small areas of upland vegetation and other non-marsh cover categories occur within the restoration area boundary at some sites. While the area of each of these is provided in the tables, they are generally mapped on the Figures in Appendix B as upland "buffer" areas.

Site Descriptions

Discussions of the cover type composition in 2008 at each of the reference marshes and wetland restoration sites are provided in this section. Reference marshes are discussed first, followed by the CT Site, the ACW Site and the Delaware *Phragmites*-dominated restoration sites.

Detailed information on cover type areas for the 2008 monitoring year are presented in Tables 8-1 through 8-4. The percentage of the total marsh area[4] for applicable cover types has been calculated and is included in these tables. Maps showing the 2008 vegetative cover of each reference marsh and wetland restoration site are provided in Appendix B. These maps correspond to the reference marsh and wetland restoration area cover type data presented in Tables 8-1 through 8-4 and show the areas of each site that are vegetated as per the categories below.

Reference Marshes

The extent of each cover category at the reference marshes was based on the interpretation of the 2008 CIR and true color aerial photography as shown in Figures B-1 (MHC Reference Marsh) and B-2 (MBW Reference Marsh) in Appendix B. The acreage of the vegetation cover categories and cover types mapped in 2008 within each of the reference marshes and the relative percent of the total marsh area that each type represents are summarized in Table 8-1.

A total of 74.2 percent of the MHC Reference Marsh was covered by *Spartina spp.* and Other

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[4] The total marsh area excludes: 1) areas of each reference marsh and wetland restoration site that are above MHHW, as defined by vegetation interpretation; and 2) tidal wetland areas that were not affected by PSEG's wetland restoration activities at a given site. The latter includes areas that were outside of the salt hay farming dikes at the time of PSEG's acquisition of the site and areas landward of upland dikes that were constructed by PSEG as part of the wetland restoration designs for the sites.

Desirable Marsh Vegetation in 2008. *Spartina alterniflora* as the single dominant comprised 23.3 percent of the total marsh area. *Phragmites australis* dominated over areas representing 8.7 percent of the marsh plain in 2008. Interior Water Areas, primarily Channels, made up 15.2 percent.

A total of 81.0 percent of the MBW Reference Marsh was covered by *Spartina spp.* and Other Desirable Marsh Vegetation in 2008. *Spartina alterniflora* as the single dominant comprised 61.9 percent of the total marsh area. *Phragmites australis* dominated areas covered 3.5 percent of the marsh plain. Non-vegetated Marsh Plain and Internal Water Areas made up 3.6 percent and 7.4 percent, respectively, of this reference marsh.

Commercial Township Salt Hay Farm Restoration Site

The extent of each cover category and cover type at the CT Site based on the interpretation of the 2008 CIR aerial photography is shown in Figure B-3 in Appendix B. The acreage of the vegetation cover categories and cover types mapped within the CT Site and the relative percent of the total marsh area that each type represents are summarized in Table 8-2.

Spartina spp./Other Desirable Marsh Vegetation (50.8%) and Non-vegetated Marsh Plain (36.7%) were the dominant cover categories at the CT Site in 2008. Areas dominated by *Spartina alterniflora* represented the most extensive vegetated cover type (occurring over 44.7% of the restoration area). Mud Flat (22.3%) and Mud Flat/*Spartina alterniflora* (13.4%) were the most prevalent non-vegetated cover types. *Phragmites* Dominated Vegetation comprised 2.9 percent of the total marsh area and was also present within areas mapped as *Spartina* spp./Other Desirable Marsh Vegetation with *Phragmites* cover category (0.3%). Internal Water Areas were primarily Channels (7.5%) and Ponded Water (1.2%).

Alloway Creek Watershed *Phragmites* Dominated Wetland Restoration Site

The extent of each cover category at the ACW Site based on the interpretation of the 2008 true color aerial photography is shown in Figure B-4 in Appendix B. The acreage of the vegetation cover categories, cover types mapped and the relative percent of the total marsh area that each type represents are summarized in the Table 8-3.

Spartina spp./Other Desirable Marsh Vegetation comprised 74.7 percent of the total marsh area at the ACW Site in 2008. Individual cover types present within this cover category included: *Spartina alterniflora*/Desirable Mixed Marsh (41.4%), Desirable Mixed Marsh (26.3%), and Mixed Marsh (2.7%). The *Phragmites* Dominated Vegetation cover category represented 7.8 percent of the total marsh area, with monotypic *Phragmites australis* stands representing 3.1 percent, and *Phragmites australis* dominating with other vegetation types representing 4.7 percent. Also included in this cover category are areas of the ACW Site dominated by Dead *Phragmites australis,* representing 1.5 percent of the total marsh area. Non-vegetated Marsh Plain comprised 3.7 percent of the total marsh area. Areas covered by wrack accounted for most (2.5%) of these areas. Channels represent 13.7 percent of the ACW Site.

Delaware *Phragmites* Dominated Wetland Restoration Sites

The extent of each cover category at the Delaware *Phragmites* dominated wetland restoration sites based on the interpretation of the 2008 true color aerial photography is shown in Figures B-5 (The Rocks) and B-6 (Cedar Swamp) in Appendix B. The acreage of the vegetation cover categories and cover types mapped within each restoration site and the relative percent of the total marsh area that each type represents are summarized in Table 8-4.

The Rocks. *Spartina spp.*/Other Desirable Marsh Vegetation (85.9%) was the most extensive cover category at The Rocks Site in 2008. Individual cover types present within this cover category included: *Spartina alterniflora/*Desirable Mixed Marsh (65.9%), Desirable Mixed Marsh (10.4%), and Mixed Marsh (3.8%). The *Phragmites* Dominated Vegetation cover category represented 8.3 percent of the total marsh area, with monotypic *Phragmites australis* stands representing 3.4 percent, and *Phragmites australis* dominating with other types representing 4.9 percent. Also included in this cover category are areas dominated by Dead *Phragmites australis,* representing 1.5 percent of the total marsh area. Non-vegetated Marsh Plain comprised 1.1 percent of the total marsh area. Areas covered by wrack accounted for most (0.9%) of these areas. Internal Water Areas represent 4.2 percent of The Rocks Site, represented primarily by Channels (4.0%).

Cedar Swamp. *Spartina spp.*/Other Desirable Marsh Vegetation (82.7%) was the most extensive cover category at the Cedar Swamp Site in 2008. Individual cover types present within this cover category included: *Spartina alterniflora/Spartina cynosuroides* (37.1%), Desirable Mixed Marsh (18.1%), *Spartina alterniflora*/Desirable Mixed Marsh (8.4%), and *Spartina alterniflora* (7.9%). In addition, *Spartina* spp. /Other Desirable Marsh Vegetation with *Phragmites* represented 5.4 percent of this category, represented primarily by Mixed Marsh areas (4.7%). The *Phragmites* Dominated Vegetation cover category represented 5.3 percent of the total marsh area, with monotypic *Phragmites australis* stands representing 2.4 percent, and *Phragmites australis* dominating with other types representing 2.9 percent. Also included in this cover category are areas dominated by Dead *Phragmites australis,* representing 1.2 percent of the total marsh area. Non-vegetated Marsh Plain comprised 1.6 percent of the total marsh area. Areas covered by wrack accounted for most (1.3%) of these areas. Internal Water Areas represent 10.1 percent of the Cedar Swamp Site, represented primarily by Channels (10.1%).

GEOMORPHOLOGIC MAPPING

Maps showing existing hydraulic features on the restoration sites as interpreted from the September 2008 CIR and true color aerial photography of the reference marshes and wetland restoration sites are provided in Appendix C. Mapped features include:

- Center lines of channels between one and five feet in width;
- Edges of channels greater than five feet in width;
- Ponded areas;
- Dikes, dike breaches and internal berms; and
- Miscellaneous roadways.

These maps present the extent of channel systems and other water areas (e.g., ponded areas) as interpreted from the above-referenced photography for these sites. Comments regarding the mapping of the sites are provided in the following paragraphs.

Reference Marshes

The channel systems at the MHC and MBW Reference Marshes based on 2005 CIR and true color aerial photography are shown on Figures C-1 and C-2 in Appendix C. Data representing the 2005 geomorphological characteristics of these reference marshes are presented in Table 8-5.

Commercial Township Salt Hay Farm Wetland Restoration Site

The channel systems at the CT Site in 2008 are shown on Figure C-3 in Appendix C. Data representing the geomorphological characteristics of the CT Site are presented in Table 8-5.

Alloway Creek Watershed *Phragmites* Dominated Wetland Restoration Site

The channel systems at the ACW Site in 2008 are shown on Figure C-4 in Appendix C. Data representing the geomorphological characteristics of the ACW Site are presented in Table 8-5.

Delaware *Phragmites* Dominated Wetland Restoration Sites

The channel systems at The Rocks and Cedar Swamp sites in 2008 are shown on Figures C-5 and C-6 in Appendix C. Data representing the geomorphological characteristics of The Rocks and Cedar Swamp are presented in Table 8-5.

REFERENCE MARSH TRANSECT SAMPLING

Quadrat sampling was conducted during the peak (August) 2008 growing season at the MHC Reference Marsh and MBW Reference Marsh. Percent cover, species identification, flowering status, and height data were collected from both clip and ocular quadrats. Standing crop data (live standing and dead standing) and litter were collected from clip quadrats only.

The field and lab data representing the clip and ocular quadrats along the reference marsh transects during the peak season 2008 macrophyte sampling events are presented in Appendix D. The individual 2008 quadrat data, as well as the means, for percent cover, height (*Spartina alterniflora* and *Spartina cynosuroides*), live standing crop, dead standing crop, and litter for each transect and for all transects at each reference marsh are presented in Appendix D, Tables D-1 and D-2. For each site these means were calculated for: 1) *Spartina alterniflora* dominated[5] (S-d) quadrats, 2) non-*Spartina alterniflora* dominated (e.g., *Phragmites* dominated) quadrats, and 3) for all quadrats.

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[5] *Spartina alterniflora* dominated quadrats include those dominated by *Spartina cynosuroides*.

While the tables in Appendix D present all macrophyte field and laboratory data in detail, several tables have been prepared which summarize the reference marsh transect data collected during the peak growing season. Table 8-6 presents a summary of percent cover by dominance type (*Spartina alterniflora* dominated, non-*Spartina alterniflora* dominated, and all species) for all quadrats (clip and ocular). A summary of percent cover and standing crop data, from clip quadrats only is presented in Table 8-7. The mean percent cover (and mean standing crop), standard error of the mean, standard deviation, minimum, maximum, and number of quadrats for each dominance type are provided in both tables. In addition to the summaries by site, summaries by transect also have been prepared. Table 8-8 presents the means and measures of dispersion (standard error of the mean and standard deviation) by transect for percent cover, height, and standing crop. Data from both clip and ocular quadrats, as applicable, have been used in the calculations in Table 8-8.

Species Composition. *Spartina alterniflora* was the dominant species sampled along transects at the MHC Reference Marsh and MBW Reference Marsh in 2008, recorded in 70 and 92 percent of the quadrats sampled at each site, respectively. Additional species found to be present in the quadrats at the reference marshes are presented in Table 8-9.

Percent Cover. Peak season 2008 percent cover was estimated within all (ocular and clip) quadrats sampled at each reference marsh during the peak season sampling event. The total number of quadrats sampled and number of *Spartina* dominated (S-d) quadrats were as follows:

Site	Peak Season (#)
MHC Reference Marsh	72 (51 S-d)
MBW Reference Marsh	24 (22 S-d)

The mean percent coverage (± SE) for all quadrats in the 2008 sampling event at each reference marsh is graphically shown in Figure 8-8 and was as follows:

Site	Peak Season (%)
MHC Reference Marsh	50 (±2)
MBW Reference Marsh	36 (±2)

The mean percent cover for *Spartina alterniflora* dominated and non-*Spartina alterniflora* dominated quadrats is shown in Figure 8-8. Histograms illustrating the distribution of percent cover determinations for all *Spartina alterniflora* dominated quadrats sampled at the reference marshes are presented in Figures 8-9 and 8-10.

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at each reference marsh during the 2008 peak season sampling event. For *Spartina alterniflora* dominated quadrats (which include *Spartina alterniflora* and *Spartina cynosuroides),* the mean height (±SE) for the 2008 sampling event at each reference marsh was as follows:

Site	Peak Season (cm)
MHC Reference Marsh	100 (±4)
MBW Reference Marsh	95 (±5)

Heights of other species measured within quadrats during the 2008 peak season are presented in Tables D-1 and D-2 (Appendix D).

Flowering Status. Flowering *Spartina alterniflora* was present in 3 percent of the quadrats in which this species occurred along transects at the MHC Reference Marsh during the 2008 peak season sampling event. In comparison, flowering *Spartina alterniflora* was present in 4 percent of the quadrats in which this species occurred at the MBW Reference Marsh. The flowering status for plants within each quadrat sampled is provided in Tables D-1 and D-2 (Appendix D).

Live Standing Crop. Peak season 2008 live standing crop was determined for each reference marsh based on collections of standing living plant materials from clip quadrats along transects. The total number of clip quadrats as well as *Spartina* dominated (S-d) clip quadrats at each reference site were as follows:

Site	Peak Season (#)
MHC Reference Marsh	18 (11 S-d)
MBW Reference Marsh	6 (5 S-d)

The mean values (±SE) for live standing crop in *Spartina alterniflora* dominated quadrats, non-*Spartina alterniflora* dominated quadrats, and all quadrats sampled at each reference marsh in 2008 are presented in Table 8-7 and shown in Figure 8-11. The mean live standing crop for all quadrats was as follows:

Site	Peak Season (gdw/m^2)
MHC Reference Marsh	778 (±77)
MBW Reference Marsh	676 (±96)

Dead Standing Crop. Dead standing crop was determined for each reference marsh based on collections of standing dead plant materials from clip quadrats along transects. The mean values (±SE) for dead standing crop in *Spartina alterniflora* dominated quadrats, non-*Spartina alterniflora* dominated quadrats, and all quadrats sampled at each reference marsh in 2008 are presented in Table 8-7. The mean values (±SE) for dead standing crop for all quadrats at each reference marsh were as follows:

Site	Peak Season (gdw/m^2)
MHC Reference Marsh	12 (±12)
MBW Reference Marsh	33 (±28)

Litter. Plant litter biomass present on the marsh surface was determined based on collection of unattached dead plant materials within clip quadrats along transects at the reference marshes. The mean values (±SE) for litter in *Spartina alterniflora* dominated quadrats, non-*Spartina alterniflora* dominated quadrats, and all quadrats sampled at each reference marsh in 2008 are presented in Table 8-7. The mean values (±SE) for litter biomass in all quadrats at each reference marsh were as follows:

Site	Peak Season (gdw/m^2)
MHC Reference Marsh	107 (±33)
MBW Reference Marsh	125 (±38)

The above tabulations are based on the pooled data for all quadrats (*Spartina alterniflora* dominated and non-*Spartina alterniflora* dominated) in all transects at the reference marshes during the peak-growing season. The following sections present a summary of data from Tables D-1 and D-2 (Appendix D) for quadrats along transects at each reference marsh.

Mad Horse Creek Reference Marsh - Transects

The field and laboratory data representing the clip and ocular quadrats along the MHC Reference Marsh transects during the peak season 2008 macrophyte sampling events are presented in Table D-1, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter for each transect are also presented on this table. These means were calculated independently for 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* was the dominant species present in quadrats sampled along transects at MHC Reference Marsh, occurring in 70 percent of the quadrats sampled. The percentage of quadrats in which *Spartina alterniflora* occurred along each transect was as follows: MHT1 (63 percent), MHT2 (100 percent), and MHT3 (100 percent). Additional species found to be present in the quadrats at MHC Reference Marsh were *Amaranthus cannabinus*, *Distichlis spicata*, *Scirpus robustus*, *Spartina patens* and *Spartina cynosuroides*.

Percent Cover. The mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at MHC Reference Marsh during the 2008 peak growing season are presented in Table 8-8. Field data for each quadrat are presented in Table D-1 (Appendix D). The total number of quadrats (clip and ocular) along each transect was as follows:

Transect	Peak Season (#)
MHT1	24 (18 S-d)
MHT2	8 (4 S-d)
MHT3	40 (29 S-d)

The mean percent cover (± SE) for all quadrats along each transect in 2008, and for *Spartina alterniflora* dominated quadrats (shown graphically in Figure 8-12) only were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
MHT1	43 (±4)	48(±3)
MHT2	50 (±9)	59 (±11)
MHT3	54 (±3)	57 (±4)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at MHC Reference Marsh during the 2008 peak season sampling event. For *Spartina* dominated quadrats, the mean height (±SE) of *Spartina alterniflora* and/or *Spartina cynosuroides* was as follows:

Transect	Peak Season (cm)
MHT1	83 (±5)
MHT2	108 (±5)
MHT3	108 (±5)

Heights for all species of vegetation present in the quadrats in 2008 are presented in Table D-1.

Live Standing Crop. Live standing crop was determined for each transect at MHC Reference Marsh based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats along each transect was as follows:

Transect	Peak Season (#)
MHT1	6 (4 S-d)
MHT2	2 (1 S-d)
MHT3	10 (6 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the 2008 peak season sampling of MHC Reference Marsh transects, and for all *Spartina alterniflora* dominated clip quadrats, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MHT1	620 (±141)	660 (±194)
MHT2	585 (±183)	768 (±n/a)
MHT3	911 (±91)	943(±133)

Mean live standing crop determinations for *Spartina alterniflora* dominated quadrats only sampled during the 2008 peak season are shown graphically in Figure 8-13.

Dead Standing Crop. The mean values (±SE) for dead standing crop in all clip quadrats during the 2008 peak season sampling of MHC Reference Marsh transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MHT1	0 (±0)	0 (±0)
MHT2	108 (±108)	0 (±n/a)
MHT3	0 (±0)	0 (±0)

Litter. The mean values (±SE) for litter biomass in clip quadrats during the 2008 peak season sampling of MHC Reference Marsh transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MHT1	67 (±23)	47 (±31)
MHT2	52 (±4)	48 (±n/a)
MHT3	142 (±58)	193 (±90)

Moores Beach West Reference Marsh - Transects

The field and laboratory data representing clip and ocular quadrats along MBW Reference Marsh transects during the 2008 peak season macrophyte sampling events are presented in Table D-2, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. The means were calculated independently for: 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* was the dominant species present in quadrats sampled along transects at MBW Reference Marsh, occurring in 92 percent of the quadrats sampled in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred along each transect was as follows: MBT1 (100 percent), MBT2 (100 percent), and MBT3 (100 percent). No other species occurred within the quadrats sampled.

Percent Cover. The mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at MBW Reference Marsh during the 2008 peak growing season are presented in Table 8-8. Field data for each quadrat are presented in Table D-2. The total number of quadrats (clip and ocular) from which percent cover data were collected along each transect was as follows:

Transect	Peak Season (#)
MBT1	8 (7 S-d)
MBT2	8 (8 S-d)
MBT3	8 (7 S-d)

The mean percent cover (±SE) for all quadrats along each transect, and for all *Spartina alterniflora* dominated quadrats (shown graphically in Figure 8-12) were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
MBT1	31 (±3)	33 (±3)
MBT2	38 (±3)	38 (±3)
MBT3	38 (±4)	41 (±3)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at MBW Reference Marsh during the 2008 peak season sampling event. The mean height (±SE) for *Spartina* dominated quadrats (which included *Spartina alterniflora* and *Spartina cynosuroides*) at MBW Reference Marsh was as follows:

Transect	Peak Season (cm)
MBT1	102 (±10)
MBT2	102 (±7)
MBT3	82 (±6)

Live Standing Crop. Live standing crop was determined for each transect at MBW Reference Marsh based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats sampled along each transect in 2008 was as follows:

Transect	Peak Season (#)
MBT1	2 (1 S-d)
MBT2	2 (2 S-d)
MBT3	2 (2 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the 2008 peak season sampling of MBW Reference Marsh transects, and for all *Spartina alterniflora* dominated clip quadrats, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MBT1	827 (±94)	921 (±n/a)
MBT2	599 (±172)	599 (±172)
MBT3	603 (±254)	603 (±254)

Live standing crop determinations for the 2008 peak season are shown graphically in Figure 8-13.

Dead Standing Crop. The mean values (±SE) for dead standing crop in all clip quadrats during the 2008 peak season sampling of MBW Reference Marsh transects, and for all *Spartina alterniflora* dominated clip quadrats, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MBT1	12 (±12)	24 (±n/a)
MBT2	71 (±71)	71 (±71)
MBT3	0 (±n/a)	0 (±n/a)

Litter. The mean values (±SE) for litter biomass in all clip quadrats during the 2008 peak season sampling of MBW Reference Marsh transects, and for all *Spartina alterniflora* dominated clip quadrats, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
MBT1	143 (±54)	197 (±n/a)
MBT2	36 (±36)	36 (±36)
MBT3	133 (±100)	133 (±100)

REFERENCE MARSH PLOT SAMPLING

The field and laboratory data representing clip quadrats within 60 m x 60 m plots during the peak season 2008 macrophyte sampling event are presented in Appendix E. The individual quadrat data as well as means for percent cover and live standing crop are presented in Tables E-1 (MHC Reference Marsh) and E-2 (MBW Reference Marsh). Summary data for each plot, and for each reference marsh are presented in Table 8-10. The summary data includes mean percent cover, live standing crop and dead standing crop as well as measures of dispersion (standard deviation, standard error of the mean, minimum and maximum). Because the plots were located to provide representative data for selected *Spartina alterniflora* dominated areas of each site, means and measures of dispersion have not been calculated for *Spartina alterniflora* dominated quadrats separately.

The percent cover and standing crop data for the MHC Reference Marsh and MBW Reference Marsh plots as a whole are presented here, followed by a discussion of individual plots within each location.

Percent Cover. Peak season 2008 percent cover was estimated within randomly sampled quadrats in three 60 m x 60 m plots located at each reference marsh. Since each plot contained nine (9) randomly located quadrats, the total number of percent cover estimates for each reference marsh was twenty-seven (27). The mean percent coverage (±SE) for all quadrats at each reference marsh was as follows:

Site	Peak Season (%)
MHC Reference Marsh	54 (±2)
MBW Reference Marsh	29 (±3)

Live Standing Crop. Peak season 2008 live standing crop was determined for each reference marsh based on collections of standing living plant materials from the 27 quadrats within each of the 60 m x 60 m plots at each of the reference marshes. The mean live standing crop (±SE) for all quadrats at each reference marsh was as follows:

Site	Peak Season (gdw/m^2)
MHC Reference Marsh	793 (±48)
MBW Reference Marsh	738 (±66)

The following sections present data for individual 60 m x 60 m plots at each reference marsh in 2008.

Mad Horse Creek Reference Marsh - Plots

Three 60 m x 60 m plots were sampled at MHC Reference Marsh in August 2008. Nine (9) quadrats were sampled within each plot for percent cover and live standing crop. Individual quadrat data are presented in Table E-1.

Species Composition. *Spartina alterniflora* was the dominant species present in quadrats sampled in plots at MHC Reference Marsh, occurring in 96 percent of the quadrats sampled in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred within each plot was as follows: MHP1 (100 percent), MHP2 (100 percent), and MHP3 (89 percent). Additional species found to be present in the quadrats at MHC Reference Marsh were *Spartina cynosuroides*, *Scirpus robustus*, *Spartina patens* and *Distichlis spicata*..

Percent Cover. The peak season 2008 mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum), for each plot are presented in Table 8-10. The mean percent cover (±SE) for each plot is graphically shown in Figure 8-14 and was as follows:

Plot	Peak Season (%)
MHP1	61 (±3)
MHP2	52 (±3)
MHP3	49 (±5)

Live Standing Crop. The peak season 2008 mean live standing crop as well as measures of distribution around the mean for each plot is presented in Table 8-10. The mean live standing crop (±SE) for each plot is graphically shown in Figure 8-15 and was as follows:

Plot	Peak Season (gdw/m^2)
MHP1	745 (±79)
MHP2	749 (±91)
MHP3	885 (±80)

Moores Beach West Reference Marsh - Plots

Three 60 m x 60 m plots were sampled at MBW Reference Marsh in August 2008. Nine (9) quadrats were sampled within each plot for percent cover and live standing crop. Individual quadrat data are presented in Table E-2.

Species Composition. *Spartina alterniflora* was the dominant species present in quadrats sampled in plots at MBW Reference Marsh, occurring in 70 percent of the quadrats sampled in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred within each plot was as follows: MBP1 (100 percent), MBP2 (100 percent), and MBP3 (100 percent).

Percent cover. The peak season 2008 mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum), for each plot are presented in Table 8-10. The mean percent cover (±SE) for each plot is graphically shown in Figure 8-14 and was as follows:

Plot	Peak Season (%)
MBP1	27 (±4)
MBP2	32 (±4)
MBP3	28 (±8)

Live standing crop. The peak season 2008 mean live standing crop as well as measures of dispersion for each plot are presented in Table 8-10. The mean live standing crop (±SE) for each plot is graphically shown in Figure 8-15 and were as follows:

Plot	Peak Season (gdw/m^2)
MBP1	649 (±75)
MBP2	728 (±99)
MBP3	839 (±158)

COMMERCIAL TOWNSHIP SALT HAY FARM WETLAND RESTORATION SITE TRANSECT SAMPLING

The field and laboratory data representing the clip and ocular quadrats along transects at the CT Site during the 2008 peak season macrophyte sampling event are presented in Table D-3 in Appendix D. The individual quadrat data, as well as the means for percent cover, height (*Spartina alterniflora* and *Spartina cynosuroides*), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. For each transect, these means were calculated independently for: 1) *Spartina alterniflora* dominated (S-d) quadrats, 2) other (e.g., *Phragmites* dominated) quadrats, and 3) the site as a whole. Tables 8-6, 8-7, and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop, and litter biomass as previously described. The mean percent cover and live standing crop for the 2008 peak growing season also are presented graphically in Figures 8-16 and 8-21, respectively.

Data were collected from both clip and ocular quadrats. Percent cover, species identification, flowering status and height data were collected from both clip and ocular quadrats; live standing crop, dead standing crop, and litter biomass were collected from clip quadrats only.

Species Composition. *Spartina alterniflora* was present in 75 percent of the quadrats sampled at the CT Site in 2008. The other quadrats sampled were located in mudflat areas of the marsh plain.

Percent Cover. Percent cover was estimated within all (ocular and clip) quadrats sampled at the sites during the 2008 peak season sampling event. A total of 32 quadrats were sampled along transects at the CT Site. The mean percent cover (±SE) for all quadrats during the 2008 peak season sampling event at the salt hay farm wetland restoration site (graphically shown in Figure 8-16) was 29% (±4%). Figure 8-17 shows the percent cover groupings for *Spartina alterniflora* dominated quadrats at the CT Site.

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the site during the 2008 peak growing season sampling event. For *Spartina alterniflora* dominated quadrats (which include *Spartina alterniflora* and *Spartina cynosuroides),* the mean heights (±SE) at the CT Site in 2008 was 164cm (±5 cm). Heights for other species of vegetation present in the quadrats are presented in Table D-4.

Flowering Status. Flowering *Spartina alterniflora* was present in 72 percent of the quadrats in which this species occurred along transects at the CT Site during the 2008 peak season sampling event. The flowering status for plants within each quadrat sampled is provided in Table D-3.

Live Standing Crop. Peak season 2008 live standing crop was determined for the site based on collections of standing living plant materials from clip quadrats along the transects. The number of clip quadrats sampled along transects in 2008 was eight (8), all of which were *Spartina alterniflora* dominated. The mean value (±SE) for live standing crop at the CT Site is shown in Figure 8-21 and was 1,366 gdw/m^2 (±242 gdw/m^2).

Dead Standing Crop. Dead standing crop was determined for the site based on collections of standing dead plant materials from clip quadrats along transects. The mean values (±SE) for dead standing crop in *Spartina alterniflora* dominated quadrats, non-*Spartina alterniflora* dominated quadrats, and all quadrats sampled at the site in 2008 are presented in Table 8-7. There was no dead standing crop present during the 2008 sampling event.

Litter. The plant litter biomass present on the marsh surface was determined based on collection of unattached dead plant materials within clip quadrats along transects at the restoration site in 2008. The mean value (±SE) for litter biomass at the site was 41 gdw/m^2 (±19 gdw/m^2).

The above discussions are based on the pooled data for all quadrats at the CT Site during the peak growing season. The following sections present a summary of data from Appendix D, Table D-3 for quadrats along individual transects at the site.

CT Site - Transects

The field and laboratory data representing the clip and ocular quadrats along the Commercial Township Wetland Restoration Site transects during the peak season 2008 macrophyte sampling event are presented in Table D-3, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. These means were calculated independently for: 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* was present in 78 percent of the quadrats sampled along transects at the CT Site in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred along each transect was as follows: CTT1 (100 percent), CTT2 (63 percent), CTT3 (75 percent) and CTT4 (75 percent).

Percent Cover. The mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at the CT Site during the 2008 peak growing season are presented in Table 8-8. Field data for each quadrat are presented in Table D-3. The number of quadrats (clip and ocular) along each transect was as follows:

Transect	Peak Season (#)
CTT1	8 (8 S-d)
CTT2	8 (5 S-d)
CTT3	8 (6 S-d)
CTT4	8 (4 S-d)

The mean percent cover (±SE) for all quadrats along each transect, and for *Spartina alterniflora* dominated quadrats (shown graphically in Figure 8-22,) were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
CTT1	48 (±2)	48 (±2)
CTT2	14 (±4)	23 (±2)
CTT3	30 (±8)	40 (±6)
CTT4	23 (±7)	40 (±3)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the CT Site during the 2008 peak season sampling event. For *Spartina* dominated quadrats, the mean height (±SE) of *Spartina alterniflora* and *Spartina cynosuroides* were as follows:

Transect	Peak Season (cm)
CTT1	173 (±3)
CTT2	128 (±0)
CTT3	173 (±12)
CTT4	175 (±4)

Live Standing Crop. Peak season 2008 live standing crop was determined for each transect at the site based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats along each transect was as follows:

Transect	Peak Season (#)
CTT1	2 (2 S-d)
CTT2	2 (2 S-d)
CTT3	2 (2 S-d)
CTT4	2 (2 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the peak season sampling of the CT Site transects, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-24), were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
CTT1	2,127 (±486)	2,127 (±486)
CTT2	502 (±52)	502 (±52)
CTT3	1,527 (±74)	1,527 (±74)
CTT4	1,307 (±193)	1,307 (±193)

Dead Standing Crop. The mean values (±SE) for dead standing crop in all clip quadrats during the 2008 peak season sampling of the CT Site transects, and for *Spartina alterniflora*-dominated quadrats only, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
CTT1	0 (±0)	0 (±0)
CTT2	0 (±0)	0 (±0)
CTT3	0 (±0)	0 (±0)
CTT4	0 (±0)	0 (±0)

Litter. The mean values (±SE) for litter biomass in all clip quadrats during the 2008 peak season sampling of the CT Site transects, and for *Spartina alterniflora*-dominated quadrats only, were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (gdw/m^2)
CTT1	117 (±1)	117 (±1)
CTT2	0 (±0)	0 (±0)
CTT3	45 (±29)	45 (±29)
CTT4	0 (±0)	0 (±0)

COMMERCIAL TOWNSHIP SALT HAY FARM WETLAND RESTORATION SITE PLOT SAMPLING

Four 60 m x 60 m plots were sampled at the CT Site in August 2008. Nine (9) quadrats were sampled within each plot for percent cover and live standing crop. Individual quadrat data are presented in Appendix E, Table E-3.

Species Composition. *Spartina alterniflora* was present in 72 percent of the quadrats sampled within plots at the CT Site in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred in each plot was as follows: CTP1 (33 percent), CTP2 (89 percent), CTP3 (78 percent) and CTP4 (89 percent).

Percent Cover. The 2008 peak season mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum), for the plots at each site are presented in Table 8-10. The mean percent cover for the plots at the CT Site (graphically shown in Figure 8-26) were as follows:

Transect	Peak Season (%)
CTP1	18 (±9)
CTP2	46 (±8)
CTP3	45 (±11)
CTP4	46 (±7)

Live Standing Crop. The 2008 peak season mean live standing crop as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum), for the plots at each site are presented in Table 8-10. The mean live standing crop for the plots at the CT Site (graphically shown in Figure 8-27) were as follows:

Transect	Peak Season (gdw/m^2)
CTP1	509 (±256)
CTP2	1,301 (±267)
CTP3	794 (±178)
CTP4	878 (±162)

ALLOWAY CREEK WATERSHED *PHRAGMITES* DOMINATED WETLAND RESTORATION SITE TRANSECT SAMPLING

The field and laboratory data representing the clip and ocular quadrats along transects at the ACW Site during the 2008 peak season macrophyte sampling event is presented in Table D-4, in Appendix D. The individual quadrat data, as well as the means for percent cover, height (*Spartina alterniflora* and *Spartina cynosuroides*), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. For each transect, these means were calculated independently for: 1) *Spartina alterniflora*-dominated (S-d) quadrats, 2) other (e.g., *Phragmites* dominated) quadrats, and 3) the site as a whole. Tables 8-6, 8-7, and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop, and litter biomass as previously described. The average percent cover and live standing crop for the peak growing season also are presented graphically in Figures 8-16 and 8-21, respectively.

Data were collected from both clip and ocular quadrats. Percent cover, species identification, flowering status and height data were collected from both clip and ocular quadrats; live standing crop, dead standing crop, and litter biomass were collected from clip quadrats only.

Species Composition. *Spartina alterniflora* was the most common dominant species present in quadrats sampled along transects at the ACW Site, occurring in 79 percent of the quadrats sampled. *Phragmites australis* was present in 32 percent of the quadrats. Other species occurring within quadrats included *Spartina cynosuroides*, *Echinochloa walteri, Amaranthus cannabinus, Cyperus strigosis, Scirpus validus, Scirpus robustus,* and *Polygonum punctatum*, *Pluchea purpurascens, Typha angustifolia, Peltandra virginica,* and *Eleocharis parvula.*

Percent Cover. Percent cover was estimated within all (ocular and clip) quadrats sampled at the sites during the 2008 peak season sampling event. A total of 56 quadrats were sampled along transects at the ACW Site. The mean percent cover (±SE) for all quadrats (graphically shown in Figure 8-16) were 40% (±3%). Figure 8-18 shows the percent cover groupings for *Spartina alterniflora* dominated quadrats at the ACW Site.

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the site during the 2008 peak growing season sampling event. For *Spartina alterniflora* dominated quadrats (which include *Spartina alterniflora* and *Spartina cynosuroides),* the mean heights (±SE) at the ACW Site were 129 (±7). Heights for other species of vegetation present in the quadrats are presented in Table D-4.

Flowering Status. Flowering *Spartina alterniflora* was present in 34 percent of the quadrats in which this species occurred along transects at the ACW Site during the 2008 peak season sampling event. The flowering status for species within each quadrat at the ACW Site in 2008 is provided in Table D-4 (Appendix D).

Live Standing Crop. Peak season 2008 live standing crop was determined for the ACW Site based on collections of standing living plant materials from clip quadrats along transects. The number of clip quadrats along each transect was 14 (9 S-d). The mean value (±SE) for live standing crop for all quadrats is shown in Figure 8-21 and was 940 (±160) (gdw/m^2).

In addition to the mean live standing crop for all quadrats in the restoration sites, the mean live standing crop values for *Spartina alterniflora* dominated and non-*Spartina alterniflora* dominated quadrats were calculated and are presented in Table 8-7.

Dead Standing Crop. Peak season 2008 dead standing crop was determined based on collections of standing dead plant materials from clip quadrats along transects at the restoration sites. The mean value (±SE) for dead standing crop at the site was 10 (±10) (gdw/m^2).

Litter. The plant litter biomass present on the marsh surface in 2008 was determined based on collection of unattached dead plant materials within clip quadrats along transects at the restoration sites. The mean value (±SE) for litter biomass at the site was 54 (±13) (gdw/m^2).

The above discussions are based on the pooled data for all quadrats at the ACW Site during the peak growing season. The following sections present a summary of data from Appendix D, Table D-4 for quadrats along individual transects at the site. Savvy

ACW Site - Transects

The field and laboratory data representing the clip and ocular quadrats along the ACW Site transects during the peak season 2008 macrophyte sampling event are presented in Table D-4, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. These means were calculated independently for: 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* was present in 79 percent of the quadrats sampled along transects at the ACW Site in 2008. The percentage of quadrats in which *Spartina alterniflora* occurred along each transect was as follows: ACWT1 (88 percent), ACWT2 (81 percent), ACWT3 (75 percent) and ACWT4 (75 percent).

Percent Cover. The peak season 2008 mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at the ACW Site are presented in Table 8-8. Field data for each quadrat are presented in Table D-4. The number of quadrats (clip and ocular) along each transect was as follows:

Transect	Peak Season (#)
ACWT1	8 (7 S-d)
ACWT2	16 (14 S-d)
ACWT3	16 (6 S-d)
ACWT4	16 (5 S-d)

The mean percent cover (±SE) for all quadrats along each transect, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-22), were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
ACWT1	44 (±5)	49 (±3)
ACWT2	43 (±5)	41 (±3)
ACWT3	48 (±6)	60 (±9)
ACWT4	27 (±2)	29 (±2)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the ACW Site during the 2008 peak season sampling event. For *Spartina* dominated quadrats, the mean height (±SE) of *Spartina alterniflora* and *Spartina cynosuroides* for each transect at the site was as follows:

Transect	Peak Season (cm)
ACWT1	113 (±12)
ACWT2	143 (±9)
ACWT3	96 (±9)
ACWT4	182 (±9)

Heights for other species of vegetation present in the quadrats are presented in Table D-4.

Live Standing Crop. Peak season 2008 live standing crop was determined for each transect at the site based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats along each transect was as follows:

Transect	Peak Season (#)
ACWT1	2 (2 S-d)
ACWT2	4 (3 S-d)
ACWT3	4 (2 S-d)
ACWT4	4 (2 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the 2008 peak season sampling of the ACW Site transects, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-24), were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
ACWT1	784 (±103)	784 (±103)
ACWT2	1,307 (±529)	1,694 (±509)
ACWT3	656 (±85)	599 (±142)
ACWT4	935 (±157)	879 (±234)

Dead Standing Crop. The mean values (±SE) for dead standing crop in all clip quadrats during the 2008 peak season sampling of the ACW Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
ACWT1	0 (±0)	0 (±0)
ACWT2	0 (±0)	0 (±0)
ACWT3	34 (±34)	0 (±0)
ACWT4	0 (±0)	0 (±0)

Litter. The mean values (±SE) for litter biomass in all clip quadrats during the 2008 peak season sampling of the ACW Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
ACWT1	88 (±13)	88 (±13)
ACWT2	92 (±25)	101 (±33)
ACWT3	53 (±21)	20 (±20)
ACWT4	0 (±0)	0 (±0)

ALLOWAY CREEK WATERSHED *PHRAGMITES* DOMINATED WETLAND RESTORATION SITE PLOT SAMPLING

Three 60 m x 60 m plots were sampled at the ACW Site in August 2008. Nine (9) quadrats were sampled within each plot for percent cover and live standing crop. Individual quadrat data are presented in Appendix E, Table E-4.

Species Composition. *Spartina alterniflora* was the most common dominant species present in quadrats sampled within plots at the ACW Site, occurring in 81 percent of the quadrats sampled. The percentage of quadrats in which *Spartina alterniflora* occurred within each plot was as follows: ACWP1 (67 percent), ACWP2 (89 percent), and ACWP3 (89 percent).

Percent Cover. The peak season 2008 mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum), for the plots at each site are presented in Table 8-10. The mean percent cover for the plots at the ACW Site (graphically shown in Figure 8-26) was as follows:

Plot	Peak Season (%)
ACWP1	32 (±4)
ACWP2	48 (±6)
ACWP3	59 (±10)

Live Standing Crop. The peak season 2008 mean live standing crop as well as measures of dispersion for the plots at each site are presented in Table 8-10. The mean live standing crop for the plots at the ACW Site (graphically shown in Figure 8-27) were as follows:

Plot	Peak Season (gdw/m^2)
ACWP1	733 (±200)
ACWP2	773 (±110)
ACWP3	849 (±179)

DELAWARE *PHRAGMITES* DOMINATED WETLAND RESTORATION SITES TRANSECT SAMPLING

The field and laboratory data representing the clip and ocular quadrats along transects at The Rocks and Cedar Swamp Sites in Delaware during the 2008 peak season macrophyte sampling event are presented in Tables D-5 and D-6, in Appendix D. The individual quadrat data, as well as the means for percent cover, height (*Spartina alterniflora* and *Spartina cynosuroides*), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. For each transect, these means were calculated independently for: 1) *Spartina alterniflora*-dominated (S-d) quadrats, 2) other (e.g., *Phragmites* dominated) quadrats, and 3) the site as a whole. Tables 8-6, 8-7, and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop, and litter biomass as previously described. The average percent cover and live standing crop for the peak-growing season also are presented graphically in Figures 8-16 and 8-21, respectively.

Data were collected from both clip and ocular quadrats. Percent cover, species identification, flowering status and height data were collected from both clip and ocular quadrats; live standing crop, dead standing crop, and litter biomass were collected from clip quadrats only.

Species Composition. *Spartina alterniflora* and/or *Spartina cynosuroides* occurred within 85 percent of the quadrats sampled along transects at The Rocks Site in 2008. *Phragmites australis* was present in 21 percent of the quadrats. The vegetation cover at The Rocks Site is diverse, with fourteen other species occurring within the quadrats sampled.

Spartina alterniflora and/or *Spartina cynosuroides* occurred within 95 percent of the quadrats sampled along transects at the Cedar Swamp Site in 2008. *Phragmites australis* was present in 13 percent of the quadrats. Other species present at Cedar Swamp included *Scirpus robustus, Pluchea purpurascens, Iva frutescens, Polygonum punctatum*, *Atriplex patula*, and *Amaranthus cannabinus.*

Percent Cover. Percent cover was estimated within all (ocular and clip) quadrats sampled at the sites during the 2008 peak season sampling event. A total of 70 quadrats were sampled along transects at The Rocks Site and 64 quadrats were sampled at the Cedar Swamp Site. The mean percent cover (±SE) for all quadrats during the 2008 peak season sampling event at the Delaware *Phragmites* dominated wetland restoration sites (graphically shown in Figure 8-16) were as follows:

Site	Peak Season (%)
The Rocks	47 (±2)
Cedar Swamp	40 (±2)

Figures 8-19 and 8-20 show the percent cover groupings for *Spartina alterniflora* dominated quadrats at The Rocks and Cedar Swamp Sites, respectively.

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the site during the peak growing season sampling event. For *Spartina alterniflora* dominated quadrats (which include *Spartina alterniflora* and *Spartina cynosuroides),* the mean height (±SE) for the 2008 sampling event at each Delaware *Phragmites* dominated restoration site was as follows:

Site	Peak Season (cm)
The Rocks	147 (±9)
Cedar Swamp	120 (±8)

Heights for all species of vegetation present in the quadrats are presented in Tables D-5 and D-6.

Flowering Status. Flowering *Spartina alterniflora* was present in 20 percent of the quadrats in which this species occurred along transects at The Rocks Site during the 2008 peak season sampling event. The flowering status for species within each quadrat at The Rocks Site in 2008 is provided in Table D-5 (Appendix D).

Flowering *Spartina alterniflora* was present in 2 percent of the quadrats in which this species occurred along transects at the Cedar Swamp Site during the 2008 peak season sampling event. The flowering status for species within each quadrat at the Cedar Swamp Site in 2008 is provided in Table D-6 (Appendix D).

Live Standing Crop. Peak season 2008 live standing crop was determined for each site based on collections of standing living plant materials from clip quadrats along transects. The number of clip quadrats along each transect was as follows:

Site	Peak Season (#)
The Rocks	18 (11 S-d)
Cedar Swamp	16 (12 S-d)

The mean value (±SE) for live standing crop at each site is shown in Figure 8-21 and was as follows:

Site	Peak Season (gdw/m^2)
The Rocks	1,083 (±181)
Cedar Swamp	882 (±153)

In addition to the mean live standing crop for all quadrats in the restoration site, the mean live standing crop values for *Spartina alterniflora* dominated and non-*Spartina alterniflora* dominated quadrats were calculated and are presented in Table 8-7.

Dead Standing Crop. Peak season 2008 dead standing crop was determined based on collections of standing dead plant materials from clip quadrats along transects at the restoration sites. The mean values (±SE) for dead standing crop were as follows:

Site	Peak Season (gdw/m^2)
The Rocks	14 (±14)
Cedar Swamp	131 (±46)

Litter. The peak season 2008 plant litter biomass present on the marsh surface was determined based on collection of unattached dead plant materials within clip quadrats along transects at the restoration sites. The mean value (±SE) for litter biomass at the sites was as follows:

Site	Peak Season (gdw/m^2)
The Rocks	29 (±11)
Cedar Swamp	216 (±50)

The above discussions are based on the pooled data for all quadrats at The Rocks and Cedar Swamp Sites during the peak growing season. The following sections present a summary of data from Appendix D, Tables D-5 and D-6 for quadrats along individual transects at each site.

The Rocks Site – Transects

The field and laboratory data representing the clip and ocular quadrats along The Rocks Site transects during the peak season 2008 macrophyte sampling event are presented in Table D-5, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. These means were calculated independently for: 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* and/or *Spartina cynosuroides* was present in 86 percent of the quadrats sampled along transects at The Rocks Site in 2008. The percentage of quadrats in which one or both of these species occurred along each transect was as follows: TRT1 (88 percent), TRT2 (100 percent), TRT3 (73 percent) and TRT4 (100 percent). Some of the quadrats sampled along TRT3 are dominated by *Spartina patens* and/or *Scirpus olneyi*. Most of the occurrence of *Phragmites australis* was evenly distributed throughout quadrats along TRT2 -TRT4, with this species occurring in 21 percent of the quadrats sampled along the transects.

Percent Cover. The mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at The Rocks Site during the 2008 peak growing season are presented in Table 8-8. Field data for each quadrat are presented in Table D-5. The number of quadrats (clip and ocular) along each transect was as follows:

Transect	Peak Season (#)
TRT1	16 (14 S-d)
TRT2	16 (12 S-d)
TRT3	30 (19 S-d)
TRT4	8 (6 S-d)

The mean percent cover (±SE) for all quadrats along each transect, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-23), were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
TRT1	45 (±3)	45 (±3)
TRT2	41(±4)	44 (±5)
TRT3	51 (±4)	47 (±4)
TRT4	45 (±10)	50 (±11)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at The Rocks Site during the 2008 peak season sampling event. For *Spartina* dominated quadrats, the mean height (±SE) of *Spartina alterniflora* and *Spartina cynosuroides* for each transect at the site was as follows:

Transect	Peak Season (cm)
TRT1	101 (±8)
TRT2	142 (±10)
TRT3	191 (±17)
TRT4	116 (±15)

Heights for other species of vegetation present in the quadrats are presented in Table D-5.

Live Standing Crop. Peak season 2008 live standing crop was determined for each transect at the site based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats along each transect was as follows:

Transect	Peak Season (#)
TRT1	4 (2 S-d)
TRT2	4 (3 S-d)
TRT3	8 (4 S-d)
TRT4	2 (2 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the peak season sampling of The Rocks Site transects, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-25), were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
TRT1	890 (±259)	519 (±85)
TRT2	1,256 (±146)	1,114 (±49)
TRT3	1,217 (±378)	1,631 (±723)
TRT4	584 (±1)	584 (±1)

Dead Standing Crop. The peak season 2008 mean values (±SE) for dead standing crop in all clip quadrats during the peak season sampling of The Rocks Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
TRT1	0 (±0)	0 (±0)
TRT2	0 (±0)	0 (±0)
TRT3	0 (±0)	0 (±0)
TRT4	129 (±129)	129 (±129)

Litter. The mean values (±SE) for litter biomass in all clip quadrats during the 2008 peak season sampling of The Rocks Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
TRT1	0 (±0)	0 (±0)
TRT2	12 (±7)	16 (±8)
TRT3	51 (±22)	95 (±33)
TRT4	34 (±26)	34 (±26)

Cedar Swamp Site - Transects

The field and laboratory data representing the clip and ocular quadrats along the Cedar Swamp Site transects during the peak season 2008 macrophyte sampling event are presented in Table D-6, in Appendix D. The means for percent cover, species height (*Spartina alterniflora* dominated only), live standing crop, dead standing crop and litter biomass for each transect are also presented on this table. These means were calculated independently for: 1) *Spartina alterniflora* dominated quadrats along each transect, 2) other (e.g., *Phragmites* dominated) quadrats along each transect, and 3) for all quadrats along each transect. Means of each type also were calculated for the site as a whole (i.e., means of all quadrats along all transects). Tables 8-6, 8-7 and 8-8 provide summary information for percent cover, height, live standing crop, dead standing crop and litter biomass as previously described.

Species Composition. *Spartina alterniflora* and/or *Spartina cynosuroides* was present in 95 percent of the quadrats sampled along transects at the Cedar Swamp Site in 2008. The percentage of quadrats in which one or both of these species occurred along each transect was as follows: CST1 (94 percent), CST2 (92 percent), CST3 (100 percent) and CST4 (100 percent). All of the occurrences of *Phragmites australis* were within quadrats along CST2, with this species occurring in 13 percent of the quadrats sampled at the site.

Percent Cover. The mean percent aerial cover, as well as measures of dispersion (standard error of the mean, standard deviation), for quadrats along each transect at the Cedar Swamp Site during the 2008 peak growing season are presented in Table 8-8. Field data for each quadrat are presented in Table D-6. The number of quadrats (clip and ocular) along each transect was as follows:

Transect	Peak Season (#)
CST1	16 (14 S-d)
CST2	24 (16 S-d)
CST3	16 (16 S-d)
CST4	8 (6 S-d)

The mean percent cover (±SE) for all quadrats along each transect, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-23), were as follows:

Transect	All Quadrats (%)	S-d Quadrats (%)
CST1	43 (±2)	44 (±3)
CST2	35 (±3)	41 (±2)
CST3	51 (±3)	51 (±3)
CST4	31 (±4)	35 (±3)

Vegetation Height. The average height of each plant species present was measured for all (ocular and clip) quadrats sampled at the Cedar Swamp Site during the 2008 peak season sampling event. For *Spartina* dominated quadrats, the mean height (±SE) of *Spartina alterniflora* and *Spartina cynosuroides* for each transect at the site was as follows:

Transect	Peak Season (cm)
CST1	158 (±20)
CST2	122 (±12)
CST3	97 (±13)
CST4	91 (±5)

Heights for other species of vegetation present in the quadrats are presented in Table D-6.

Live Standing Crop. Peak season 2008 live standing crop was determined for each transect at the site based on collections of living standing plant materials from clip quadrats along each transect. The number of clip quadrats along each transect was as follows:

Transect	Peak Season (#)
CST1	4 (4 S-d)
CST2	6 (3 S-d)
CST3	4 (4 S-d)
CST4	2 (1 S-d)

The mean values (±SE) for live standing crop in all clip quadrats during the 2008 peak season sampling of the Cedar Swamp Site transects, and for *Spartina alterniflora*-dominated quadrats only (shown graphically in Figure 8-25), were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
CST1	1,619 (±326)	1,619 (±326)
CST2	631 (±187)	577 (±199)
CST3	649 (±183)	649 (±183)
CST4	630 (±46)	676 (±n/a)

Dead Standing Crop. The mean values (±SE) for dead standing crop in all clip quadrats during the 2008 peak season sampling of the Cedar Swamp Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
CST1	200 (±123)	200 (±123)
CST2	182 (±83)	102 (±102)
CST3	0 (±0)	0 (±0)
CST4	103 (±103)	0 (±n/a)

Litter. The mean values (±SE) for litter biomass in all clip quadrats during the 2008 peak season sampling of the Cedar Swamp Site transects were as follows:

Transect	All Quadrats (gdw/m^2)	S-d Quadrats (%)
CST1	394 (±135)	394 (±135)
CST2	178 (±50)	185 (±70)
CST3	185 (±96)	185 (±96)
CST4	34 (±12)	47 (±n/a)

DELAWARE *PHRAGMITES* DOMINATED WETLAND RESTORATION SITES PLOT SAMPLING

One 60 m x 60 m plot was sampled at both The Rocks and Cedar Swamp Sites in August 2008. Nine (9) quadrats were sampled within each plot for percent cover and live standing crop. Individual quadrat data are presented in Appendix E, Tables E-5 and E-6.

Species Composition. *Spartina alterniflora* was the most common dominant species present in quadrats sampled within the plot at The Rocks Site, occurring in 56 percent of the quadrats sampled. Other species present were *Spartina patens, Spartina cynosuroides, Polygonum punctatum, Scirpus robustus, Scirpus pungens, Typha angustifolia* and *Amaranthus cannabinus.*

Spartina alterniflora was the most common dominant species present in quadrats sampled within the plot at the Cedar Swamp Site, occurring in all (100 percent) of the quadrats sampled. Other species present were *Spartina cynosuroides, Pluchea purpuresence,* and *Polygonum punctatum.*

Percent Cover. The peak season 2008 mean percent aerial cover as well as measures of dispersion (standard error of the mean, standard deviation, minimum and maximum) for the plots at each site are presented in Table 8-10. The mean percent cover values for the plots at each site (graphically shown in Figure 8-26) were as follows:

Site	Peak Season (%)
The Rocks (TRP1)	65 (±8)
Cedar Swamp (CSP1)	58 (±6)

Live Standing Crop. The peak season 2008 mean live standing crop as well as measures of dispersion for the plots at each site are presented in Table 8-10. The mean live standing crop values for the plots at each site (graphically shown in Figure 8-27) were as follows:

Site	Peak Season (gdw/m^2)
The Rocks (TRP1)	1,773 (±216)
Cedar Swamp (CSP1)	738 (±81)

DISCUSSION

COVER TYPE MAPPING

Cover category and cover type mapping and area determinations were completed for two reference marshes and four wetland restoration sites in 2008. This mapping is presented as a series of six maps within Appendix B and detailed listings of the areas of the various cover types within the mapped cover categories are provided in Tables 8-1 through 8-4. The mapping represents wetland systems ranging from relatively stable reference marshes to sites at various phases of post-restoration development. The completion of the restoration of normal tidal inundation and drainage of the marsh at the CT Site has promoted the spread of the *Spartina alterniflora* communities at that site. Glyphosate-based herbicide with a surfactant applications at the ACW Site in New Jersey and Cedar Swamp and The Rocks in Delaware have maintained progress in controlling *Phragmites australis* at these sites and resulted in the expansion of *Spartina alterniflora* and other desirable marsh species as dominant species at these sites in 2008.

GEOMORPHOLOGIC MAPPING

Evidence of successful wetland restoration at the CT Site is provided by the quantitative analysis of 2008 geomorphology mapping. The drainage density in 2008 (1,150 ft/acre) was higher than found for the MBW Reference Marsh in 2005 (438 ft/acre). This drainage density is evidence of progress in the development of a natural channel systems since 2002, when the drainage density was 374 ft/acre. The channel frequency at the CT Site in 2008 (24.2 channels/acre) was also higher than that found in MBW Reference Marsh in 2005 (4.8 channels/acre). The drainage frequency data are a further indication of the progress in channel development that occurred since 2002, when the channel frequency was 3.7 channels/acre.

The drainage density at the MHC Reference Marsh in 2005 was 708 ft/acre. The drainage density value for the ACW Site in 2008 was 690 ft/acre. Drainage densities for the *Phragmites* dominated sites in Delaware ranged from 537 ft/acre at The Rocks to 602 ft/acre at Cedar Swamp. The drainage density for the ACW Site is below that of the MHC Reference Marsh. The Cedar Swamp Site and The Rocks Site are also below the MHC Reference Marsh.

The channel frequency for the MHC Reference Marsh in 2005 was 8.9 channels/acre. The channel frequency value for the ACW Site in 2008 was 10.2 channels/acre. The Rocks and Cedar Swamp 2008 channel frequencies were 8.6 channels/acre and 8.3 channels/acre, respectively.

ABOVE-GROUND NET PRIMARY PRODUCTION

Extensive studies of the net primary production of *Spartina alterniflora* have been conducted along the Atlantic and Gulf coasts of the United States. Mitsch and Gosselink (1993) provide a comparison of many of the measured values, ranging from 330 gdw/m^2/yr to 3,700 gdw/m^2/yr. Higher above-ground productivity is generally found in southern coastal plain marshes than those in northern latitudes. Turner (1976) states that this higher production is related to a greater influx of solar energy and a longer growing season. The relatively high productivity of some southern marshes may also be associated with higher nutrient import associated with sediments deposited by rivers of that region (White et al. 1978).

One of the methods that has been utilized to measure net primary production in tidal marshes is the Peak Standing Crop (PSC) Method. In the PSC Method, the average peak living standing crop over 2 or more consecutive years is used to represent annual net primary productivity (Hsieh 1997). Hsieh lists the following four assumptions relating to the use of the PSC Method:

1. There is no carry-over in living standing crop from one year to another.
2. There is no significant mortality during the growing season.
3. There is no significant growth after the peak of living standing crop.
4. There is no significant grazing.

Since the PSC Method does not account for growing season mortality or loss of live standing crop biomass due to tidal flux and decomposition, the estimates derived from the method are minimum production values. Mitsch and Gosselink (1993) list several primary production determinations for *Spartina alterniflora* marshes derived utilizing the PSC Method as follows:

	Kaswadji et al. (1990)	Kirby and Gosselink (1976)	Hopkinson et al (1980)	Shew et al (1981)
Peak Standing Crop (gdw/m^2/yr)	831 ± 41	903	754	242

White et al. (1978) list two additional peak above-ground biomass determinations in North Carolina and New Jersey as 1,320 gdw/m^2 and 1,592 gdw/m^2, respectively. Gross et al. (1991) sampled monthly in both short-form and tall-form *Spartina alterniflora* stands near Lewes, Delaware. They found live aboveground *Spartina alterniflora* during September to range from approximately 500 gdw/m^2 to 1,500 gdw/m^2 in short form and tall form stands, respectively.

Annual production estimates (gdw/m^2) were determined at both reference marshes and wetland restoration sites using the PSC Method. These estimates were derived utilizing data for all clip quadrats sampled along transects at each site in 2008 and from all quadrats sampled within permanent plots at each site in 2008.

MACROPHYTE PRODUCTION AT THE REFERENCE MARSHES

The MHC Reference Marsh and MBW Reference Marsh are both *Spartina alterniflora* dominated tidal wetland systems. At the end of the 2008 growing season, 74.2 percent of MHC and 83.8 percent of MBW was vegetated by *Spartina* spp. and other desirable marsh vegetation. Marsh production in terms of the mean dry weight of live standing macrophytes collected from *Spartina alterniflora*-dominated quadrats sampled along transects during the peak season of 2008 was 824 ±103 gdw/m^2 at MHC Reference Marsh and 665 ±116 gdw/m^2 at MBW Reference

Marsh. Values for quadrats sampled within the permanent plots established at each site were 793 ±48 gdw/m^2 at the MHC Reference Marsh and 738 ±66 gdw/m^2 at the MBW Reference Marsh. These production values are within the published ranges that are summarized above.

MACROPHYTE PRODUCTION AT COMMERCIAL TOWNSHIP SITE

At the end of the 2008 growing season, 50.3 percent of the CT Site was vegetated by *Spartina* spp. and other desirable marsh vegetation. Marsh production in terms of the mean dry weight of live standing macrophytes collected from *Spartina alterniflora* dominated quadrats along transects at the CT Site was 1,366 ±242 gdw/m^2. Mean dry weight of live standing macrophytes collected at the permanent plots throughout the site was 871 ±116 gdw/m^2. These production values are within the published ranges that are summarized above and are comparable to the production at the MBW Reference Marsh in 2008.

MACROPHYTE PRODUCTION AT ALLOWAY CREEK SITE

At the end of the 2008 growing season, 74.7 percent of the ACW Site was vegetated by *Spartina* spp. and other desirable marsh vegetation. Marsh production in terms of the mean dry weight of live standing macrophytes collected from *Spartina alterniflora* dominated quadrats along transects at the ACW Site was 1,067 ±223 gdw/m^2. Mean dry weight of live standing macrophytes collected at the permanent plots throughout the site was 785 ±93 gdw/m^2. These production values are within the published ranges that are summarized above and are comparable to the production at the MHC Reference Marsh in 2008.

MACROPHYTE PRODUCTION AT THE ROCKS AND CEDAR SWAMP SITES

At the end of the 2008 growing season, 85.9 percent of The Rocks Site was vegetated by *Spartina* spp. and other desirable marsh vegetation. Marsh production in terms of the mean dry weight of live standing macrophytes collected from *Spartina alterniflora* dominated quadrats along transects at The Rocks Site was 1,097 ± 280 gdw/m^2. Mean dry weight of live standing macrophytes collected at the permanent plots throughout the site was 1,773 ±216 gdw/m^2. These production values are within the published ranges that are summarized above, and comparable to the production at the MHC Reference Marsh in 2008.

At the end of the 2008 growing season, 82.7 percent of the Cedar Swamp Site was vegetated by *Spartina* spp. and other desirable marsh vegetation. Marsh production in terms of the mean dry weight of live standing macrophytes collected from *Spartina alterniflora* dominated quadrats along transects at the Cedar Swamp Site was 957 ±186 gdw/m^2. Mean dry weight of live standing macrophytes collected at the permanent plots throughout the site was 738 ±81 gdw/m^2. These production values are within the published ranges that are summarized above, and comparable to the production at the MHC Reference Marsh in 2008.

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Chapter 8 Tables

Table 8-1
2008 Reference Marsh Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Mad Horse Creek**		**Moores Beach West**	
	Acres	**Percent of Total Marsh** (a)	**Acres**	**Percent of Total Marsh** (a)
Spartina **spp./ Other Desirable Marsh Vegetation**				
w/o Phragmites				
Amaranthus cannabinus	0	0.0%	0	0.0%
A. cannabinus / Desirable Mixed Marsh	0	0.0%	0	0.0%
A. cannabinus / S. alterniflora	5	0.1%	0	0.0%
Spartina alterniflora	895	23.3%	783	61.9%
S. alterniflora / A. cannabinus	79	2.1%	0	0.0%
S. alterniflora / Beach	2	0.0%	1	0.1%
S. alterniflora / Chanel Banks	0	0.0%	0	0.0%
S. alterniflora / Dead *S. alterniflora*	0	0.0%	0	0.0%
S. alterniflora / Desirable Mixed Marsh	55	1.4%	2	0.2%
S. alterniflora / High Marsh	0	0.0%	0	0.0%
S. alterniflora / Mud Flat	95	2.5%	48	3.8%
S. alterniflora / Mud Flat / Wrack	4	0.1%	0	0.0%
S. alterniflora / Mud Flat / *A. cannabinus*	0	0.0%	0	0.0%
S. alterniflora / Salt Hay	0	0.0%	164	13.0%
S. alterniflora / *S. cynosuroides*	264	6.9%	0	0.0%
S. alterniflora / Wrack	1	0.0%	2	0.2%
S. alterniflora / Wrack / Mud Flat	0	0.0%	0	0.0%
Salt Hay *(S. patens;D.spicata; J. gerardii)*	0	0.0%	2	0.2%
Salt Hay / High Marsh	0	0.0%	3	0.3%
Salt Hay */ S. alterniflora*	0	0.0%	11	0.9%
S. cynosuroides	23	0.6%	0	0.0%
S. cynosuroides / Dead *P. australis*	0	0.0%	0	0.0%
S. cynosuroides / S. alterniflora	337	8.8%	0	0.0%
S. cynosuroides / Wrack	1	0.0%	0	0.0%
S. patens	1	0.0%	0	0.0%
S. patens / S. alterniflora	2	0.1%	0	0.0%
Amaranthus cannabinus	0	0.0%	0	0.0%
A. cannabinus / S. alterniflora	0	0.0%	0	0.0%
A. cannabinus / Desirable Mixed Marsh	0	0.0%	0	0.0%
Desirable Mixed Marsh	872	22.7%	0	0.0%
Desirable Mixed Marsh / Beach	0	0.0%	0	0.0%
Desirable Mixed Marsh / Mud Flat	22	0.6%	0	0.0%
Desirable Mixed Marsh / Mud Flat / Wrack	2	0.1%	0	0.0%
Desirable Mixed Marsh / Wrack	0	0.0%	0	0.0%
High Marsh Shrubs	26	0.7%	0	0.0%
High Marsh	3	0.1%	3	0.3%
High Marsh / Deciduous Forest	1	0.0%	2	0.1%
High Marsh / Dead Trees	0	0.0%	1	0.1%
High Marsh / Salt Hay	0	0.0%	1	0.1%
High Marsh / *S. alterniflora*	0	0.0%	1	0.1%
subtotal w/o Phragmites	2691	70.2%	1024	81.0%

Table 8-1
2008 Reference Marsh Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Mad Horse Creek**		**Moores Beach West**	
	Acres	**Percent of Total Marsh** (a)	**Acres**	**Percent of Total Marsh** (a)
w/ Phragmites				
Desriable mixed marsh / P. australis	1	0.0%	0	0.0%
S. alterniflora / P. australis	22	0.6%	0	0.0%
S. alterniflora / P. australis / Mud Flat	1	0.0%	0	0.0%
Salt Hay / Dead *P. australis*	0	0.0%	0	0.0%
S. cynosuroides / P. australis	14	0.4%	0	0.0%
S. cynosuroides / P. australis / Wrack	1	0.0%	0	0.0%
S. cynosuroides / P. australis / S. alterniflora	2	0.1%	0	0.0%
S. cynosuroides / S. alternoflora / P. australis	1	0.0%	0	0.0%
Mixed Marsh	91	2.4%	2	0.2%
Mixed Marsh / Beach	2	0.0%	2	0.2%
Mixed Marsh / Dead *P. australis*	0	0.0%	0	0.0%
Mixed Marsh / Developed Land	0	0.0%	0	0.0%
Mixed Marsh / Mud Flat	3	0.1%	0	0.0%
Mixed Marsh / Wrack	1	0.0%	0	0.0%
High Marsh / *P. australis*	12	0.3%	31	2.5%
High Marsh Shrubs / Mixed Marsh	1	0.0%	0	0.0%
subtotal w/ Phragmites	153	4.0%	36	2.8%
Subtotal	**2844**	**74.2%**	**1059**	**83.8%**
***Phragmites* Dominated Vegetation**				
Dead P. australis Dominant				
Dead *P. australis*	2	0.0%	0	0.0%
Dead *P. australis /* Mud Flat	0	0.0%	0	0.0%
Dead *P. australis /* Mixed Marsh	0	0.0%	0	0.0%
Dead *P. australis / P. australis*	0	0.0%	0	0.0%
Dead *P. australis /* Wrack	0	0.0%	0	0.0%
Dead *P. australis / S. alterniflora*	0	0.0%	0	0.0%
Subtotal	***3***	***0.1%***	***0***	***0.0%***
P. australis Dominant				
Phragmites australis	243	6.3%	5	0.4%
P. australis / Salt Hay	0	0.0%	0	0.0%
P. australis / High Marsh	0	0.0%	36	2.9%
P. australis / Dead *P. australis*	3	0.1%	0	0.0%
P. australis / Dead Trees	0	0.0%	3	0.2%
P. australis / Desirable Mixed Marsh	20	0.5%	0	0.0%
P. australis / High Marsh Shrubs	3	0.1%	0	0.0%
P. australis / Mud Flat	1	0.0%	0	0.0%
P. australis / Mud Flat / *S. alterniflora*	0	0.0%	0	0.0%
P. australis / Beach	1	0.0%	0	0.0%
P. australis / Mixed Marsh	1	0.0%	0	0.0%
P. australis / S. alterniflora	34	0.9%	0	0.0%
P. australis / S. alterniflora / S. cynosuroides	1	0.0%	0	0.0%
P. australis / S. cynosuroides	19	0.5%	0	0.0%
P. australis / S. cynosuroides / S. alterniflora	0	0.0%	0	0.0%
P. australis / Wrack	2	0.0%	0	0.0%
Subtotal	**329**	**8.6%**	**45**	**3.5%**

Table 8-1
2008 Reference Marsh Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Mad Horse Creek**		**Moores Beach West**	
	Acres	**Percent of Total Marsh** [(a)]	**Acres**	**Percent of Total Marsh** [(a)]
Non-vegetated Marsh Plain				
Mud Flat	9	0.2%	1	0.1%
Mud Flat / Desirable Mixed marsh	2	0.1%	0	0.0%
Mud Flat / Mixed Marsh	2	0.0%	1	0.1%
Mud Flat / *P. australis*	0	0.0%	0	0.0%
Mud Flat / *S. alterniflora*	27	0.7%	18	1.4%
Mud Flat / *S. alterniflora /* Wrack	0	0.0%	0	0.0%
Mud Flat / Beach	0	0.0%	3	0.3%
Mud Flat / Wrack	1	0.0%	0	0.0%
Mud Flat / Wrack / *S. alterniflora*	0	0.0%	0	0.0%
Mud Flat / Wrack / Mixed Marsh	0	0.0%	0	0.0%
Beach	3	0.1%	9	0.7%
Beach / Mixed Marsh	0	0.0%	5	0.4%
Beach / Mud Flat	0	0.0%	1	0.1%
Beach / *S. alterniflora*	1	0.0%	2	0.1%
Beach / *P. australis*	0	0.0%	0	0.0%
Wrack	16	0.4%	1	0.1%
Wrack / Desirable Mixed Marsh	0	0.0%	0	0.0%
Wrack / Desirable Mixed Marsh / Mud Flat	1	0.0%	0	0.0%
Wrack / Mixed Marsh	3	0.1%	0	0.0%
Wrack / Mud Flat	3	0.1%	0	0.0%
Wrack / Mud Flat / Mixed Marsh	0	0.0%	0	0.0%
Wrack / *S. alterniflora*	1	0.0%	2	0.2%
Wrack / *S. alterniflora /* Mud Flat	1	0.0%	0	0.0%
Wrack / *S. cynosuroides*	1	0.0%	0	0.0%
Wrack / *P. australis*	3	0.1%	0	0.0%
Subtotal	**77**	**2.0%**	**45**	**3.6%**
Internal Water Areas				
Channels	579	15.1%	87	6.9%
Ponded Water	3	0.1%	7	0.5%
Ponded Water / *S. alterniflora*	0	0.0%	0	0.0%
Ponded Water / Wrack	0	0.0%	0	0.0%
Subtotal	**582**	**15.2%**	**94**	**7.4%**
Open Water				
Delaware Bay	1	0.0%	21	1.6%
Upland Vegetation / Miscellaneous Cover Categories				
Agricultural Land	25	--	15	--
Old Field	2	--	15	--
Old Field/Deciduous Forest	0	--	1	--
Deciduous Forest	64	--	33	--
Deciduous Forest / High Marsh	1	--	21	--
Deciduous Forest / High Marsh Shrubs	7	--	0	--
Developed Land	3	--	8	--
Dike	1	--	0	--
Road	3	--	1	--
Subtotal [(b)]	**105**	--	**95**	--
Total Marsh Area	**3835**	**100.0%**	**1264**	**100.0%**
Total Site Area	**3942**	--	**1359**	--

[(a)] Includes water areas, but does not include upland developed land on the site.

[(b)] Cover category subtotals may not reflect sum of individual cover type acreages due to rounding

Table 8-2
2008 Commercial Township Salt Hay Farm Wetland Restoration Site - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Commercial Township**	
	Acres	**Percent of Total Marsh**
Spartina spp**./Other Desirable Marsh Vegetation**		
w/o P. australis		
Desirable Mixed Marsh	12	0.4%
HMS	2	0.1%
High Marsh	13	0.4%
High Marsh / Mud Flat	1	0.0%
Salt Hay (*S. patens*; *D. spicata*; *J .gerardii*)	1	0.0%
Salt Hay / Desirable Mixed Marsh	0	0.0%
Salt Hay / *S. alterniflora*	1	0.0%
Spartina alterniflora	1293	44.7%
S. alterniflora / Dead Trees	3	0.1%
S. alterniflora / Desirable Mixed Marsh	19	0.7%
S. alterniflora / Mud Flat	118	4.1%
S. alterniflora / Wrack	0	0.0%
S. patens	0	0.0%
subtotal w/o P. australis	*1463*	*50.5%*
w/ P. australis		
Desirable Mixed Marsh / P. australis	2	0.1%
High Marsh / *P. australis*	0	0.0%
Mixed Marsh	0	0.0%
Salt Hay / *P. australis*	0	0.0%
S. alterniflora / P. australis	7	0.2%
subtotal w/ P. australis	*9*	*0.3%*
Subtotal	**1472**	**50.8%**
***P. australis* Dominated Vegetation**		
P. australis Dominant		
Phragmites australis	54	1.9%
P. australis / Dead Trees / High Marsh	1	0.0%
P. australis / Dike	6	0.2%
P. australis / High Marsh	0	0.0%
P. australis / High Marsh / Shrubs	0	0.0%
P. australis / Mud Flat	0	0.0%
P. australis / S. alterniflora	23	0.8%
P. australis / Salt Hay	1	0.0%
subtotal - P. australis	*85*	*2.9%*
Subtotal	**85**	**2.9%**

Table 8-2
2008 Commercial Township Salt Hay Farm Wetland Restoration Site -
Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Commercial Township**	
	Acres	**Percent of Total Marsh**
Non-Vegetated Marsh Plain		
Algal mat	5	0.2%
Beach	0	0.0%
Beach / Desriable Mixed Marsh	0	0.0%
Beach / Mud Flat	2	0.1%
Mud Flat	646	22.3%
Mud Flat / *P. australis*	0	0.0%
Mud Flat / Pond	0	0.0%
Mud Flat / Salt Hay		0.0%
Mud Flat/ *S. alterniflora*	389	13.4%
Mud Flat / Wrack	0	0.0%
Wrack	15	0.5%
Wrack / Desirable Mixed Marsh	1	0.0%
Wrack / Mud Flat	3	0.1%
Wrack / *S. alterniflora*	1	0.0%
Wrack / *P. australis*		0.0%
Subtotal	**1063**	**36.7%**
Internal Water Areas		
Channels (>5 ft. wide at low tide)	217	7.5%
Channel Mud Flat		0.0%
Ponded Water	34	1.2%
Ponded Water / *S. alterniflora*		0.0%
Subtotal	**251**	**8.7%**
Open Water		
Delaware Bay	22	0.7%
Upland Vegetation / Miscellaneous Cover Categories (b)		
Dike / *Phragmites australis*	3	0.1%
Subtotal (c)	**3**	**0.1%**
Total Site Area	**2895**	**100%**

(a) Areas listed are for portions of the site within the Wetland Restoration Area Boundary, as show Figures B-3 and B-4.

(b) Areas of upland / developed land listed, are in most cases due to annual variability in the mappi edge cover types and should not be interpreted as an effect of wetland restoration.

(c) Cover category subtotals may not reflect sum of individual cover type acreages due to roundin

Table 8-3
2008 Alloway Creek Watershed Phragmites Dominated Wetland Restoration Site - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Alloway Creek Watershed** [(a)]	
	Acres	**Percent of Total Marsh**
***Spartina* spp./ Other Desirable Marsh Vegetation**		
Desirable Mixed Marsh	421	26.3%
Desirable Mixed Marsh / Mud Flat	3	0.2%
Desirable Mixed Marsh / Wrack	6	0.4%
Echinochloa walteri	1	0.0%
Eleocharis spp. / S. alterniflora	0	0.0%
High Marsh	4	0.3%
High Marsh Shurbs	1	0.1%
Spartina alterniflora	22	1.4%
S. alterniflora / Desirable Mixed Marsh	663	41.4%
S. alterniflora / Desirable Mixed Marsh / Mud Flat	7	0.4%
S. alterniflora / Mud Flat	4	0.3%
Spartina cynosuroides	0	0.0%
Typha spp.	1	0.1%
subtotal w/o P. australis	*1134*	*70.9%*
w/ P. australis		
Desirable Mixed Marsh / *P. australis*	2	0.1%
Desirable Mixed Marsh / Dead *P. australis*	4	0.3%
Mixed Marsh	44	2.7%
Mixed Marsh / Mud Flat	4	0.3%
Mixed marsh / Dead *P. australis*	0	0.0%
Mixed Marsh / Wrack	5	0.3%
S. alterniflora / Dead *P. australis*	0	0.0%
S. alterniflora / P. australis	1	0.1%
subtotal w/ P. australis	61	3.8%
Subtotal [(a)]	**1195**	**74.7%**

Table 8-3
2008 Alloway Creek Watershed Phragmites Dominated Wetland Restoration Site - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Alloway Creek Watershed** [(a)]	
	Acres	**Percent of Total Marsh**
***P. australis* Dominated Vegetation**		
Dead P. australis Dominant		
Dead *P. australis*	4	0.2%
Dead *P. australis /* Desirable Mixed Marsh	1	0.1%
Dead *P. australis /* Mixed Marsh	4	0.2%
Dead *P. australis / P. australis*	15	0.9%
Subtotal	***23***	***1.5%***
P. australis Dominant		
Phragmites australis	50	3.1%
P. australis / Dead *P. australis*	1	0.0%
P. australis / Desirable Mixed Marsh	29	1.8%
P. australis / Mud Flat	0	0.0%
P. australis / *S. alterniflora*	23	1.4%
Subtotal	***102***	***6.4%***
Subtotal (a)	**125**	**7.8%**
Non-Vegetated Marsh Plain		
Mud Flat	11	0.7%
Mud Flat / Dead *P. australis*	0	0.0%
Mud Flat / Desirable Mixed Marsh	0	0.0%
Mud Flat / Mixed Marsh	3	0.2%
Mud Flat / *P. australis*	0	0.0%
Mud Flat / *S. alterniflora*	2	0.1%
Mud Flat / Wrack	1	0.1%
Wrack	12	0.7%
Wrack / Desirable Mixed Marsh	3	0.2%
Wrack / Mud Flat	14	0.9%
Wrack / Mud Flat / Desirable Mixed Marsh	1	0.1%
Wrack / Mud Flat / Mixed Marsh	1	0.0%
Wrack / Mixed Marsh	9	0.6%
Wrack / *P. australis*	0	0.0%
Wrack / *S. alterniflora*	0	0.0%
Subtotal	**59**	**3.7%**

Table 8-3
2008 Alloway Creek Watershed Phragmites Dominated Wetland Restoration Site - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**Alloway Creek Watershed** [(a)]	
	Acres	**Percent of Total Marsh**
Internal Water Areas		
Channels	219	13.7%
Subtotal	**219**	**13.7%**
Upland Vegetation / Miscellaneous Cover Categories		
Agricultural	0	0.0%
Deciduous Forest	0	0.0%
Developed	0	0.0%
Road	0	0.0%
Upland Island	1	0.1%
Subtotal	**2**	**0.1%**
Total Area	**1600**	**100.0%**

(a) Cover category subtotals may not reflect sum of individual acreages due to rounding.

Table 8-4
2008 Delaware Phragmites Dominated Wetland Restoration Sites - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**The Rocks**		**Cedar Swamp**	
	Acres	**Percent of Total Marsh(a)**	**Acres**	**Percent of Total Marsh(a)**
***Spartina spp.* / Other Desirable Vegetation**				
w/o P. australis				
Desirable Mixed Marsh	76	10.4%	338	18.1%
Desirable Mixed Marsh / Mud Flat	0	0.0%	2	0.1%
Desirable Mixed Marsh / Sand / Wrack	1	0.1%	0	0.0%
Desirable Mixed Marsh / Wrack	0	0.0%	0	0.0%
High Marsh	3	0.4%	0	0.0%
High Marsh Shrubs	2	0.3%	23	1.2%
High Marsh Shrubs / *P. australis*	0	0.0%	0	0.0%
High Marsh Shrubs / *S. alterniflora*	0	0.0%	1	0.0%
Salt Hay (*Spartina patens, Distichlis spicata, Juncus gerardii)*	3	0.4%	0	0.0%
Salt Hay / Desirable Mixed Marsh	3	0.4%	1	0.1%
Salt Hay / *S. alterniflora*	1	0.2%	0	0.0%
Salt Hay / *Scirpus olneyi*	0	0.0%	0	0.0%
Spartina alterniflora	5	0.7%	146	7.9%
S. alterniflora / Beach	0	0.0%	4	0.2%
S. alterniflora / Desirable Mixed Marsh	485	65.9%	157	8.4%
S. alterniflora / Mud Flat	2	0.3%	2	0.1%
S. alterniflora / S. cynosuroides	0	0.0%	691	37.1%
Spartina cynosuroides	1	0.2%	4	0.2%
S. cynosuroides / Desirable Mixed Marsh	0	0.1%	0	0.0%
S. cynosuroides / S. alterniflora	2	0.2%	70	3.8%
Scirpus olneyi	1	0.1%	0	0.0%
Scirpus punctatum	0	0.0%	2	0.1%
subtotal w/o P. australis	*587*	*79.8%*	*1441*	*77.4%*
w/ P. australis				
Desirable Mixed Marsh / *P. australis*	2	0.3%	0	0.0%
Desirable Mixed Marsh / Dead *P. australis*	13	1.8%	1	0.1%
Mixed Marsh	28	3.8%	87	4.7%
Mixed Marsh / Beach	0	0.0%	2	0.1%
Mixed Marsh / Dead *P. australis*	0	0.0%	6	0.3%
Mixed Marsh / Mud Flat	1	0.1%	4	0.2%
Mixed Marsh / *S. alterniflora*	0	0.0%	0	0.0%
Mixed Marsh / Wrack	0	0.0%	0	0.0%
S. alterniflora / P. australis	0	0.1%	0	0.0%
S. alterniflora / Mixed Marsh	0	0.0%	0	0.0%
S. cynosuroides / P. australis	0	0.0%	0	0.0%
Salt Hay / Mixed Marsh	0	0.0%	0	0.0%
subtotal w/ P. australis	*45*	*6.1%*	*100*	*5.4%*
Subtotal	**632**	**85.9%**	**1541**	**82.7%**
***P. australis* Dominated Vegetation**				
Dead P. australis Dominant				
Dead *P. australis*	3	0.4%	8	0.4%
Dead *P. australis /* Desirable Mixed Marsh	6	0.8%	0	0.0%
Dead *P. australis /* Mixed Marsh	0	0.0%	7	0.4%
Dead *P. australis* / Mud Flat	0	0.0%	0	0.0%
Dead *P. australis* / High Marsh Shrubs	0	0.0%	0	0.0%
Dead *P. australis / P. australis*	1	0.2%	6	0.3%
Dead *P. australis / P. australis / S. cynosuroides*	0	0.0%	0	0.0%
Dead *P. australis / P. australis /* Desirable Mixed Marsh	1	0.1%	0	0.0%
Dead *P. australis / S. alterniflora*	0	0.0%	0	0.0%
subtotal - Dead P. australis	*11*	*1.5%*	*22*	*1.2%*

Table 8-4
2008 Delaware Phragmites Dominated Wetland Restoration Sites - Cover Category Summary
PSEG Detrital Production Monitoring

Cover Category / Cover Type	**The Rocks**		**Cedar Swamp**	
	Acres	**Percent of Total Marsh**[a]	**Acres**	**Percent of Total Marsh**[a]
P. australis Dominant				
Phragmites australis	25	3.4%	45	2.4%
P. australis / Dead *P. australis*	0	0.0%	3	0.1%
P. australis / Dead *P. australis* / Wrack	0	0.0%	0	0.0%
P. australis / Desirable Mixed Marsh	9	1.2%	8	0.4%
P. australis / High Marsh	0	0.0%	0	0.0%
P. australis / Mixed Marsh	0	0.0%	0	0.0%
P. australis / Mud Flat	0	0.0%	0	0.0%
P. australis / Mud Flat / *S. alterniflora*	0	0.0%	0	0.0%
P. australis / S. alterniflora	12	1.6%	1	0.0%
P. australis / S. alterniflora / S. cynosuroides	0	0.0%	0	0.0%
P. australis / S. cynosuroides	4	0.5%	20	1.1%
P. australis / Wrack	1	0.1%	0	0.0%
P. australis / Wrack / *S. alterniflora*	0	0.0%	0	0.0%
subtotal - P. australis	*51*	*6.9%*	*76*	*4.1%*
Subtotal	**61**	**8.3%**	**98**	**5.3%**
Non-vegetated Marsh Plain				
Beach	0	0.0%	0	0.0%
Beach / Mixed Marsh	0	0.0%	1	0.1%
Beach / *S. alterniflora*	0	0.0%	0	0.0%
Mud Flat	0	0.0%	0	0.0%
Mud Flat / Desirable Mixed Marsh	0	0.0%	0	0.0%
Mud Flat / Mixed Marsh	0	0.0%	1	0.0%
Mud Flat / *P. australis*	0	0.0%	0	0.0%
Mud Flat / *S. alterniflora*	1	0.1%	1	0.0%
Mud Flat / Wrack	0	0.0%	1	0.1%
Wrack	5	0.7%	23	1.2%
Wrack / Dead *P. australis*	0	0.0%	0	0.0%
Wrack / Dead *P. australis / P. australis*	0	0.0%	0	0.0%
Wrack / Desirable Mixed Marsh	1	0.1%	0	0.0%
Wrack / Mixed Marsh	1	0.1%	0	0.0%
Wrack / *P. australis*	0	0.0%	0	0.0%
Wrack / *S. alterniflora*	0	0.0%	0	0.0%
Wrack / Mud Flat	0	0.0%	1	0.1%
Subtotal	**8**	**1.1%**	**29**	**1.6%**
Internal Water Areas				
Channels	30	4.0%	188	10.1%
Ponded Water	1	0.1%	0	0.0%
Subtotal	**31**	**4.2%**	**188**	**10.1%**
Open Water				
Appoquinimink River	3	0.5%	5	0.3%
Subtotal	**3**	**0.5%**	**5**	**0.3%**
Upland Vegetation / Miscellaneous Cover Categories				
Deciduous Forest	0	0.1%	1	0.0%
Developed Land	0	0.0%		0.0%
Subtotal [b]	**0**	**0.1%**	**1**	**0.0%**
Total Marsh Area	**736**	**100%**	**1863**	**100%**

[a] Includes water areas, but does not include upland developed land on the site.

[b] Cover category subtotals may not reflect sum of individual cover type acreages due to rounding.

TABLE 8-5
Channel Geomorphology for Reference Marshes and Restoration Sites

Site	Channel Class	Number of Channels	Sinuous Length (feet)	Average Length (feet)	Site Area (acres)	Drainage Density (ft/acre)	Channel Frequency	% of Total Channel Length	Length Ratio	Bifurcation Ratio	Average Channel Sinuosity
Mad Horse 2005	18	2	79	40			0.003	0.0%	1.2	--	1.0
	17	4	130	33			0.006	0.0%	0.8	2.0	1.1
	16	22	910	41			0.030	0.2%	0.9	5.5	1.1
	15	36	1597	44			0.050	0.3%	1.1	1.6	1.1
	14	57	2246	39			0.079	0.4%	0.9	1.6	1.1
	13	86	3962	46			0.119	0.8%	1.0	1.5	1.1
	12	91	4194	46			0.126	0.8%	0.9	1.1	1.2
	11	155	8340	54			0.215	1.6%	1.0	1.7	1.1
	10	236	12829	54			0.327	2.5%	1.0	1.5	1.2
	9	349	19793	57			0.484	3.9%	1.0	1.5	1.1
	8	601	34438	57			0.833	6.7%	0.9	1.7	1.1
	7	916	58897	64			1.270	11.5%	1.0	1.5	1.2
	6	1,175	75738	64			1.629	14.8%	0.9	1.3	1.2
	5	1,174	86941	74			1.627	17.0%	0.8	1.0	1.2
	4	954	86042	90			1.322	16.8%	0.6	0.8	1.2
	3	501	73952	148			0.694	14.5%	0.1	0.5	1.2
	2	27	28659	1061			0.037	5.6%	0.7	0.1	1.3
	1	8	12180	1523			0.011	2.4%	--	0.3	1.3
	Total	6,394	510926		721	708	8.863	100.0%			
Moore's Beach 2005	23	5	320	64			0.004	0.1%	1.6	--	1.1
	22	4	163	41			0.003	0.0%	0.6	0.8	1.1
	21	4	258	65			0.003	0.0%	0.9	1.0	1.0
	20	4	303	76			0.003	0.1%	1.2	1.0	1.2
	19	14	860	61			0.010	0.1%	1.2	3.5	1.1
	18	19	1006	53			0.014	0.2%	0.9	1.4	1.1
	17	35	2054	59			0.026	0.3%	0.9	1.8	1.1
	16	48	3000	63			0.035	0.5%	1.1	1.4	1.1
	15	72	3934	55			0.053	0.7%	0.9	1.5	1.1
	14	118	7542	64			0.087	1.3%	1.0	1.6	1.1
	13	145	8878	61			0.107	1.5%	0.9	1.2	1.1
	12	219	14237	65			0.161	2.4%	1.0	1.5	1.1
	11	323	21641	67			0.238	3.6%	1.0	1.5	1.1
	10	470	33097	70			0.346	5.6%	1.0	1.5	1.1
	9	577	41238	71			0.425	6.9%	0.9	1.2	1.1
	8	738	56707	77			0.543	9.5%	0.9	1.3	1.1
	7	857	69901	82			0.631	11.7%	0.9	1.2	1.1
	6	920	79205	86			0.677	13.3%	0.9	1.1	1.1
	5	848	77738	92			0.624	13.1%	0.8	0.9	1.1
	4	670	72863	109			0.493	12.2%	0.6	0.8	1.1
	3	353	67362	191			0.260	11.3%	0.2	0.5	1.1
	2	17	17517	1030			0.013	2.9%	0.5	0.0	1.3
	1	8	15413	1927			0.006	2.6%	--	0.5	1.2
	Total	6,468	595237		1,359	438	4.760	100.0%			

TABLE 8-5
Channel Geomorphology for Reference Marshes and Restoration Sites

Site	Channel Class	Number of Channels	Sinuous Length (feet)	Average Length (feet)	Site Area (acres)	Drainage Density (ft/acre)	Channel Frequency	% of Total Channel Length	Length Ratio	Bifurcation Ratio	Average Channel Sinuosity
Commercial Township 2008	44	4	308	77			0.0	0.0%	--	1.0	1.1
	43	4	117	29			0.0	0.0%	0.4	1.0	1.0
	42	4	169	42			0.0	0.0%	1.4	1.0	1.1
	41	4	236	59			0.0	0.0%	1.4	1.0	1.0
	40	4	448	112			0.0	0.0%	1.9	1.8	1.1
	39	7	380	54			0.0	0.0%	0.8	0.9	1.0
	38	6	260	43			0.0	0.0%	0.7	2.2	1.0
	37	13	606	47			0.0	0.0%	2.3	1.8	1.1
	36	23	763	33			0.0	0.0%	1.3	0.7	1.0
	35	16	411	26			0.0	0.0%	0.5	1.1	1.0
	34	18	718	40			0.0	0.0%	1.7	1.2	1.1
	33	21	1074	51			0.0	0.0%	1.5	1.2	1.1
	32	25	1471	59			0.0	0.0%	1.4	1.6	1.0
	31	40	1849	46			0.0	0.1%	1.3	1.4	1.0
	30	57	2238	39			0.0	0.1%	1.2	1.2	1.1
	29	68	2780	41			0.0	0.1%	1.2	1.0	1.0
	28	70	4268	61			0.0	0.1%	1.5	1.2	1.0
	27	87	3842	44			0.0	0.1%	0.9	1.4	1.0
	26	118	4846	41			0.0	0.1%	1.3	1.5	1.0
	25	175	6964	40			0.1	0.2%	1.4	1.4	1.0
	24	253	10585	42			0.1	0.3%	1.5	1.4	1.0
	23	347	14429	42			0.1	0.4%	1.4	1.2	1.0
	22	403	15675	39			0.1	0.5%	1.1	1.3	1.0
	21	535	22711	42			0.2	0.7%	1.4	1.4	1.0
	20	760	30607	40			0.3	0.9%	1.3	1.3	1.0
	19	1014	45314	45			0.3	1.4%	1.5	1.2	1.0
	18	1249	52582	42			0.4	1.6%	1.2	1.4	1.0
	17	1689	75054	44			0.6	2.2%	1.4	1.3	1.0
	16	2134	96290	45			0.7	2.9%	1.3	1.2	1.0
	15	2642	114069	43			0.9	3.4%	1.2	1.2	1.0
	14	3072	132967	43			1.1	4.0%	1.2	1.2	1.0
	13	3547	156244	44			1.2	4.7%	1.2	1.2	1.0
	12	4210	180028	43			1.5	5.4%	1.2	1.1	1.0
	11	4726	205693	44			1.6	6.2%	1.1	1.1	1.0
	10	5205	222901	43			1.8	6.7%	1.1	1.1	1.0
	9	5721	251774	44			2.0	7.5%	1.1	1.1	1.0
	8	6183	279568	45			2.1	8.4%	1.1	1.0	1.0
	7	6394	289738	45			2.2	8.7%	1.0	1.0	1.0
	6	6300	286406	45			2.2	8.6%	1.0	0.9	1.1
	5	5839	287071	49			2.0	8.6%	1.0	0.0	1.1
	4	4725	253757	54			1.6	7.6%	0.9	0.5	1.1
	3	2324	198698	85			0.8	6.0%	0.8	0.0	1.1
	2	41	47709	1164			0.0	1.4%	0.2	0.0	1.1
	1	9	32507	3612			0.0	1.0%	0.1	--	1.2
	Total	70,086	3,336,128		2,901	1,150	24.2	100.0%			

TABLE 8-5
Channel Geomorphology for Reference Marshes and Restoration Sites

Site	Channel Class	Number of Channels	Sinuous Length (feet)	Average Length (feet)	Site Area (acres)	Drainage Density (ft/acre)	Channel Frequency	% of Total Channel Length	Length Ratio	Bifurcation Ratio	Average Channel Sinuosity
Alloway Creek Watershed 2008	30	2	63	32			0.001	0.0%	--	0.5	1.01
	29	4	95	24			0.002	0.0%	1.5	1.0	1.03
	28	4	195	49			0.002	0.0%	2.1	0.5	1.03
	27	8	390	49			0.005	0.0%	2.0	0.9	1.08
	26	9	384	43			0.006	0.0%	1.0	0.9	1.07
	25	10	417	42			0.006	0.0%	1.1	1.7	1.06
	24	6	353	59			0.004	0.0%	0.8	0.8	1.10
	23	8	606	76			0.005	0.1%	1.7	1.0	1.05
	22	8	361	45			0.005	0.0%	0.6	0.7	1.06
	21	12	776	65			0.007	0.1%	2.2	1.0	1.13
	20	12	369	31			0.007	0.0%	0.5	0.7	1.02
	19	18	534	30			0.011	0.0%	1.4	0.5	1.04
	18	33	1373	42			0.021	0.1%	2.6	0.6	1.08
	17	59	2796	47			0.037	0.3%	2.0	0.6	1.09
	16	104	4498	43			0.065	0.4%	1.6	0.8	1.07
	15	130	5983	46			0.081	0.5%	1.3	0.7	1.07
	14	176	7997	45			0.110	0.7%	1.3	0.7	1.08
	13	237	11323	48			0.148	1.0%	1.4	0.7	1.09
	12	322	16613	52			0.201	1.5%	1.5	0.7	1.10
	11	448	23951	53			0.280	2.2%	1.4	0.6	1.09
	10	713	35543	50			0.445	3.2%	1.5	0.7	1.09
	9	988	49976	51			0.617	4.5%	1.4	0.7	1.10
	8	1449	75619	52			0.905	6.8%	1.5	0.8	1.09
	7	1899	106780	56			1.186	9.7%	1.4	0.8	1.10
	6	2334	134200	57			1.458	12.1%	1.3	0.9	1.12
	5	2592	155456	60			1.619	14.1%	1.2	1.0	1.10
	4	2579	178842	69			1.611	16.2%	1.2	1.3	1.10
	3	2004	183305	91			1.252	16.6%	1.0	24.7	1.12
	2	81	46414	573			0.051	4.2%	0.3	0.9	1.16
	1	94	60272	641			0.059	5.5%	1.3	--	1.18
	Total	16,343	1,105,485		1,601	690	10.208	100.0%			
The Rocks 2008	22	2	160	80			0.003	0.0%	---	1.0	1.0
	21	2	84	42			0.003	0.0%	0.5	0.5	1.0
	20	4	122	30			0.005	0.0%	0.7	0.7	1.1
	19	6	297	49			0.008	0.1%	1.6	1.0	1.1
	18	6	136	23			0.008	0.0%	0.5	0.3	1.0
	17	18	790	44			0.024	0.2%	1.9	0.9	1.0
	16	20	718	36			0.027	0.2%	0.8	0.5	1.0
	15	38	1909	50			0.052	0.5%	1.4	0.5	1.0
	14	79	3757	48			0.107	0.9%	0.9	0.9	1.1
	13	89	4108	46			0.121	1.0%	1.0	0.7	1.2
	12	130	6684	51			0.176	1.7%	1.1	0.6	1.1
	11	220	10067	46			0.299	2.5%	0.9	0.6	1.1
	10	362	15330	42			0.491	3.9%	0.9	0.7	1.1
	9	492	22141	45			0.668	5.6%	1.1	0.8	1.1
	8	641	30476	48			0.870	7.7%	1.1	0.8	1.1
	7	777	37411	48			1.054	9.5%	1.0	0.9	1.1
	6	892	44167	50			1.210	11.2%	1.0	0.9	1.1
	5	968	51564	53			1.313	13.0%	1.1	1.0	1.1
	4	941	59922	64			1.277	15.1%	1.2	1.5	1.1
	3	641	73451	115			0.870	18.6%	1.8	37.7	1.1
	2	17	13974	822			0.023	3.5%	7.2	1.1	1.3
	1	15	18603	1240			0.020	4.7%	1.5	---	1.4
	Total	6,360	395873		737	537	8.630	100.0%			

TABLE 8-5
Channel Geomorphology for Reference Marshes and Restoration Sites

Site	Channel Class	Number of Channels	Sinuous Length (feet)	Average Length (feet)	Site Area (acres)	Drainage Density (ft/acre)	Channel Frequency	% of Total Channel Length	Length Ratio	Bifurcation Ratio	Average Channel Sinuosity
Cedar Swamp 2008	36	3	39	13			0.002	0.0%	--	0.5	0.7
	35	6	384	64			0.003	0.0%	4.9	0.8	1.2
	34	8	378	47			0.005	0.0%	0.7	0.6	1.1
	33	13	573	44			0.008	0.1%	0.9	0.8	1.1
	32	17	888	52			0.010	0.1%	1.2	0.9	1.2
	31	18	1056	59			0.010	0.1%	1.1	0.7	1.1
	30	27	1605	59			0.016	0.2%	1.0	1.4	1.0
	29	20	1196	60			0.012	0.1%	1.0	1.0	1.1
	28	21	1392	66			0.012	0.1%	1.1	1.1	1.1
	27	19	1098	58			0.011	0.1%	0.9	0.7	1.1
	26	28	1662	59			0.016	0.2%	1.0	0.9	1.1
	25	31	2134	69			0.018	0.2%	1.2	0.7	1.1
	24	46	3345	73			0.027	0.3%	1.1	0.9	1.1
	23	49	3194	65			0.028	0.3%	0.9	0.7	1.1
	22	68	4344	64			0.039	0.4%	1.0	0.6	1.1
	21	116	6470	56			0.067	0.6%	0.9	0.7	1.1
	20	171	9682	57			0.099	0.9%	1.0	0.8	1.1
	19	223	11834	53			0.129	1.1%	0.9	0.7	1.1
	18	310	19158	62			0.179	1.8%	1.2	0.7	1.1
	17	423	25051	59			0.244	2.4%	1.0	0.8	1.1
	16	557	31470	56			0.322	3.0%	1.0	0.8	1.1
	15	680	38071	56			0.393	3.7%	1.0	0.8	1.1
	14	836	47183	56			0.483	4.5%	1.0	0.8	1.1
	13	987	55592	56			0.570	5.3%	1.0	0.9	1.1
	12	1160	69377	60			0.670	6.7%	1.1	0.9	1.1
	11	1263	71421	57			0.729	6.9%	0.9	1.0	1.1
	10	1282	75839	59			0.740	7.3%	1.0	1.0	1.1
	9	1287	75952	59			0.743	7.3%	1.0	1.1	1.1
	8	1156	80962	70			0.668	7.8%	1.2	1.1	1.1
	7	1083	78640	73			0.625	7.5%	1.0	1.1	1.1
	6	982	82259	84			0.567	7.9%	1.2	1.2	1.1
	5	827	81257	98			0.478	7.8%	1.2	1.5	1.1
	4	559	85048	152			0.323	8.2%	1.5	3.5	1.1
	3	162	58554	361			0.094	5.6%	2.4	54.0	1.4
	2	3	14510	4837			0.002	1.4%	13.4	3.0	1.0
	1	1	865	865			0.001	0.1%	0.2	0.0	1.0
	Total	14,442	1042483		1,732	602	8.341	100.0%			

TABLE 8-6
AERIAL COVER SUMMARY
2008 CLIP AND OCULAR QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

	Peak Season Percent Cover
Mad Horse Creek Reference Marsh	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	54%
Standard Error of Mean	3%
Standard Deviation	18%
Minimum	25%
Maximum	95%
Count (n)	51
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	41%
Standard Error of Mean	5%
Standard Deviation	23%
Minimum	0%
Maximum	80%
Count (n)	21
All Quadrats	
Mean	50%
Standard Error of Mean	2%
Standard Deviation	20%
Minimum	0%
Maximum	95%
Count (n)	72
Moores Beach West Reference Marsh	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	38%
Standard Error of Mean	2%
Standard Deviation	9%
Minimum	25%
Maximum	55%
Count (n)	22
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	16%
Standard Error of Mean	1%
Standard Deviation	1%
Minimum	15%
Maximum	16%
Count (n)	2
All Quadrats	
Mean	36%
Standard Error of Mean	2%
Standard Deviation	11%
Minimum	15%
Maximum	55%
Count (n)	24

TABLE 8-6
AERIAL COVER SUMMARY
2008 CLIP AND OCULAR QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

	Peak Season Percent Cover
Commercial Township Site	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	39%
Standard Error of Mean	3%
Standard Deviation	12%
Minimum	10%
Maximum	55%
Count (n)	23
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	2%
Standard Error of Mean	1%
Standard Deviation	4%
Minimum	0%
Maximum	10%
Count (n)	9
All Quadrats	
Mean	29%
Standard Error of Mean	4%
Standard Deviation	20%
Minimum	0%
Maximum	55%
Count (n)	32
Alloway Creek Site	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	44%
Standard Error of Mean	3%
Standard Deviation	15%
Minimum	25%
Maximum	92%
Count (n)	32
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	34%
Standard Error of Mean	5%
Standard Deviation	24%
Minimum	5%
Maximum	100%
Count (n)	24
All Quadrats	
Mean	40%
Standard Error of Mean	3%
Standard Deviation	20%
Minimum	5%
Maximum	100%
Count (n)	56

TABLE 8-6
AERIAL COVER SUMMARY
2008 CLIP AND OCULAR QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

	Peak Season Percent Cover
The Rocks Site	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	46%
Standard Error of Mean	2%
Standard Deviation	17%
Minimum	15%
Maximum	100%
Count (n)	51
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	48%
Standard Error of Mean	7%
Standard Deviation	29%
Minimum	5%
Maximum	101%
Count (n)	19
All Quadrats	
Mean	47%
Standard Error of Mean	2%
Standard Deviation	20%
Minimum	5%
Maximum	101%
Count (n)(c)	70
Cedar Swamp Site	
***Spartina alterniflora* dominated Quadrats Only (a)**	
Mean	44%
Standard Error of Mean	2%
Standard Deviation	11%
Minimum	26%
Maximum	66%
Count (n)	52
Non-*Spartina alterniflora* dominated Quadrats Only (b)	
Mean	25%
Standard Error of Mean	4%
Standard Deviation	12%
Minimum	5%
Maximum	50%
Count (n)	12
All Quadrats	
Mean	40%
Standard Error of Mean	2%
Standard Deviation	14%
Minimum	5%
Maximum	66%
Count (n)	64

(a) Also includes *Spartina cynosuroides* dominated quadrats, when present.

(b) Includes quadrats dominated by *Spartina patens.*

TABLE 8-7
SUMMARY OF 2008 CLIP QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

		Biomass					
	Percent Cover	Live Standing		Dead Standing	Litter gdw/m^2	Total Standing	Total Biomass
		gdw/m^2	lb/acre	gdw/m^2		gdw/m^2	gdw/m^2
Mad Horse Creek Reference Marsh							
***Spartina alterniflora* dominated Quadrats Only (a)**							
Mean	53%	824	7,353	0	126	824	951
Standard Error of Mean	6%	103	923	0	53		
Standard Deviation	18%	343	3,060	0	176		
Minimum	25%	355	3,170	0	0		
Maximum	75%	1320	11,777	0	588		
Count (n)	11	11	11	11	11		
Non-*Spartina alterniflora* dominated Quadrats Only (b)							
Mean	54%	705	2,909	31	76	736	812
Standard Error of Mean	13%	110	982	0	0		
Standard Deviation	18%	308	2,751	81	59		
Minimum	35%	291	2,599	0	0		
Maximum	80%	1,120	9,991	215	154		
Count (n)	7	7	7	7	7		
All Quadrats							
Mean	53%	778	6,941	12	107	790	897
Standard Error of Mean	4%	77	686	12	33		
Standard Deviation	18%	326	2,909	51	142		
Minimum	25%	291	2,599	0	0		
Maximum	80%	1,320	161	215	588		
Count (n)	18	18	18	18	18		
Moores Beach West Reference Marsh							
***Spartina alterniflora* dominated Quadrats Only (a)**							
Mean	41%	665	5,933	41	134	706	840
Standard Error of Mean	5%	116	1,037	34	48		
Standard Deviation	11%	260	2,318	68	96		
Minimum	25%	349	3,116	0	34		
Maximum	55%	921	8,215	142	233		
Count (n)	5	5	5	4	4		
Non-*Spartina alterniflora* dominated Quadrats Only							
Mean	15%	733	2,088	0	90	733	822
Standard Error of Mean	15%	733	6,536	0	90		
Standard Deviation	--	--	--	--	--		
Minimum	15%	733	6,536	0	90		
Maximum	15%	733	6,536	0	90		
Count (n)	1	1	1	1	1		
All Quadrats							
Mean	37%	676	6,033	33	125	709	834
Standard Error of Mean	6%	96	853	28	38		
Standard Deviation	15%	234	2,088	62	86		
Minimum	15%	349	3,116	0	34		
Maximum	55%	921	54	142	233		
Count (n)	6	6	6	5	5		

TABLE 8-7
SUMMARY OF 2008 CLIP QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

		Biomass					
	Percent Cover	Live Standing		Dead Standing	Litter gdw/m^2	Total Standing	Total Biomass
		gdw/m^2	lb/acre	gdw/m^2		gdw/m^2	gdw/m^2
Commercial Township Site							
***Spartina alterniflora* dominated Quadrats Only (a`**							
Mean	39%	1366	12,185	0	41	1,366	1,406
Standard Error of Mean	4%	242	2,158	0	19		
Standard Deviation	12%	684	6,103	0	54		
Minimum	15%	450	4,017	0	0		
Maximum	50%	2613	23,317	0	119		
Count (n)	8	8	8	8	8		
Non-*Spartina alterniflora* dominated Quadrats Only							
Mean	--	--	--	--	--	--	--
Standard Error of Mean	--	--	--	--	--		
Standard Deviation	--	--	--	--	--		
Minimum	--	--	--	--	--		
Maximum	--	--	--	--	--		
Count (n)	0	0	0	0	0		
All Quadrats							
Mean	39%	1,366	12,185	0	41	1,366	1,406
Standard Error of Mean	4%	242	2,158	0	19		
Standard Deviation	12%	684	6,103	0	54		
Minimum	15%	450	4,017	0	0		
Maximum	50%	2,613	71	0	119		
Count	8	8	8	8	8		
Alloway Creek Site							
***Spartina alterniflora* dominated Quadrats Only (a)**							
Mean	40%	1067	9,523	0	58	1,067	1,125
Standard Error of Mean	4%	223	1,988	0	19		
Standard Deviation	11%	668	5,964	0	56		
Minimum	25%	457	4,078	0	0		
Maximum	55%	2709	24,172	0	145		
Count (n)	9	9	9	9	9		
Non-*Spartina alterniflora* dominated Quadrats Only (b)							
Mean	24%	710	5,348	28	48	738	786
Standard Error of Mean	2%	65	577	0	0		
Standard Deviation	15%	414	3,694	62	45		
Minimum	5%	145	1,291	0	0		
Maximum	41%	1,287	11,484	138	94		
Count (n)	5	5	5	5	5		
All Quadrats							
Mean	34%	940	8,385	10	54	950	1,004
Standard Error of Mean	4%	160	1,429	10	13		
Standard Deviation	15%	599	5,348	37	50		
Minimum	5%	145	1,291	0	0		
Maximum	55%	2,709	125	138	145		
Count	14	14	14	14	14		

TABLE 8-7
SUMMARY OF 2008 CLIP QUADRAT TRANSECT DATA
PSEG EEP DETRITAL PRODUCTION MONITORING PROGRAM

		Biomass					
	Percent Cover	Live Standing		Dead Standing	Litter gdw/m^2	Total Standing	Total Biomass
		gdw/m^2	lb/acre	gdw/m^2		gdw/m^2	gdw/m^2
The Rocks Site							
***Spartina alterniflora* dominated Quadrats Only (a)**							
Mean	46%	1097	9,790	23	45	1,121	1,166
Standard Error of Mean	5%	280	2,499	23	17		
Standard Deviation	17%	929	8,289	78	56		
Minimum	15%	381	3,399	0	0		
Maximum	85%	3651	32,577	258	154		
Count (n)	11	11	11	11	11		
Non-*Spartina alterniflora* dominated Quadrats Only (b)							
Mean	48%	1,059	6,838	0	4	1,059	1,063
Standard Error of Mean	6%	210	1,874	0	0		
Standard Deviation	27%	474	4,231	0	4		
Minimum	16%	556	4,957	0	0		
Maximum	101%	1,682	15,009	0	8		
Count (n)	7	7	7	7	7		
All Quadrats							
Mean	47%	1,083	9,659	14	29	1,097	1,126
Standard Error of Mean	5%	181	1,612	14	11		
Standard Deviation	21%	766	6,838	61	48		
Minimum	15%	381	3,399	0	0		
Maximum	101%	3,651	161	258	154		
Count	18	18	18	18	18		
Cedar Swamp Site							
***Spartina alterniflora* dominated Quadrats Only (a)**							
Mean	45%	957	8,534	92	243	1,049	1,292
Standard Error of Mean	3%	186	1,658	50	62		
Standard Deviation	9%	644	5,744	174	216		
Minimum	35%	184	1,643	0	47		
Maximum	65%	2188	19,521	502	688		
Count (n)	12	12	12	12	12		
Non-*Spartina alterniflora* dominated Quadrats Only (b)							
Mean	18%	660	5,465	249	134	908	1,042
Standard Error of Mean	5%	259	2,311	96	71		
Standard Deviation	10%	518	4,622	192	143		
Minimum	5%	107	959	0	8		
Maximum	30%	1,359	12,127	442	301		
Count (n)	4	4	4	4	4		
All Quadrats							
Mean	38%	882	7,872	131	216	1,014	1,229
Standard Error of Mean	4%	153	1,366	46	50		
Standard Deviation	15%	613	5,465	186	202		
Minimum	5%	107	959	0	8		
Maximum	65%	2,188	143	502	688		
Count	16	16	16	16	16		

(a) Also includes *Spartina cynosuroides* dominated quadrats, when present

(b) Includes quadrats dominated by *Spartina patens.*

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Mad Horse Creek Reference Marsh - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	48%	83	660	0	47
Standard Error of Mean	3%	5	194	0	31
Standard Deviation	14%	23	388	0	62
Count (*n*)	18	18	4	4	4
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	28%	--	541	0	107
Standard Error of Mean	11%	--	250	0	3
Standard Deviation	27%	--	353	0	4
Count (*n*)	6	--	2	2	2
All Quadrats					
Mean	43%	--	620	0	67
Standard Error of Mean	4%	--	141	0	23
Standard Deviation	19%	--	345	0	57
Count (*n*)	24	--	6	6	6
Mad Horse Creek Reference Marsh - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	59%	108	768	0	48
Standard Error of Mean	11%	5	--	--	--
Standard Deviation	22%	11	--	--	--
Count (*n*)	4	4	1	1	1
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	41%	--	402	215	57
Standard Error of Mean	14%	--	--	--	--
Standard Deviation	28%	--	--	--	--
Count (*n*)	4	--	1	1	1
All Quadrats					
Mean	50%	--	585	108	52
Standard Error of Mean	9%	--	183	108	4
Standard Deviation	25%	--	259	152	6
Count (n)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Mad Horse Creek Reference Marsh - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	57%	108	943	0	193
Standard Error of Mean	4%	5	133	0	90
Standard Deviation	19%	27	325	0	220
Count (*n*)	29	34	6	6	6
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	48%	--	863	0	65
Standard Error of Mean	6%	--	129	0	39
Standard Deviation	19%	--	258	0	78
Count (*n*)	11	--	4	4	4
All Quadrats					
Mean	54%	--	911	0	142
Standard Error of Mean	3%	--	91	0	58
Standard Deviation	19%	--	287	0	182
Count (n)	40	--	10	10	10
Moores Beach West Reference Marsh - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	33%	102	921	24	197
Standard Error of Mean	3%	10	--	--	--
Standard Deviation	8%	27	--	--	--
Count (*n*)	7	7	1	1	1
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	15%	--	733	--	90
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	1	--	1	1	1
All Quadrats					
Mean	31%	--	827	12	143
Standard Error of Mean	3%	--	94	12	54
Standard Deviation	10%	--	133	17	76
Count (*n*)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Moores Beach West Reference Marsh - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	38%	102	599	71	36
Standard Error of Mean	3%	7	172	71	36
Standard Deviation	9%	19	243	100	51
Count (*n*)	8	8	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	--	--	--	--	--
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	0	--	0	0	0
All Quadrats					
Mean	38%	--	599	71	36
Standard Error of Mean	3%	--	172	71	36
Standard Deviation	9%	--	243	100	51
Count (*n*)	8	--	2	2	2
Moores Beach West Reference Marsh - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	41%	82	603	0	133
Standard Error of Mean	3%	6	254	0	100
Standard Deviation	9%	16	359	0	141
Count (*n*)	7	8	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	16%	--	--	--	--
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	1	--	0	0	0
All Quadrats					
Mean	38%	--	603	0	133
Standard Error of Mean	4%	--	254	0	100
Standard Deviation	12%	--	359	0	141
Count(n)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Commercial Township Site - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	48%	173	2127	0	117
Standard Error of Mean	2%	3	486	0	1
Standard Deviation	5%	8	688	0	2
Count (*n*)	8	8	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	--	--	--	--	--
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	0	--	0	0	0
All Quadrats					
Mean	48%	--	2127	0	117
Standard Error of Mean	2%	--	486	0	1
Standard Deviation	5%	--	688	0	2
Count (*n*)	8	--	2	2	2
Commercial Township Site - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	23%	128	502	0	0
Standard Error of Mean	2%	0	52	0	0
Standard Deviation	4%	0	73	0	0
Count (*n*)	5	5	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	0%	--	--	--	--
Standard Error of Mean	0%	--	--	--	--
Standard Deviation	0%	--	--	--	--
Count (*n*)	3	--	0	0	0
All Quadrats					
Mean	14%	--	502	0	0
Standard Error of Mean	4%	--	52	0	0
Standard Deviation	12%	--	73	0	0
Count (*n*)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Commercial Township Site - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	40%	173	1527	0	45
Standard Error of Mean	6%	12	74	0	29
Standard Deviation	15%	29	104	0	41
Count (*n*)	6	6	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	0%	--	--	--	--
Standard Error of Mean	0%	--	--	--	--
Standard Deviation	0%	--	--	--	--
Count (*n*)	2	--	0	0	0
All Quadrats					
Mean	30%	--	1527	0	45
Standard Error of Mean	8%	--	74	0	29
Standard Deviation	22%	--	104	0	41
Count (*n*)	8	--	2	2	2
Commercial Township Site - Transect 4					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	40%	175	1307	0	0
Standard Error of Mean	3%	4	193	0	0
Standard Deviation	6%	8	273	0	0
Count (*n*)	4	4	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	5%	--	--	--	--
Standard Error of Mean	3%	--	--	--	--
Standard Deviation	6%	--	--	--	--
Count (*n*)	4	--	0	0	0
All Quadrats					
Mean	23%	--	1307	0	0
Standard Error of Mean	7%	--	193	0	0
Standard Deviation	19%	--	273	0	0
Count (*n*)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Alloway Creek Watershed Site - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	49%	113	784	0	88
Standard Error of Mean	3%	12	103	0	13
Standard Deviation	7%	33	146	0	19
Count (*n*)	7	7	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	15%	--	--	--	--
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	1	--	0	0	0
All Quadrats					
Mean	44%	--	784	0	88
Standard Error of Mean	5%	--	103	0	13
Standard Deviation	13%	--	146	0	19
Count (*n*)	8	--	2	2	2
Alloway Creek Watershed Site - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	41%	143	1694	0	101
Standard Error of Mean	3%	9	509	0	33
Standard Deviation	10%	34	882	0	57
Count (*n*)	14	14	3	3	3
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	53%	--	145	0	65
Standard Error of Mean	48%	--	--	--	--
Standard Deviation	67%	--	--	--	--
Count (*n*)	2	--	1	1	1
All Quadrats					
Mean	43%	--	1307	0	92
Standard Error of Mean	5%	--	529	0	25
Standard Deviation	20%	--	1058	0	50
Count (*n*)	16	--	4	4	4

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Alloway Creek Watershed Site - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	60%	96	599	0	20
Standard Error of Mean	9%	9	142	0	20
Standard Deviation	22%	23	200	0	29
Count (*n*)	6	6	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	42%	--	713	69	87
Standard Error of Mean	8%	--	128	69	8
Standard Deviation	24%	--	181	97	11
Count (*n*)	10	--	2	2	2
All Quadrats					
Mean	48%	--	656	34	53
Standard Error of Mean	6%	--	85	34	21
Standard Deviation	24%	--	169	69	42
Count (*n*)	16	--	4	4	4
Alloway Creek Watershed Site - Transect 4					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	29%	182	879	0	0
Standard Error of Mean	2%	9	234	--	0
Standard Deviation	5%	20	330	--	0
Count (*n*)	5	5	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	26%	--	991	0	0
Standard Error of Mean	3%	--	296	0	0
Standard Deviation	9%	--	419	0	0
Count (*n*)	11	--	2	2	2
All Quadrats					
Mean	27%	--	935	0	0
Standard Error of Mean	2%	--	157	0	0
Standard Deviation	8%	--	315	0	0
Count (*n*)	16	--	4	4	4

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
The Rocks Site - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	45%	101	519	0	0
Standard Error of Mean	3%	8	85	0	0
Standard Deviation	11%	32	120	0	0
Count (*n*)	14	15	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	48%	--	1262	0	0
Standard Error of Mean	8%	--	346	0	0
Standard Deviation	11%	--	489	0	0
Count (*n*)	2	--	2	2	2
All Quadrats					
Mean	45%	--	890	0	0
Standard Error of Mean	3%	--	259	0	0
Standard Deviation	11%	--	518	0	0
Count (*n*)	16	--	4	4	4
The Rocks Site - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	44%	142	1114	0	16
Standard Error of Mean	5%	10	49	0	8
Standard Deviation	17%	35	84	0	14
Count (*n*)	12	12	3	3	3
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	34%	--	1682	0	0
Standard Error of Mean	8%	--	--	--	--
Standard Deviation	17%	--	--	--	--
Count (*n*)	4	--	1	1	1
All Quadrats					
Mean	41%	--	1256	0	12
Standard Error of Mean	4%	--	146	0	7
Standard Deviation	17%	--	293	0	14
Count (*n*)	16	--	4	4	4

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
The Rocks Site - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	47%	191	1631	0	95
Standard Error of Mean	4%	17	723	0	33
Standard Deviation	17%	79	1445	0	65
Count (*n*)	19	22	4	4	4
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	57%	--	803	0	7
Standard Error of Mean	10%	--	177	0	1
Standard Deviation	33%	--	354	0	2
Count (*n*)	11	--	4	4	4
All Quadrats					
Mean	51%	--	1217	0	51
Standard Error of Mean	4%	--	378	0	22
Standard Deviation	24%	--	1070	0	63
Count (*n*)	30	--	8	8	8
The Rocks Site - Transect 4					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	50%	116	584	129	34
Standard Error of Mean	11%	15	1	129	26
Standard Deviation	26%	40	1	183	36
Count (*n*)	6	7	2	2	2
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	28%	--	--	--	--
Standard Error of Mean	23%	--	--	--	--
Standard Deviation	32%	--	--	--	--
Count (*n*)	2	--	0	0	0
All Quadrats					
Mean	45%	--	584	129	34
Standard Error of Mean	10%	--	1	129	26
Standard Deviation	27%	--	1	183	36
Count (*n*)	8	--	2	2	2

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Cedar Swamp Site - Transect 1					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	44%	158	1619	200	394
Standard Error of Mean	3%	20	326	123	135
Standard Deviation	9%	73	652	246	270
Count (*n*)	14	14	4	4	4
Non-*Spartina alterniflora* dominated Quadrats Only (d)					
Mean	36%	--	--	--	--
Standard Error of Mean	0%	--	--	--	--
Standard Deviation	0%	--	--	--	--
Count (*n*)	2	--	0	0	0
All Quadrats					
Mean	43%	--	1619	200	394
Standard Error of Mean	2%	--	326	123	135
Standard Deviation	9%	--	652	246	270
Count (*n*)	16	--	4	4	4
Cedar Swamp Site - Transect 2					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	41%	122	577	102	185
Standard Error of Mean	2%	12	199	102	70
Standard Deviation	9%	49	345	176	121
Count (*n*)	16	16	3	3	3
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	23%	--	685	263	171
Standard Error of Mean	5%	--	365	134	86
Standard Deviation	13%	--	631	232	149
Count (*n*)	8	--	3	3	3
All Quadrats					
Mean	35%	--	631	182	178
Standard Error of Mean	3%	--	187	83	50
Standard Deviation	13%	--	459	204	122
Count (*n*)	24	--	6	6	6

TABLE 8-8
SUMMARY OF 2008 CLIP and OCULAR QUADRAT DATA BY TRANSECT
PSEG EEP DETRITAL MONITORING PROGRAM

	Peak Season				
			Biomass		
	Percent Cover	Height (a) (cm)	Live Standing gdw/m^2	Dead Standing gdw/m^2	Litter gdw/m^2
Cedar Swamp Site - Transect 3					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	51%	97	649	0	185
Standard Error of Mean	3%	13	183	0	96
Standard Deviation	12%	51	367	0	192
Count (*n*)	16	16	4	4	4
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	--	--	--	--	--
Standard Error of Mean	--	--	--	--	--
Standard Deviation	--	--	--	--	--
Count (*n*)	0	--	0	0	0
All Quadrats					
Mean	51%	--	649	0	185
Standard Error of Mean	3%	--	183	0	96
Standard Deviation	12%	--	367	0	192
Count (*n*)	16	--	4	4	4
Cedar Swamp Site - Transect 4					
Spartina alterniflora dominated Quadrats Only (b)					
Mean	35%	91	676	0	47
Standard Error of Mean	3%	5	--	--	--
Standard Deviation	7%	13	--	--	--
Count (*n*)	6	6	1	1	1
Non-*Spartina alterniflora* dominated Quadrats Only (c)					
Mean	20%	--	583	207	22
Standard Error of Mean	10%	--	--	--	--
Standard Deviation	14%	--	--	--	--
Count (*n*)	2	--	1	1	1
All Quadrats					
Mean	31%	--	630	103	34
Standard Error of Mean	4%	--	46	103	12
Standard Deviation	10%	--	66	146	17
Count (*n*)	8	--	2	2	2

(a) Height calculations include values for *S. alterniflora* and *S. cynosuriodes* from Spartina-dominated quadrats only.

(b) Also includes *Spartina cynosuroides* dominated quadrats, when present.

(c) Includes quadrats dominated by *Spartina patens.*

Table 8-9
2008 Species Occurrence At Reference Marshes
PSEG Detrital Production Monitoring

Species [a]	**Reference Marsh**	
	Mad Horse Creek	**Moores Beach West**
Amaranthus cannabinus	X*	
Distichlis spicata	X*	
Phragmites australis	X*	
Scirpus robustus	X*	
Spartina alterniflora	X*	X*
Spartina cynosuroides	X*	X
Spartina patens	X*	

(a) Species listed were present within quadrats along sampling transects.

* Present as a dominant (>20 percent relative cover) in some quadrats.

TABLE 8-10
SUMMARY OF 2007 PLOT DATA
PSEG EEP VEGETATION MONITORING

	Percent Cover	Live Standing Biomass	
		gdw/m2	lb/acre
Mad Horse Creek Reference Marsh			
Plot 1 (MHP1)			
Mean	61%	745	6,643
Standard Error of Mean	3%	79	704
Standard Deviation	10%	237	2,112
Minimum	45%	546	4,872
Maximum	75%	1,289	11,500
Count (n)	9	9	
Plot 2 (MHP2)			
Mean	52%	749	6,680
Standard Error of Mean	3%	91	811
Standard Deviation	8%	273	2,434
Minimum	45%	469	4,187
Maximum	65%	1,212	10,814
Count (n)	9	9	
Plot 3 (MHP3)			
Mean	49%	885	7,892
Standard Error of Mean	5%	80	711
Standard Deviation	16%	239	2,132
Minimum	15%	508	4,532
Maximum	65%	1,164	10,386
Count (n)	9	9	
All Plots			
Mean	54%	793	7,072
Standard Error of Mean	2%	48	428
Standard Deviation	13%	249	2,224
Minimum	15%	469	4,187
Maximum	75%	1,289	11,500
Count (n)	27	27	

TABLE 8-10
SUMMARY OF 2007 PLOT DATA
PSEG EEP VEGETATION MONITORING

	Percent Cover	Live Standing Biomass	
		gdw/m2	lb/acre
Moores Beach West Reference Marsh			
Plot 1 (MBP1)			
Mean	27%	649	5,788
Standard Error of Mean	4%	75	666
Standard Deviation	13%	224	1,997
Minimum	15%	284	2,535
Maximum	55%	1,056	9,425
Count (n)	9	9	
Plot 2 (MBP2)			
Mean	32%	728	6,491
Standard Error of Mean	4%	99	883
Standard Deviation	13%	297	2,649
Minimum	1%	225	2,003
Maximum	45%	1,242	11,084
Count (n)	9	9	
Plot 3 (MBP3)			
Mean	28%	839	7,482
Standard Error of Mean	8%	158	1,407
Standard Deviation	23%	473	4,221
Minimum	5%	251	2,241
Maximum	65%	1,619	14,440
Count (n)	9	9	
All Plots			
Mean	29%	738	6,587
Standard Error of Mean	3%	66	589
Standard Deviation	17%	343	3,061
Minimum	1%	225	2,003
Maximum	65%	1,619	14,440
Count (n)	27	27	

TABLE 8-10
SUMMARY OF 2007 PLOT DATA
PSEG EEP VEGETATION MONITORING

	Percent	Live Standing Biomass	
	Cover	gdw/m2	lb/acre
Commercial Township Site			
Plot 1 (CTP1)			
Mean	18%	509	4,543
Standard Error of Mean	9%	256	2,283
Standard Deviation	28%	768	6,850
Minimum	0%	0	0
Maximum	55%	1,656	14,771
Count (n)	9	9	
Plot 2 (CTP2)			
Mean	46%	1,301	11,608
Standard Error of Mean	8%	267	2,382
Standard Deviation	24%	801	7,147
Minimum	0%	0	0
Maximum	85%	2,912	25,981
Count (n)	9	9	
Plot 3 (CTP3)			
Mean	45%	794	7,082
Standard Error of Mean	11%	178	1,589
Standard Deviation	33%	534	4,766
Minimum	0%	0	0
Maximum	85%	1,531	13,664
Count (n)	9	9	
Plot 4 (CTP4)			
Mean	46%	878	7,836
Standard Error of Mean	7%	162	1,448
Standard Deviation	20%	487	4,344
Minimum	0%	0	0
Maximum	75%	1,453	12,966
Count (n)	9	9	
All Plots			
Mean	39%	871	7,767
Standard Error of Mean	5%	116	1,034
Standard Deviation	28%	695	6,204
Minimum	0%	0	0
Maximum	85%	2,912	25,981
Count (n)	36	36	

TABLE 8-10
SUMMARY OF 2007 PLOT DATA
PSEG EEP VEGETATION MONITORING

	Percent Cover	Live Standing Biomass	
		gdw/m2	lb/acre
Alloway Creek Watershed Site			
Plot 1 (ACWP1)			
Mean	32%	733	6,537
Standard Error of Mean	4%	200	1,782
Standard Deviation	12%	599	5,345
Minimum	15%	0	0
Maximum	50%	1,773	15,823
Count (n)	9	9	
Plot 2 (ACWP2)			
Mean	48%	773	6,892
Standard Error of Mean	6%	110	986
Standard Deviation	18%	331	2,957
Minimum	16%	394	3,518
Maximum	75%	1,537	13,717
Count (n)	9	9	
Plot 3 (ACWP3)			
Mean	59%	849	7,579
Standard Error of Mean	10%	179	1,597
Standard Deviation	31%	537	4,791
Minimum	15%	0	0
Maximum	100%	1,642	14,647
Count (n)	9	9	
All Plots			
Mean	46%	785	7,003
Standard Error of Mean	5%	93	833
Standard Deviation	24%	485	4,329
Minimum	15%	0	0
Maximum	100%	1,773	15,823
Count (n)	27	27	

TABLE 8-10
SUMMARY OF 2007 PLOT DATA
PSEG EEP VEGETATION MONITORING

	Percent Cover	Live Standing Biomass	
		gdw/m2	lb/acre
The Rocks Site			
Plot 1 (TRP1)			
Mean	65%	1,773	15,823
Standard Error of Mean	8%	216	1,925
Standard Deviation	24%	647	5,774
Minimum	36%	681	6,074
Maximum	100%	2,737	24,421
Count (n)	9	9	
Cedar Swamp Site			
Plot 1 (CSP1)			
Mean	58%	738	6,587
Standard Error of Mean	6%	81	726
Standard Deviation	18%	244	2,178
Minimum	36%	410	3,660
Maximum	85%	1,209	10,786
Count (n)	9	9	

Chapter 8 Figures

PSEG

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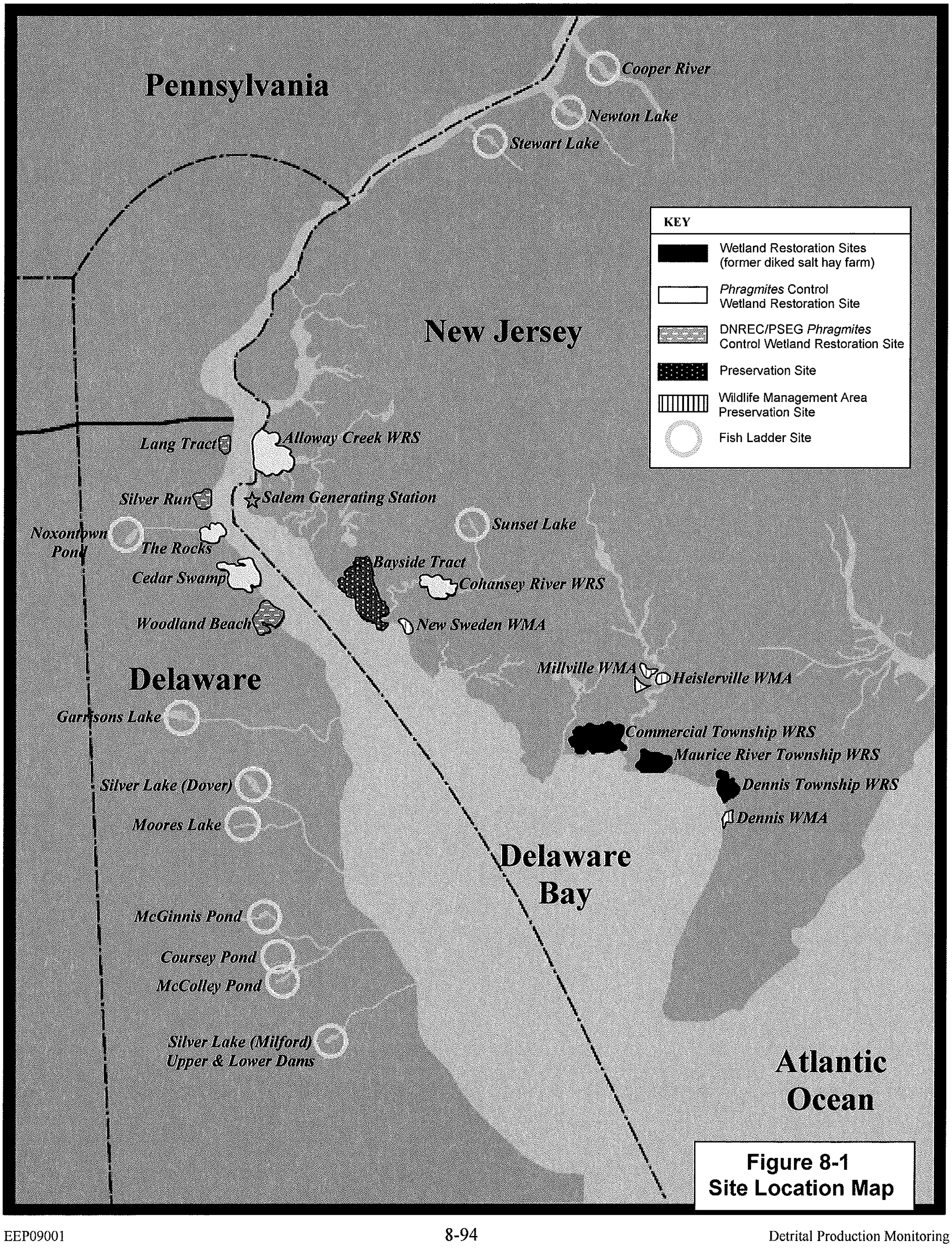
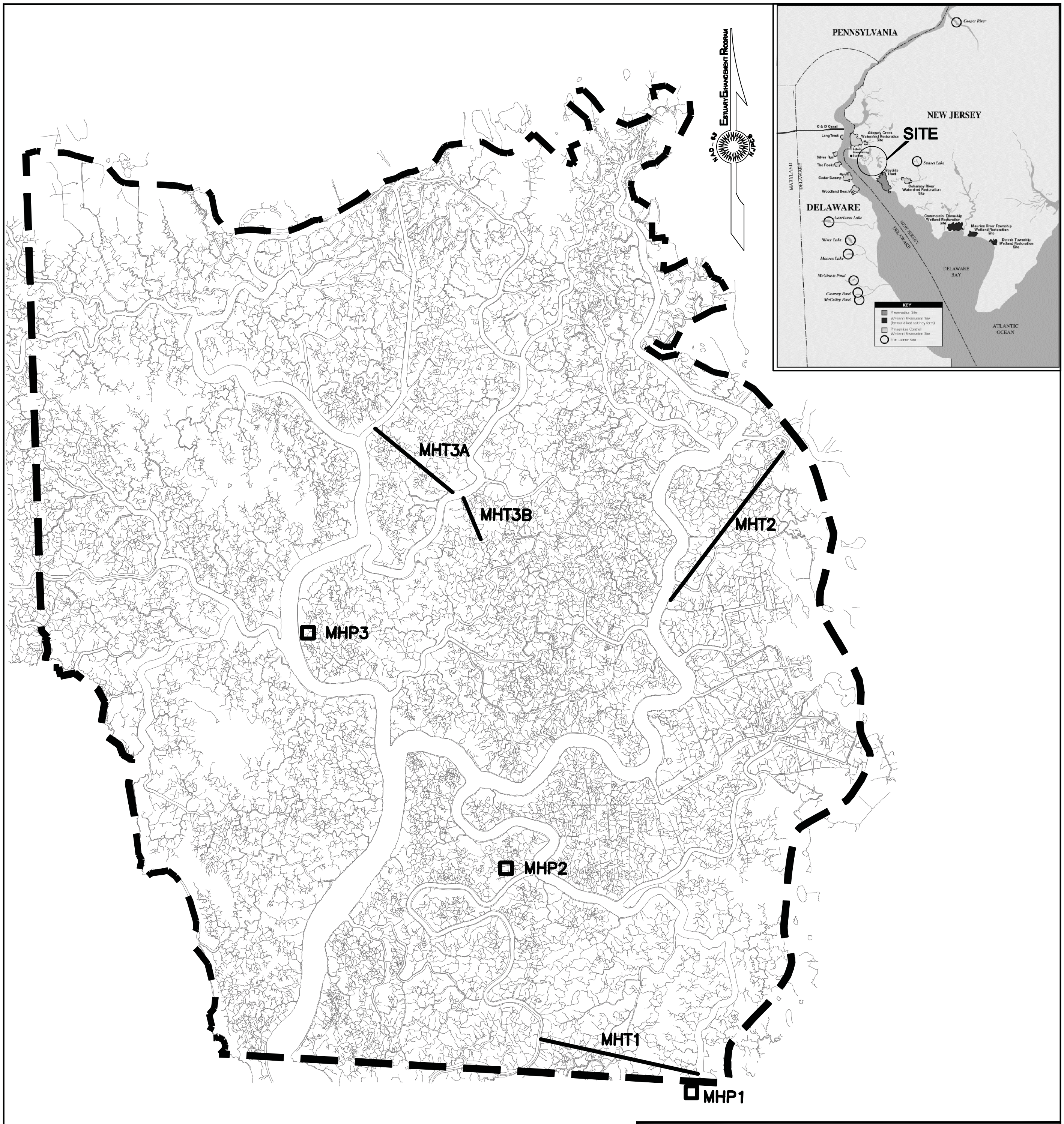


Figure 8-1
Site Location Map



NOTE:

MHT1	MAD HORSE CREEK VEGETATION TRANSECT 1
MHT2	MAD HORSE CREEK VEGETATION TRANSECT 2
MHT3	MAD HORSE CREEK VEGETATION TRANSECT 3
MHP1	MAD HORSE CREEK VEGETATION PLOT 1
MHP2	MAD HORSE CREEK VEGETATION PLOT 2
MHP3	MAD HORSE CREEK VEGETATION PLOT 3

LEGEND

▬ ▬	SITE BOUNDARY
—	EXISTING SURFACE WATER FEATURE
━	TRANSECT
□	60m x 60m PLOT

FEET 0 1200 2400 3600

METERS 0 600 1200

URS

PSEG

ESTUARY ENHANCEMENT PROGRAM

Figure 8-2

MADHORSE CREEK REFERENCE MARSH

2008 VEGETATION MONITORING

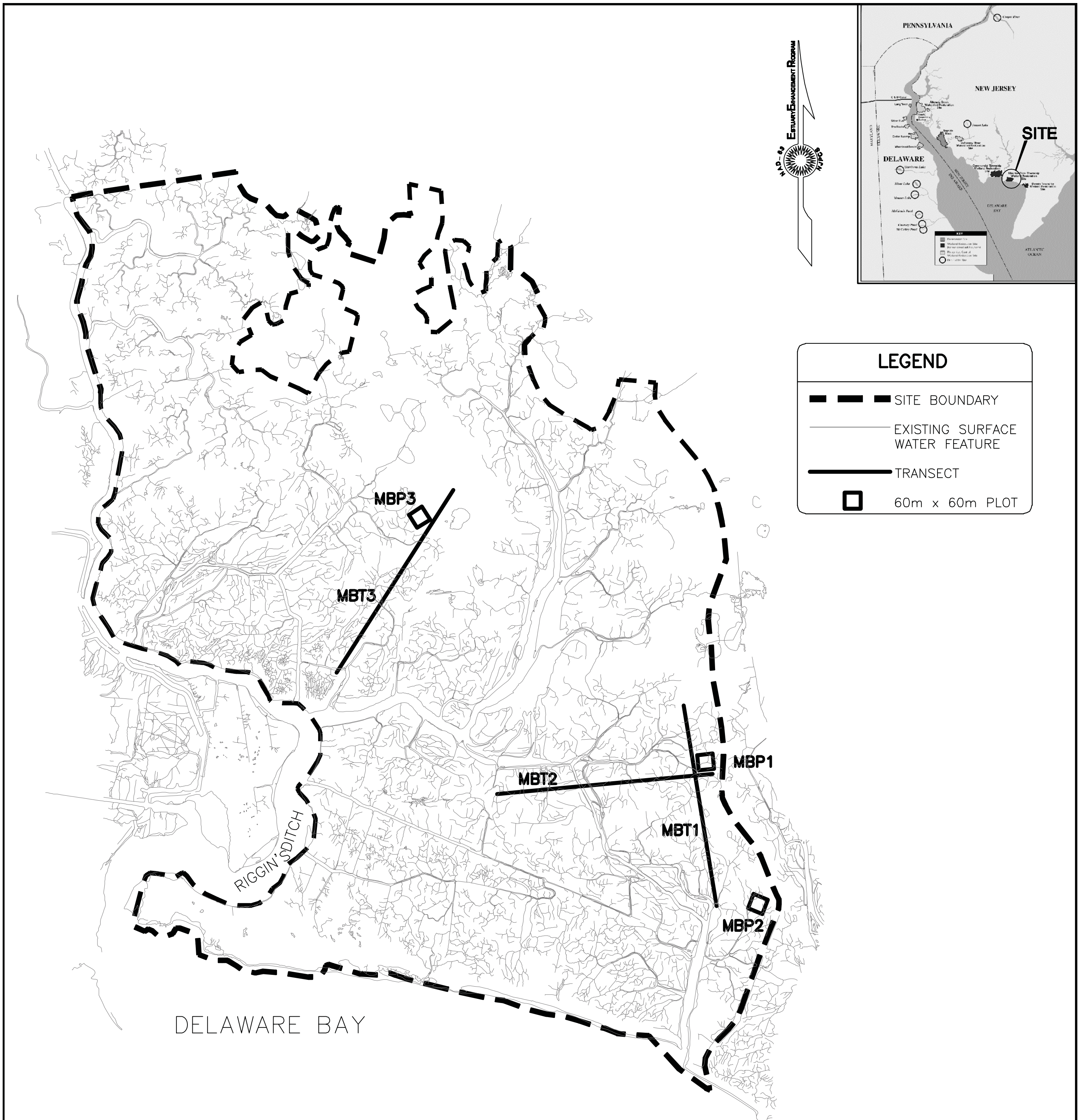
TRANSECTS AND PLOTS

LOWER ALLOWAYS CREEK TOWNSHIP

SALEM COUNTY, NEW JERSEY

CADD JL DATE APR 20, 2009 SCALE AS SHOWN

FILE 08_MH_TRA CHECKED RLH EXAMINED RLH



NOTE:

MBT1 MOORES BEACH VEGETATION TRANSECT 1
MBT2 MOORES BEACH VEGETATION TRANSECT 2
MBT3 MOORES BEACH VEGETATION TRANSECT 3
MBP1 MOORES BEACH VEGETATION PLOT 1
MBP2 MOORES BEACH VEGETATION PLOT 2
MBP3 MOORES BEACH VEGETATION PLOT 3

FEET 0 900 1800 2700
METERS 0 400 800

URS

PSEG
ESTUARY ENHANCEMENT PROGRAM

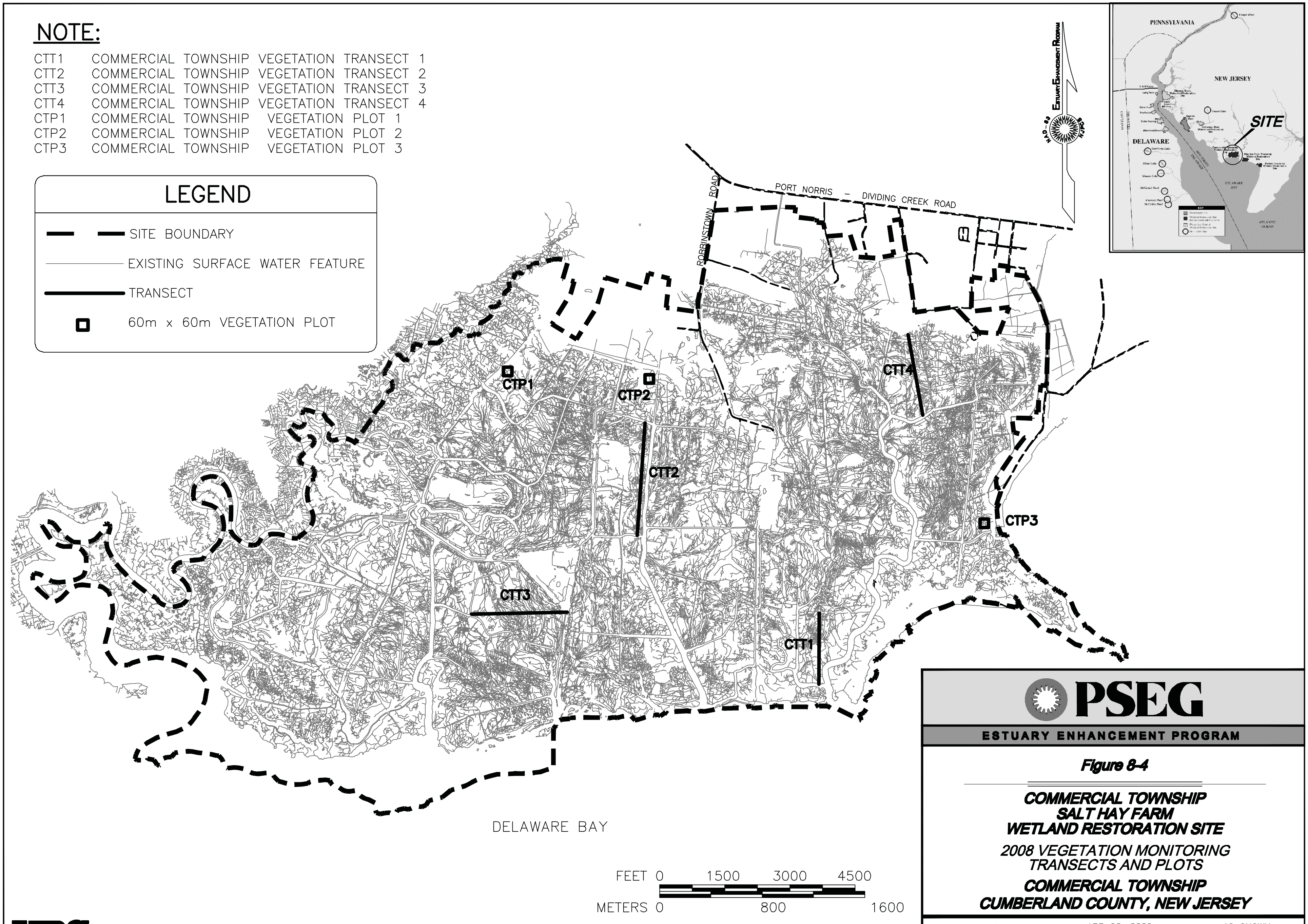
Figure 8-3

MOORES BEACH REFERENCE MARSH
2008 VEGETATION MONITORING
TRANSECTS AND PLOTS
MAURICE RIVER TOWNSHIP
CUMBERLAND COUNTY, NEW JERSEY

CADD JL DATE APR 20, 2009 SCALE AS SHOWN
FILE 08_MB_TRA CHECKED RLH EXAMINED RLH

NOTE:

CTT1	COMMERCIAL TOWNSHIP VEGETATION TRANSECT 1
CTT2	COMMERCIAL TOWNSHIP VEGETATION TRANSECT 2
CTT3	COMMERCIAL TOWNSHIP VEGETATION TRANSECT 3
CTT4	COMMERCIAL TOWNSHIP VEGETATION TRANSECT 4
CTP1	COMMERCIAL TOWNSHIP VEGETATION PLOT 1
CTP2	COMMERCIAL TOWNSHIP VEGETATION PLOT 2
CTP3	COMMERCIAL TOWNSHIP VEGETATION PLOT 3



URS

PSEG

ESTUARY ENHANCEMENT PROGRAM

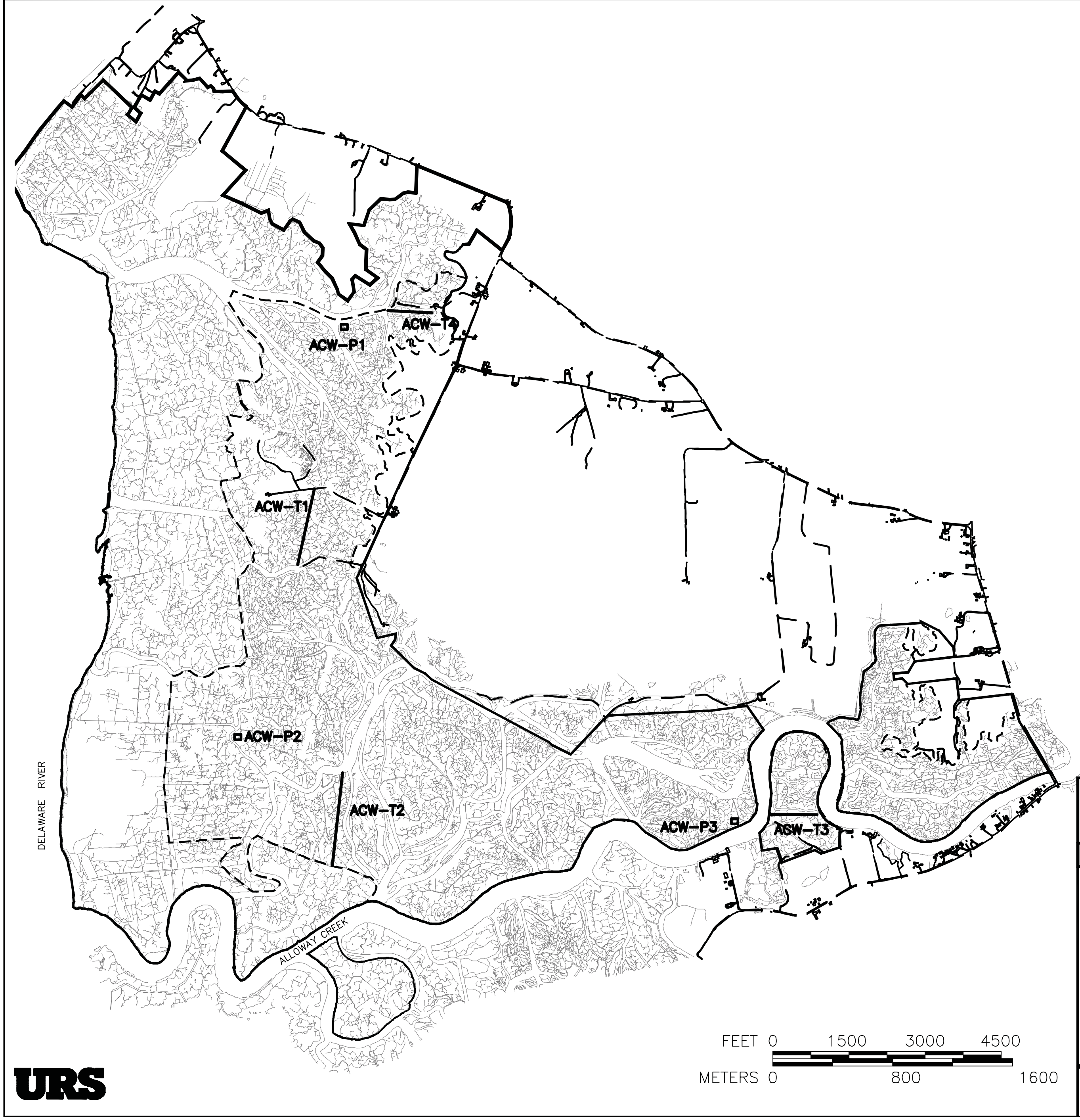
Figure 8-4

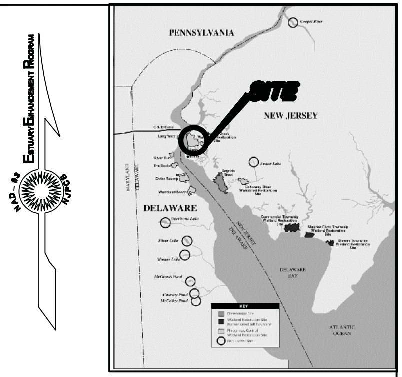
COMMERCIAL TOWNSHIP
SALT HAY FARM
WETLAND RESTORATION SITE

2008 VEGETATION MONITORING
TRANSECTS AND PLOTS

COMMERCIAL TOWNSHIP
CUMBERLAND COUNTY, NEW JERSEY

CADD	JL	DATE	APR 20, 2009	SCALE	AS SHOWN
FILE	08_CT_TRA	CHECKED	RLH	EXAMINED	RLH





LEGEND

▬	SITE BOUNDARY
- - -	WETLAND RESTORATION AREA BOUNDARY
─	EXISTING SURFACE WATER FEATURE
=======	EXISTING ROADS
─	TRANSECT
☐	60 x 60m PLOT

NOTE:

ACWT1	ALLOWAY CREEK WATERSHED TRANSECT 1
ACWT2	ALLOWAY CREEK WATERSHED TRANSECT 2
ACWT3	ALLOWAY CREEK WATERSHED TRANSECT 3
ACWT4	ALLOWAY CREEK WATERSHED TRANSECT 4
ACWP1	ALLOWAY CREEK WATERSHED VEGETATION PLOT 1
ACWP2	ALLOWAY CREEK WATERSHED VEGETATION PLOT 2
ACWP3	ALLOWAY CREEK WATERSHED VEGETATION PLOT 3

URS

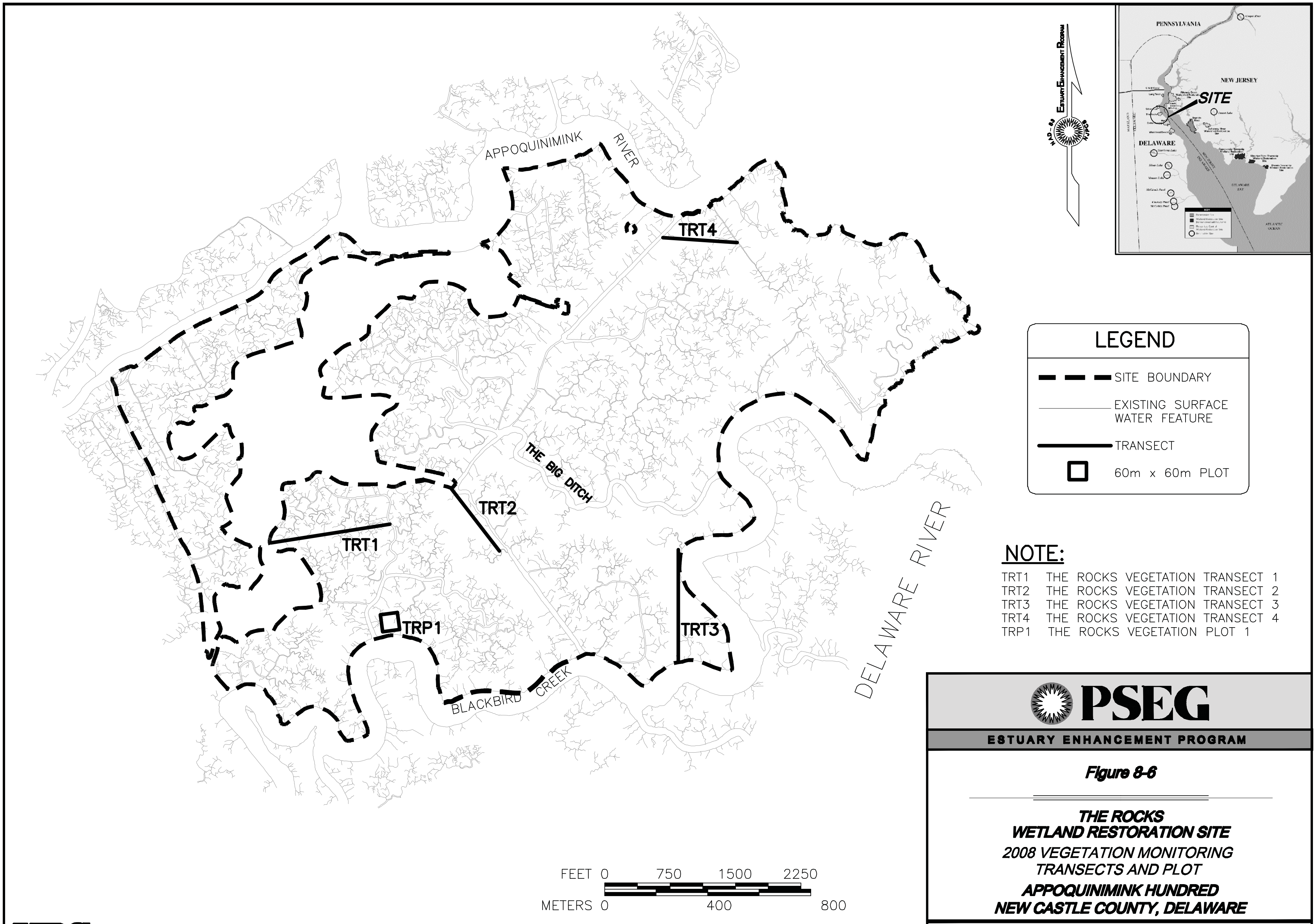
PSEG

ESTUARY ENHANCEMENT PROGRAM

Figure 8-5

ALLOW CREEK SITE
WATERSHED WETLAND RESTORATION SITE
2008 VEGETATION MONITORING
TRANSECTS AND PLOTS
ELSINBORO TOWNSHIP
SALEM COUNTY, NEW JERSEY

CADD JL DATE APR 20, 2009 SCALE AS SHOWN
FILE 08 ACW TRA CHECKED RLH EXAMINED RLH



LEGEND

▬ ▬ ▬	SITE BOUNDARY
─	EXISTING SURFACE WATER FEATURE
━	TRANSECT
☐	60m x 60m PLOT

NOTE:

TRT1	THE ROCKS VEGETATION TRANSECT 1
TRT2	THE ROCKS VEGETATION TRANSECT 2
TRT3	THE ROCKS VEGETATION TRANSECT 3
TRT4	THE ROCKS VEGETATION TRANSECT 4
TRP1	THE ROCKS VEGETATION PLOT 1

PSEG

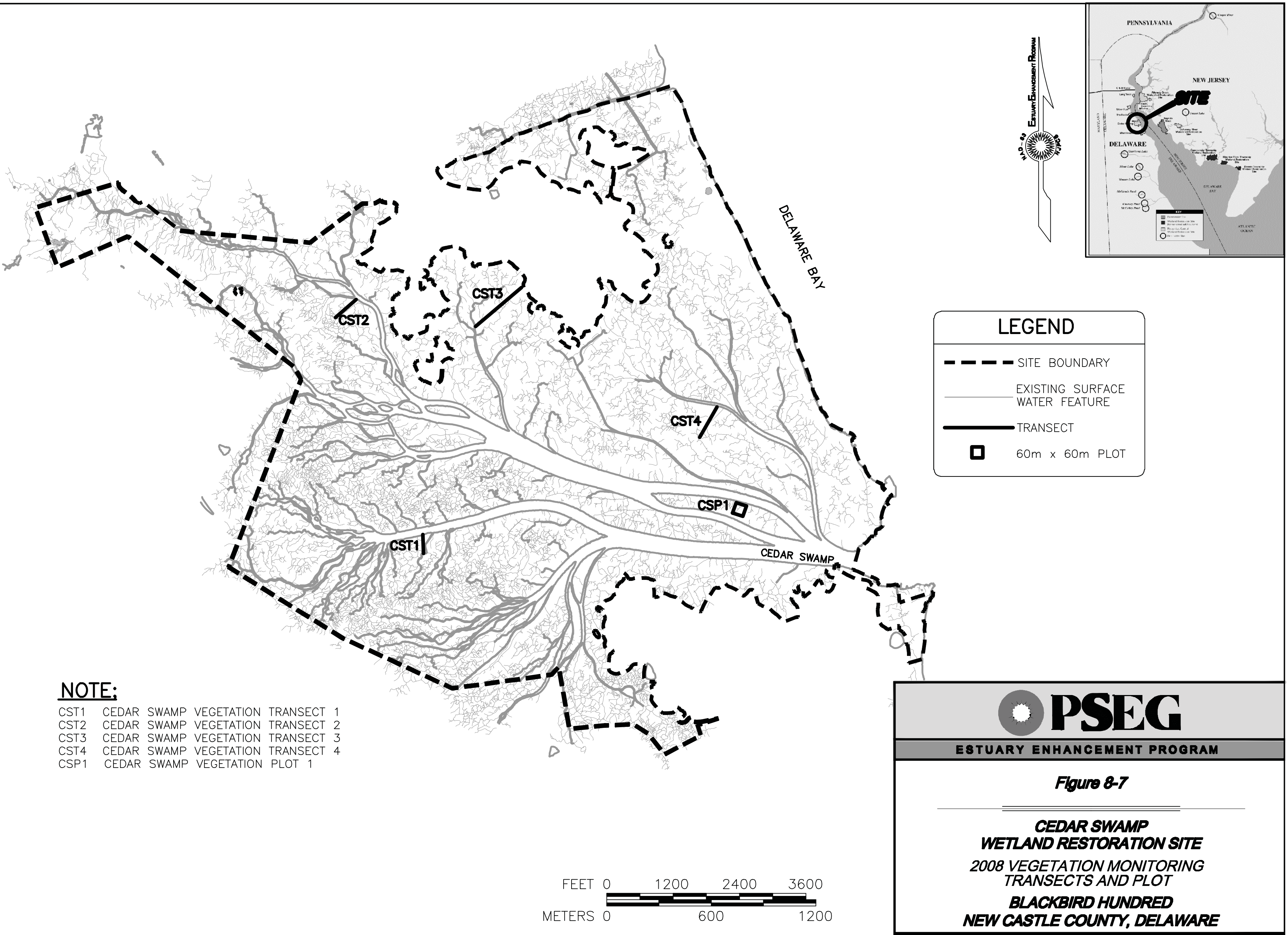
ESTUARY ENHANCEMENT PROGRAM

Figure 8-6

THE ROCKS
WETLAND RESTORATION SITE
2008 VEGETATION MONITORING
TRANSECTS AND PLOT
APPOQUINIMINK HUNDRED
NEW CASTLE COUNTY, DELAWARE

CADD JL DATE APR 20, 2009 SCALE AS SHOWN
FILE 08_TR_TRA CHECKED RLH EXAMINED RLH

URS



NOTE;

CST1	CEDAR SWAMP VEGETATION TRANSECT 1
CST2	CEDAR SWAMP VEGETATION TRANSECT 2
CST3	CEDAR SWAMP VEGETATION TRANSECT 3
CST4	CEDAR SWAMP VEGETATION TRANSECT 4
CSP1	CEDAR SWAMP VEGETATION PLOT 1

URS

PSEG

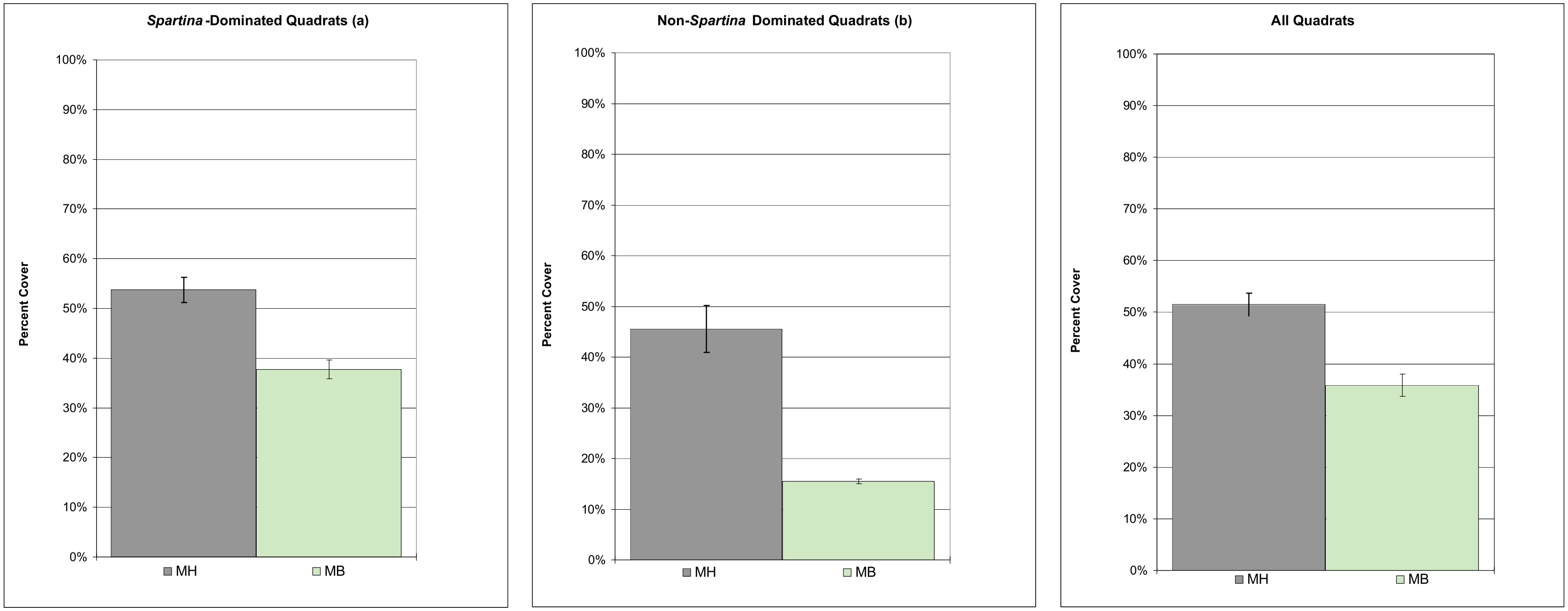
ESTUARY ENHANCEMENT PROGRAM

Figure 8-7

CEDAR SWAMP
WETLAND RESTORATION SITE
2008 VEGETATION MONITORING
TRANSECTS AND PLOT
BLACKBIRD HUNDRED
NEW CASTLE COUNTY, DELAWARE

CADD JL DATE APR 20, 2009 SCALE AS SHOWN
FILE 08_CS-TRA CHECKED RLH EXAMINED RLH

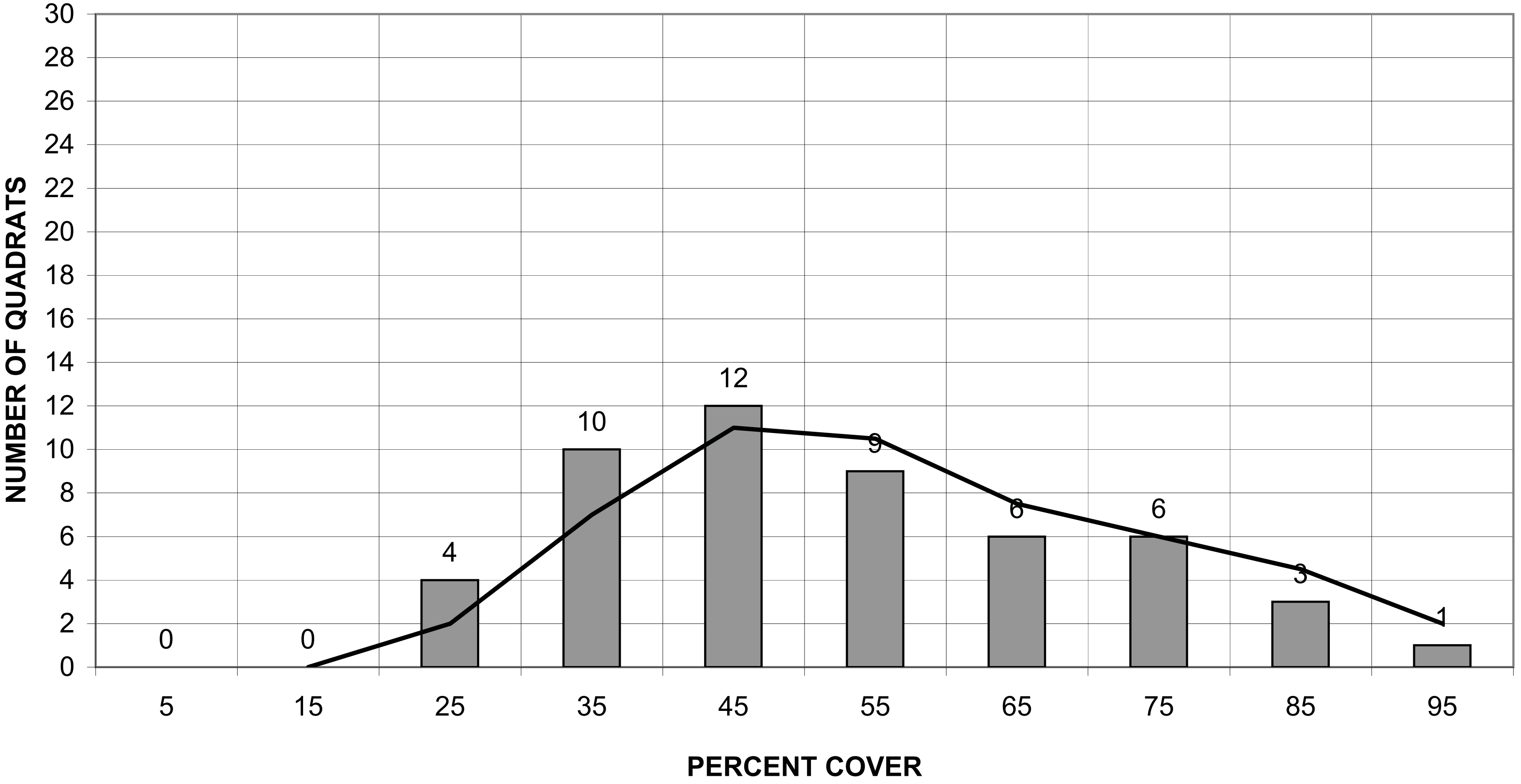
FIGURE 8-8
MEAN PERCENT COVER
2008 REFERENCE MARSH TRANSECT DATA



(a) Also includes *Spartina cynosuroides* dominated quadrats, when present.
(b) Includes quadrats dominated by *Spartina patens* , if present.
Error bar represents +/- one Standard Error of the Mean.

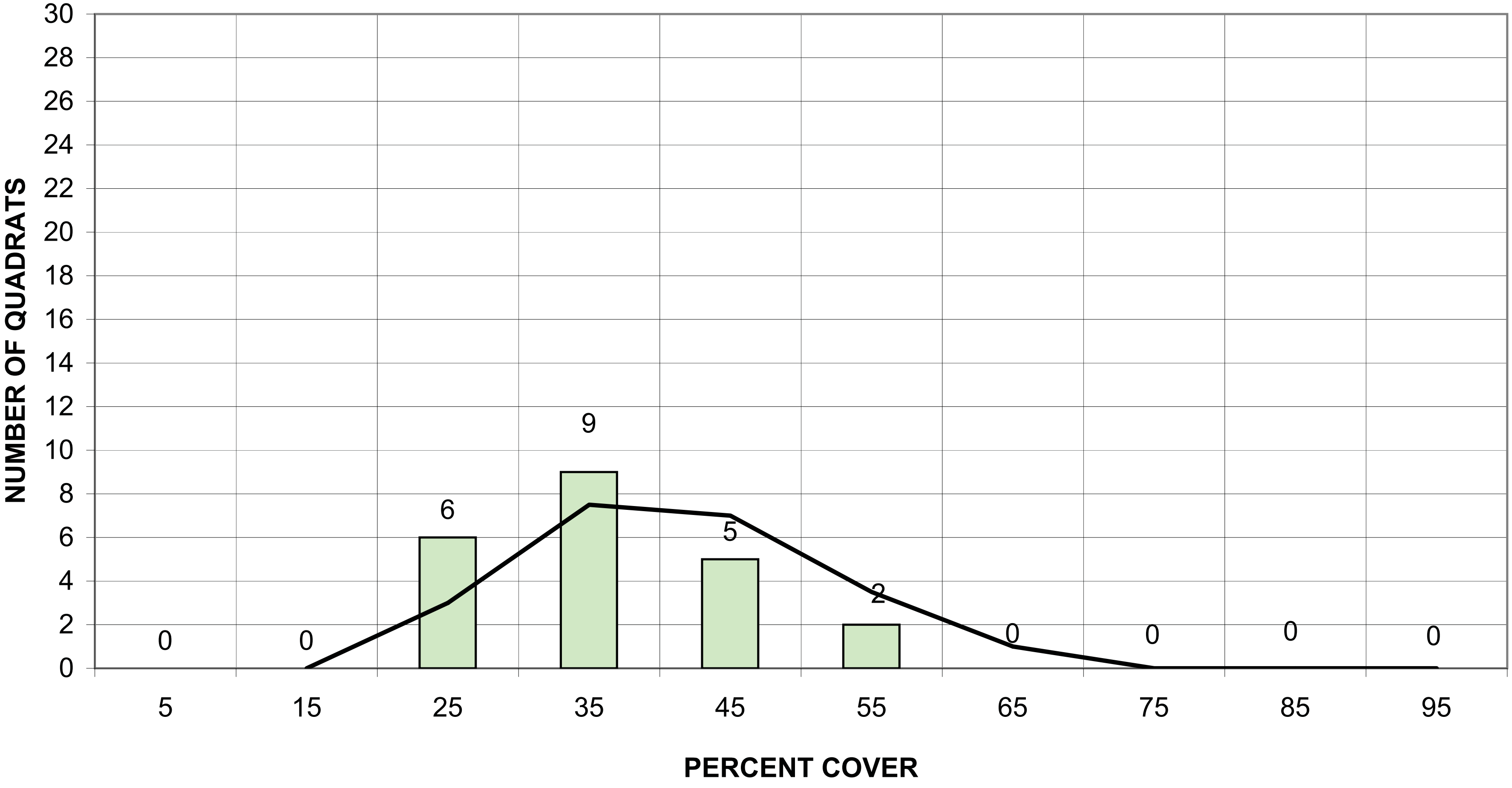
MH = Mad Horse Creek Reference Marsh
MB = Moores Beach West Reference Marsh

FIGURE 8-9
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
MAD HORSE CREEK REFERENCE MARSH TRANSECTS



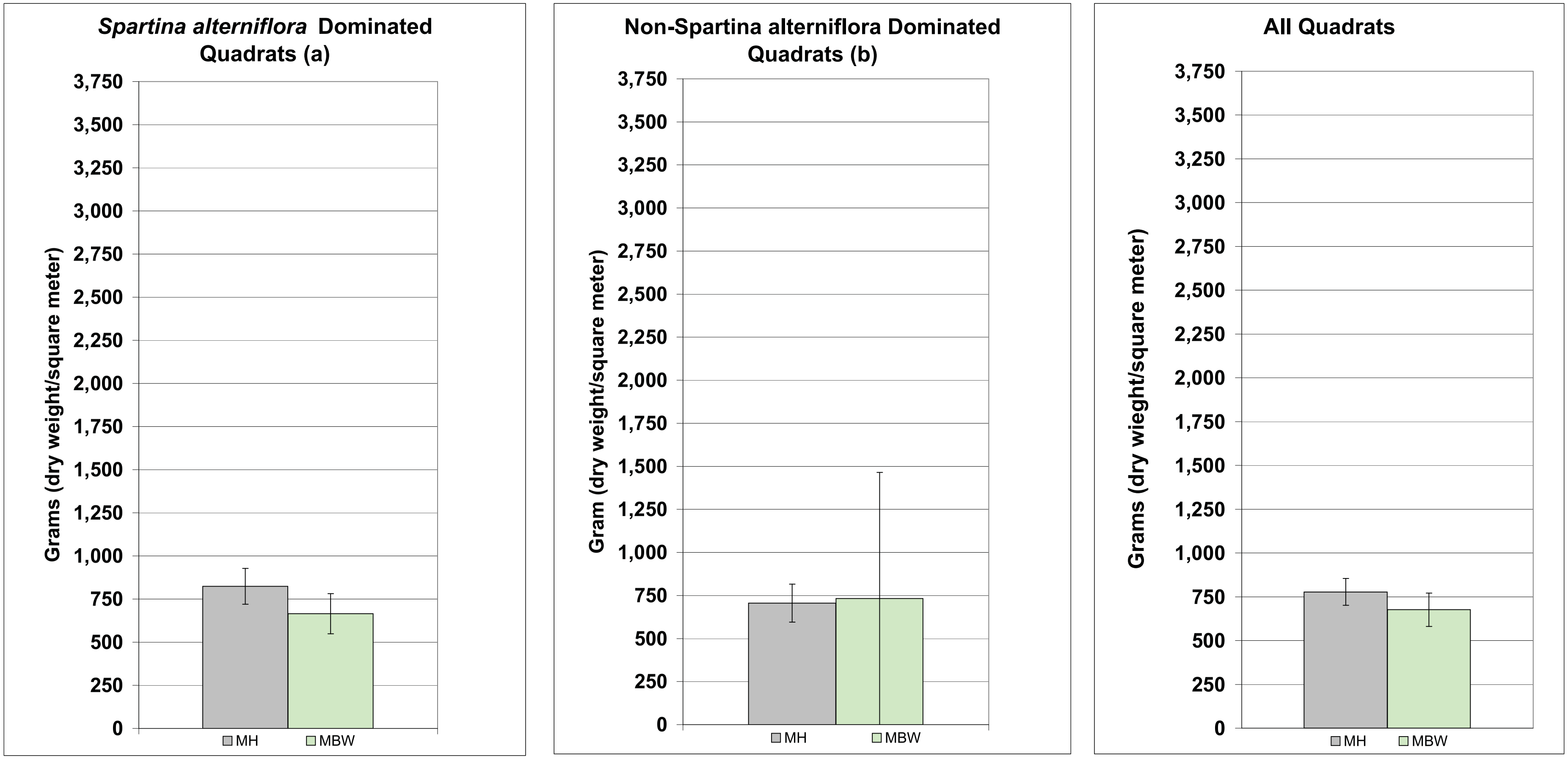
(a) Includes *S. cynosuroides* dominated quadrats, when present.

FIGURE 8-10
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
MOORES BEACH WEST REFERENCE MARSH TRANSECTS



(a) Includes *S. cvnosuroides* dominated

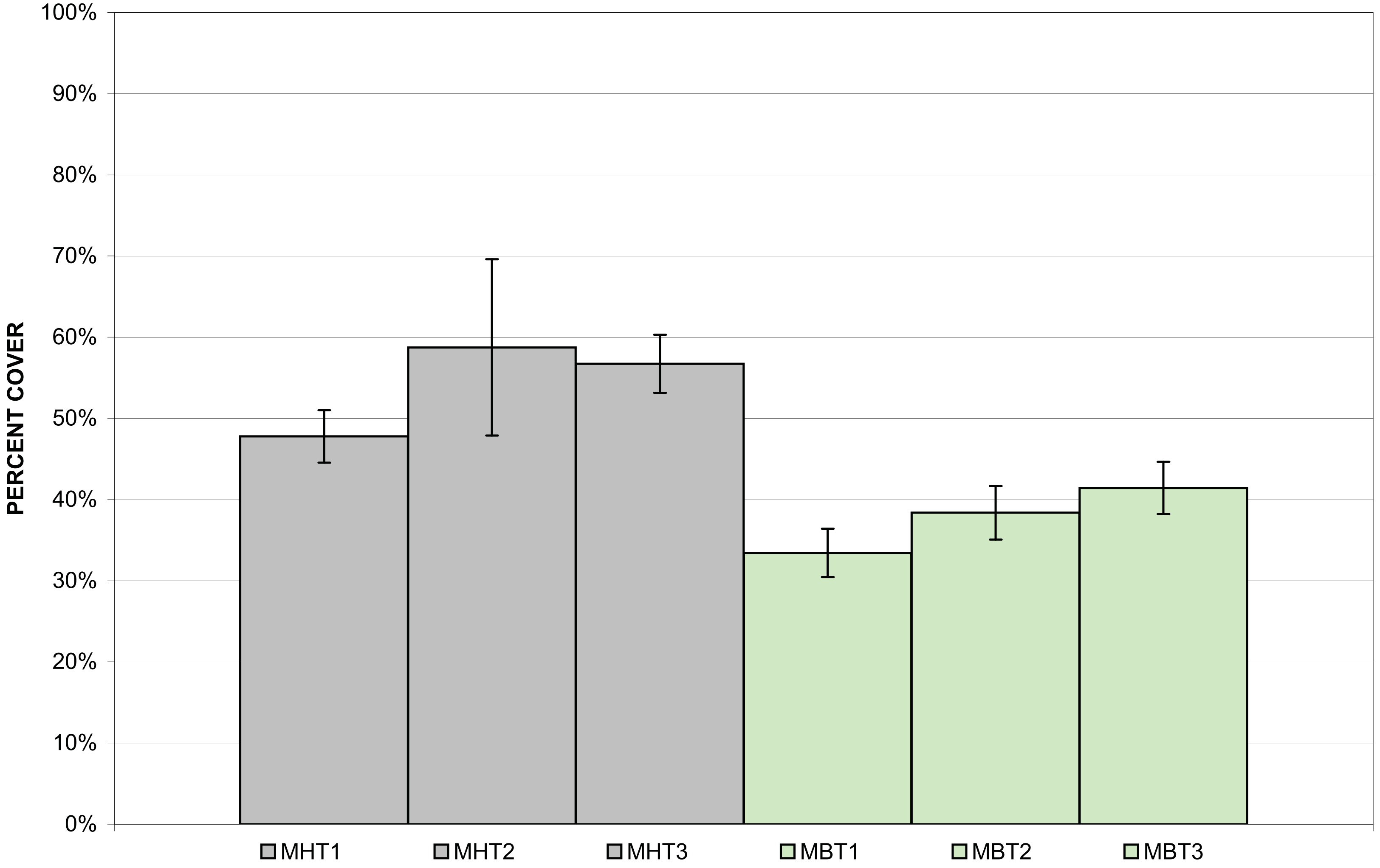
Figure 8-11
Mean Live Standing Crop
2008 Reference Marsh Transect Data



(a) Also includes *Spartina cynosuroides* dominated quadrats, when present.
(b) Includes quadrats dominated by *Spartina patens*, if present.
Error bar represents +/- one Standard Error of the Mean.

MH = Mad Horse Creek Reference Marsh
MBW = Moores Beach West Reference Marsh

FIGURE 8-12
2008 MEAN PERCENT COVER by TRANSECT
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
REFERENCE MARSHES

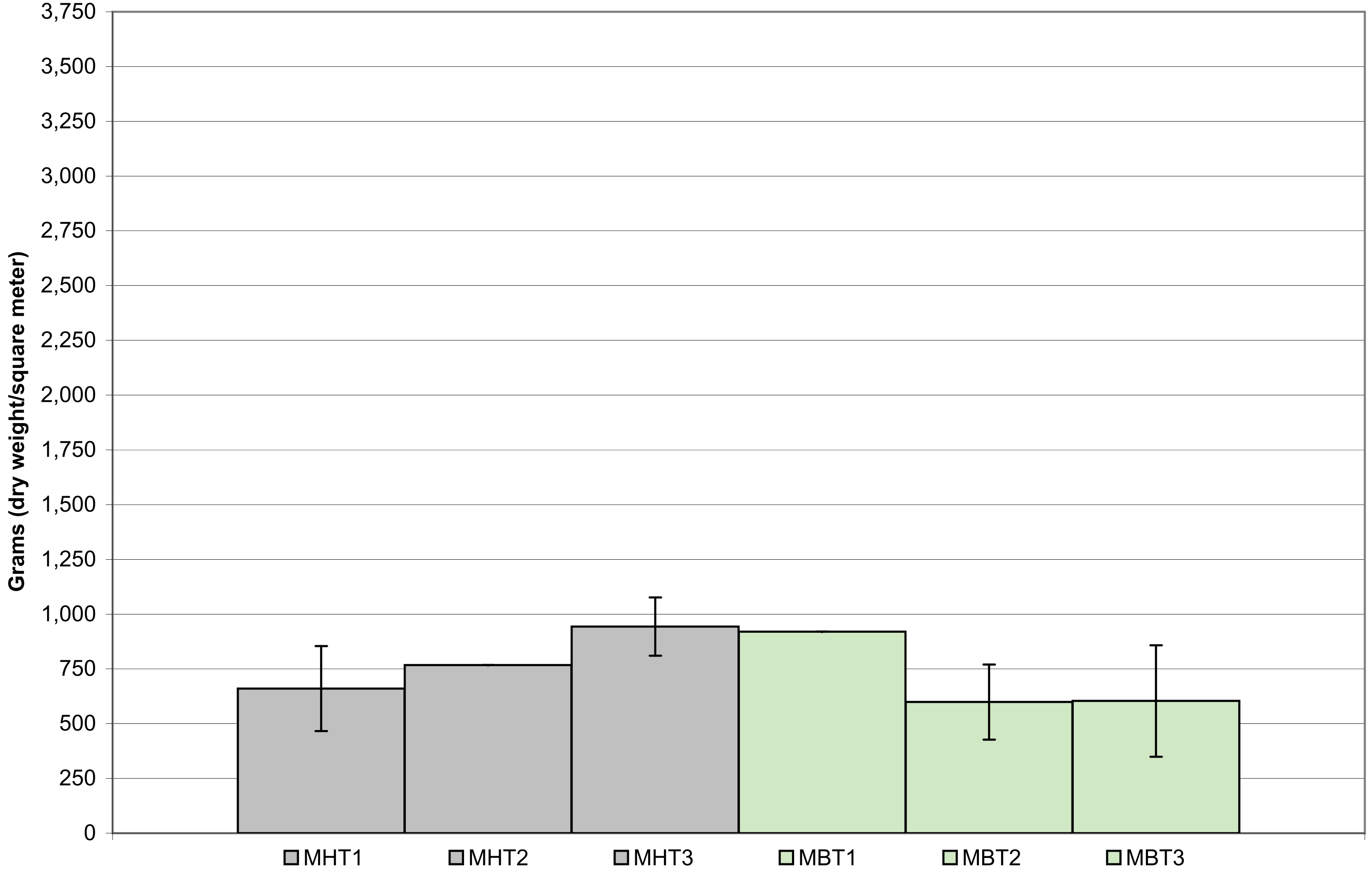


(a) Includes *S. cynosuroides* dominated quadrats.
Error bar represents +/- one Standard Error of the Mean.

MH = Mad Horse
MB = Moores Beach West

T1 = Transect 1

FIGURE 8-13
2008 MEAN LIVE STANDING CROP by TRANSECT
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
REFERENCE MARSHES

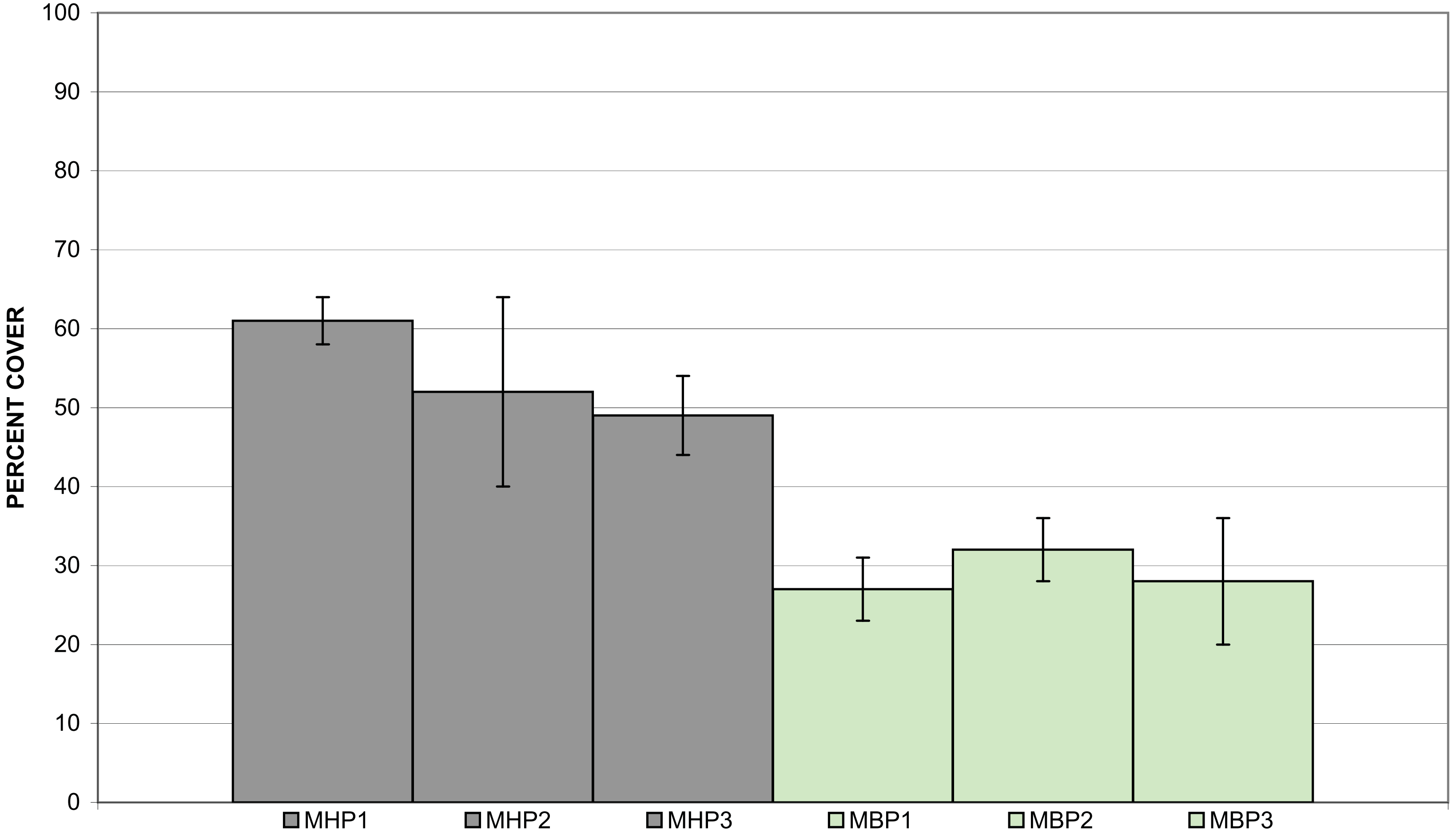


(a) Includes *S. cynosuroides* dominated quadrats.
Error bar represents +/- one Standard Error of the Mean.

MH = Mad Horse
MB = Moores Beach West

T1 = Transect 1

FIGURE 8-14
2008 MEAN PERCENT COVER 60x60 METER PLOTS
REFERENCE MARSHES

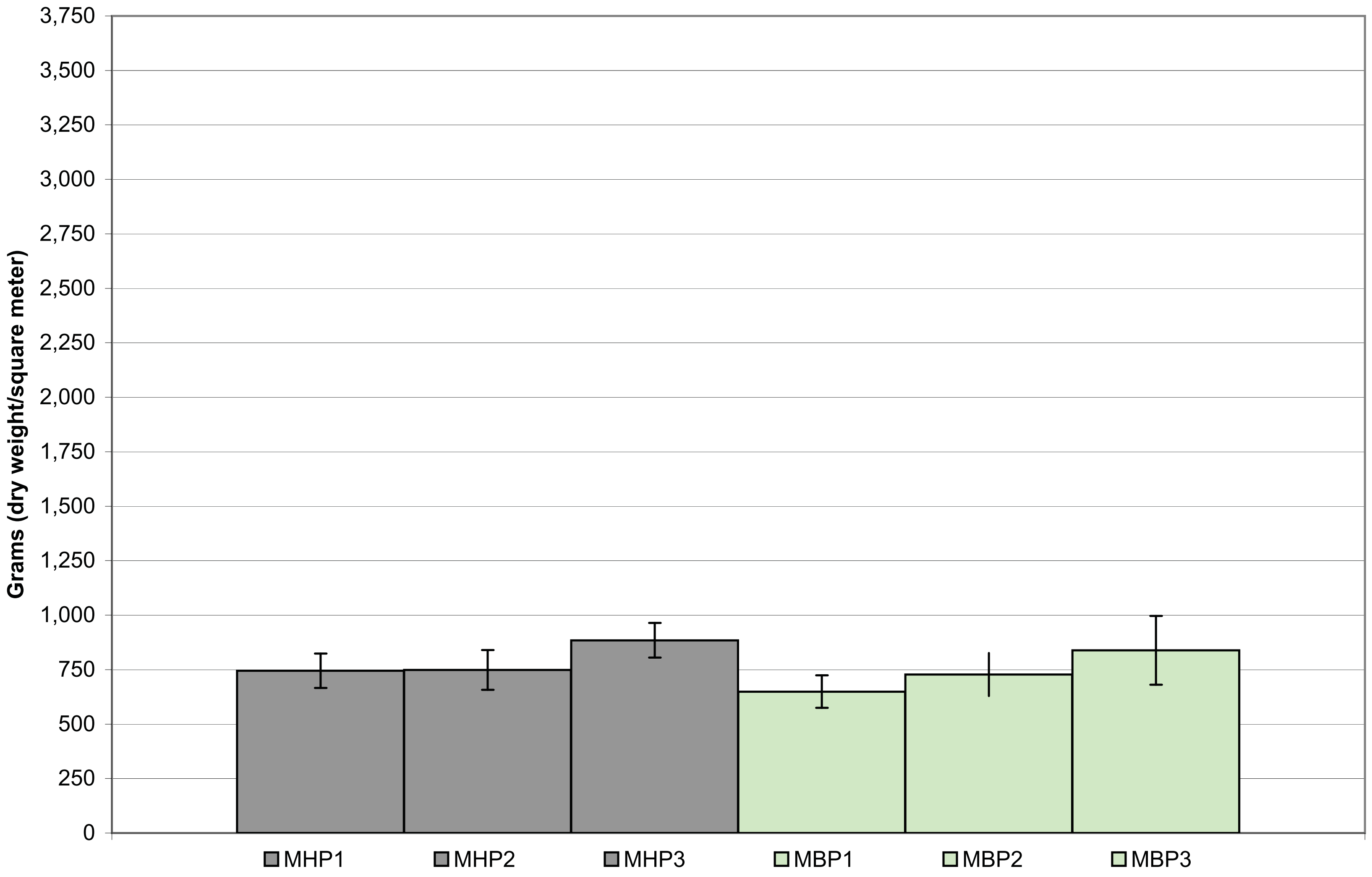


MH = Mad Horse
MB = Moores Beach West

P1 = Plot 1

Error bar represents +/- one Standard Error of the Mean.

FIGURE 8-15
2008 MEAN LIVE STANDING CROP 60x60 METER PLOTS
REFERENCE MARSHES

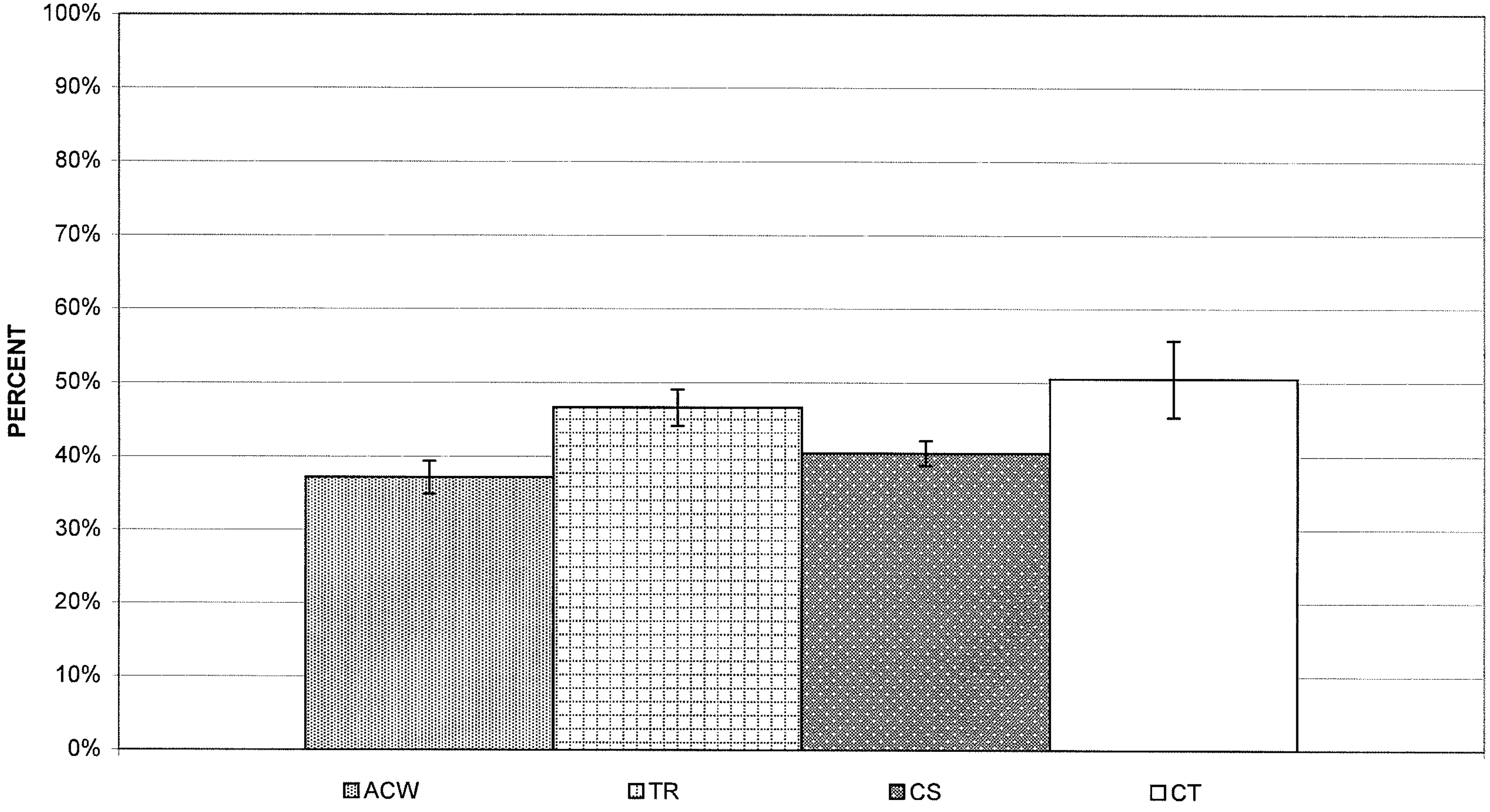


Error bar represents +/- one Standard Error of the Mean.

MH = Mad Horse
MB = Moores Beach West

P1 = Plot 1

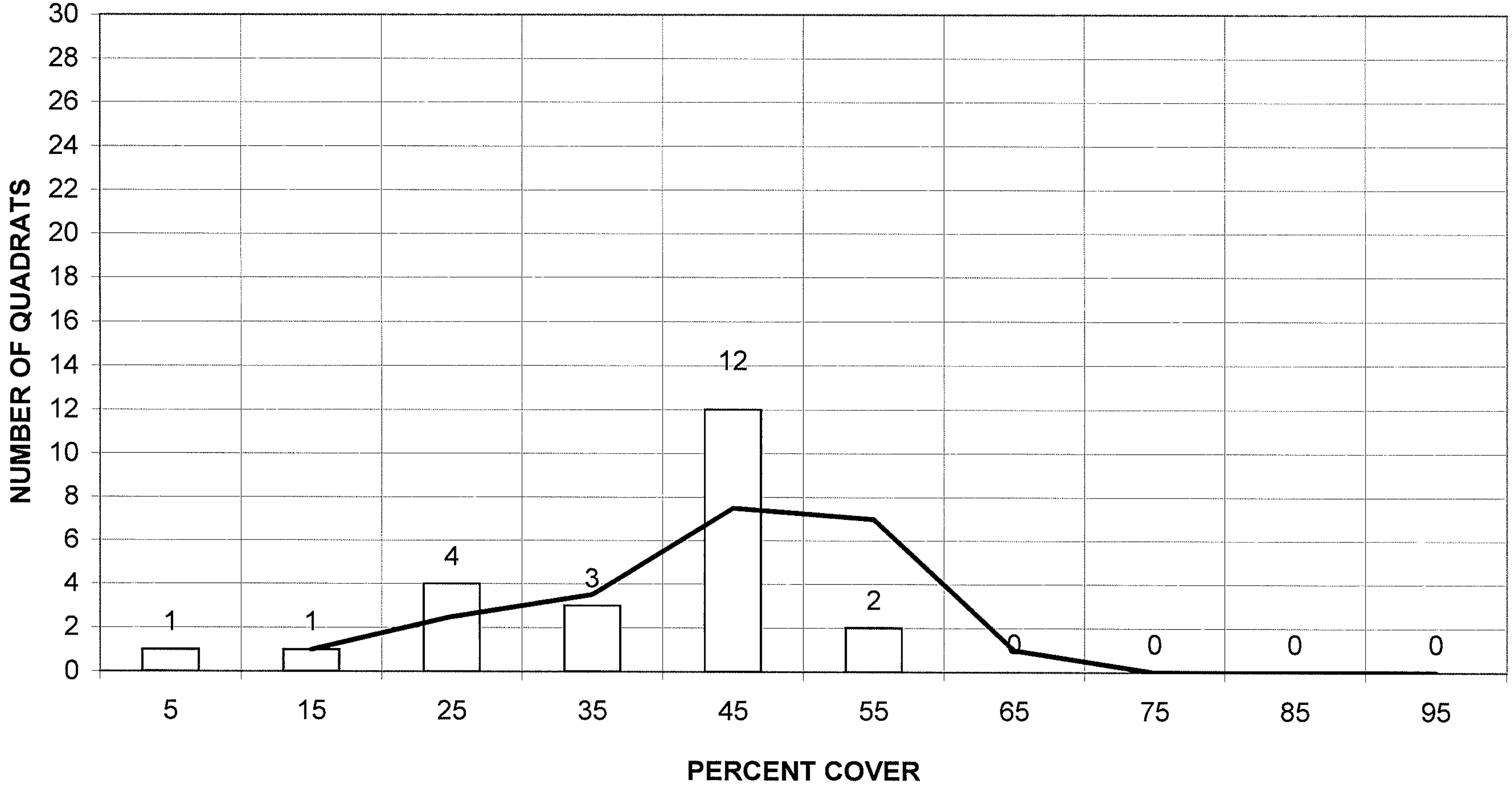
FIGURE 8-16
MEAN PERCENT COVER
2008 RESTORATION SITE TRANSECT DATA



CT = Commercial Township Site
TR = The Rocks
CS = Cedar Swamp
ACW = Alloway Creek Site

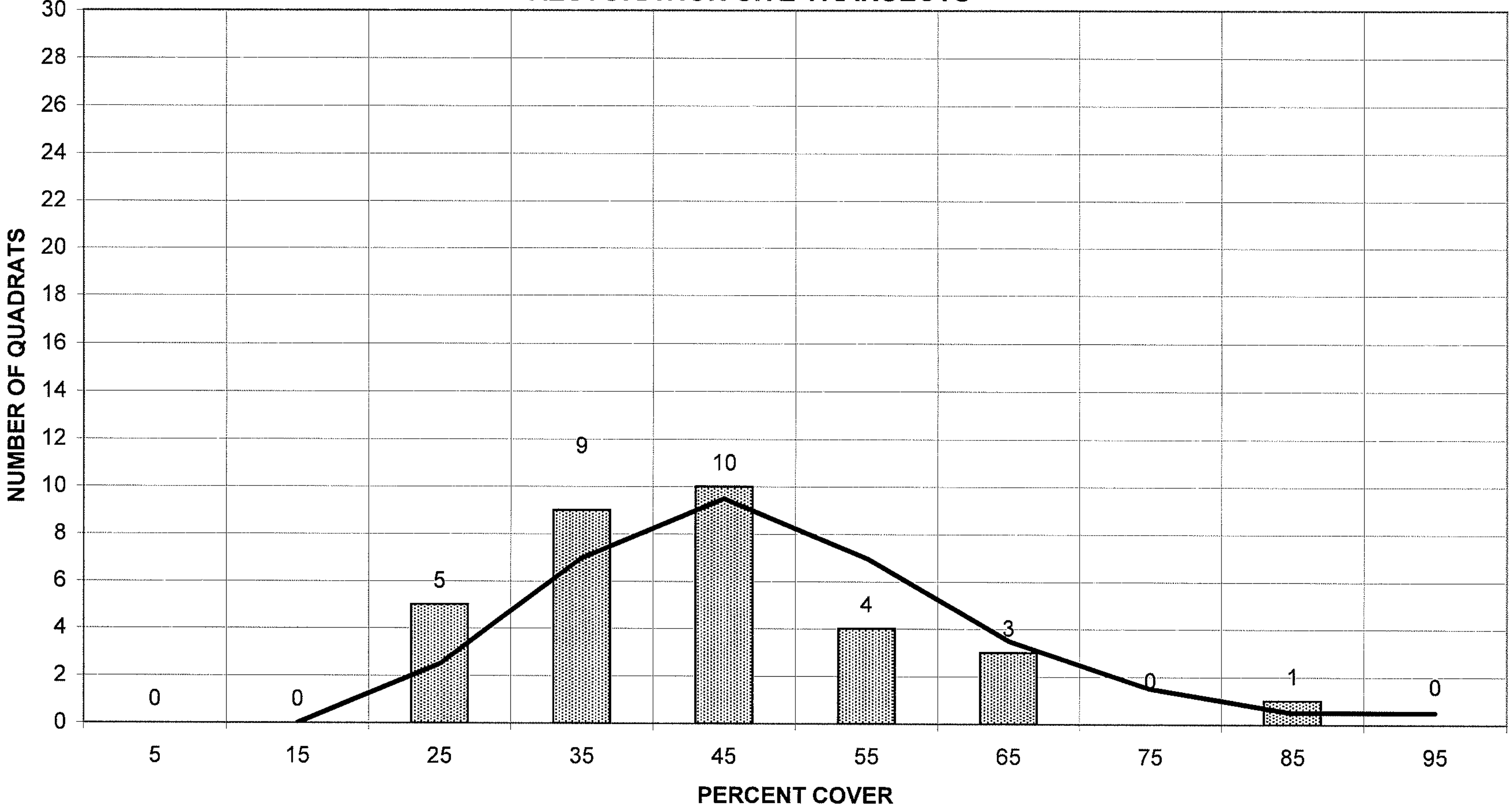
- Error bar represents +/- one Standard Error of the Mean.

FIGURE 8-17
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
COMMERCIAL TOWNSHIP SALT HAY FARM WETLAND RESTORATION SITE TRANSECTS



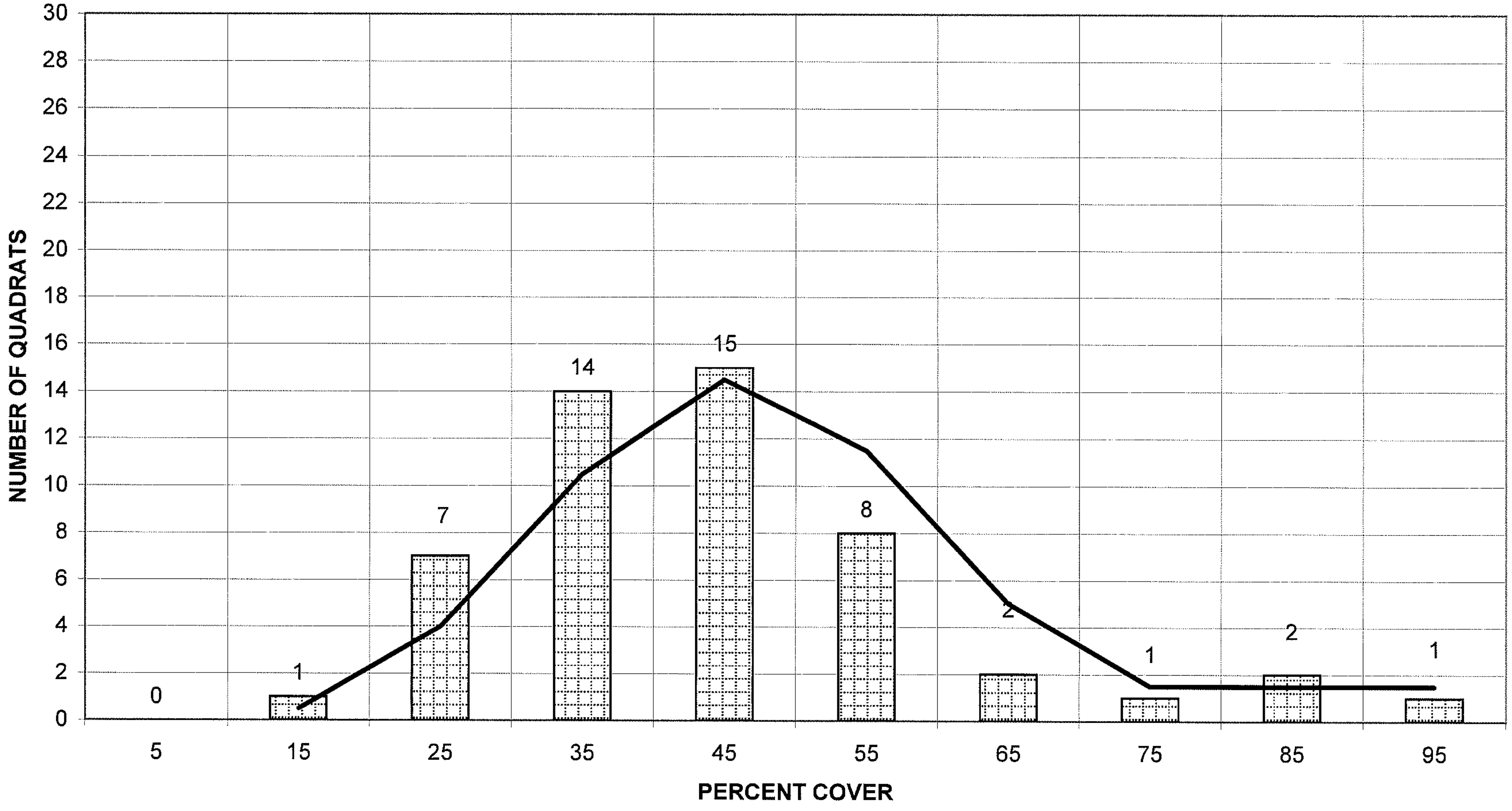
(a) Includes *S. cynosuroides* dominated quadrats, when present.

FIGURE 8-18
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
ALLOWAY CREEK WATERSHED PHRAGMITES DOMINATED WETLAND RESTORATION SITE TRANSECTS



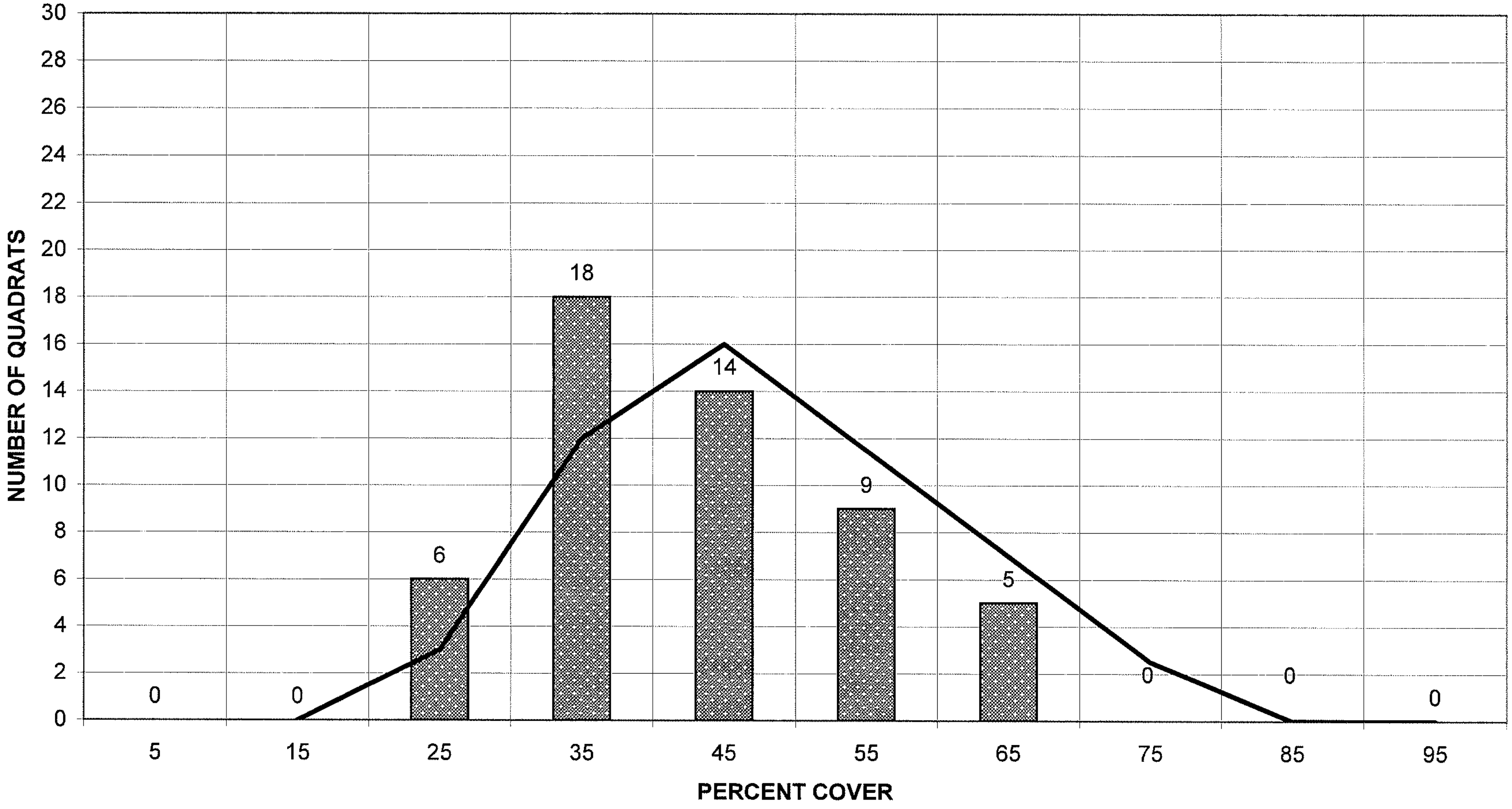
(a) Includes *S. cynosuroides* dominated quadrats, when present.

FIGURE 8-19
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
THE ROCKS PHRAGMITES DOMINATED WETLAND RESTORATION SITE TRANSECTS



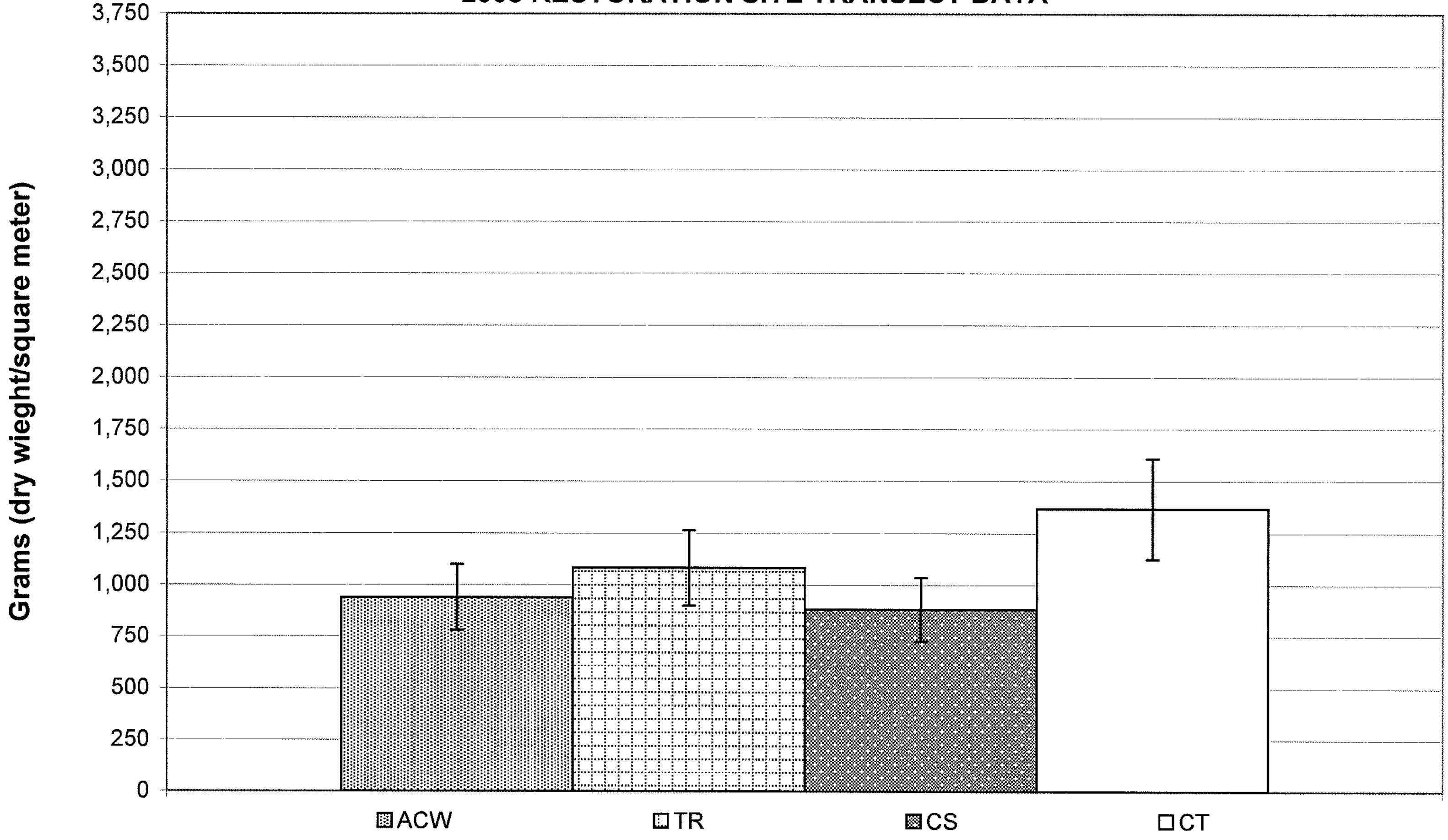
(a) Includes *S. cynosuroides* dominated quadrats, when present.

FIGURE 8-20
2008 PERCENT COVER GROUPINGS
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
CEDAR SWAMP PHRAGMITES DOMINATED WETLAND RESTORATION SITE TRANSECTS



(a) Includes *S. cynosuroides* dominated quadrats, when present.

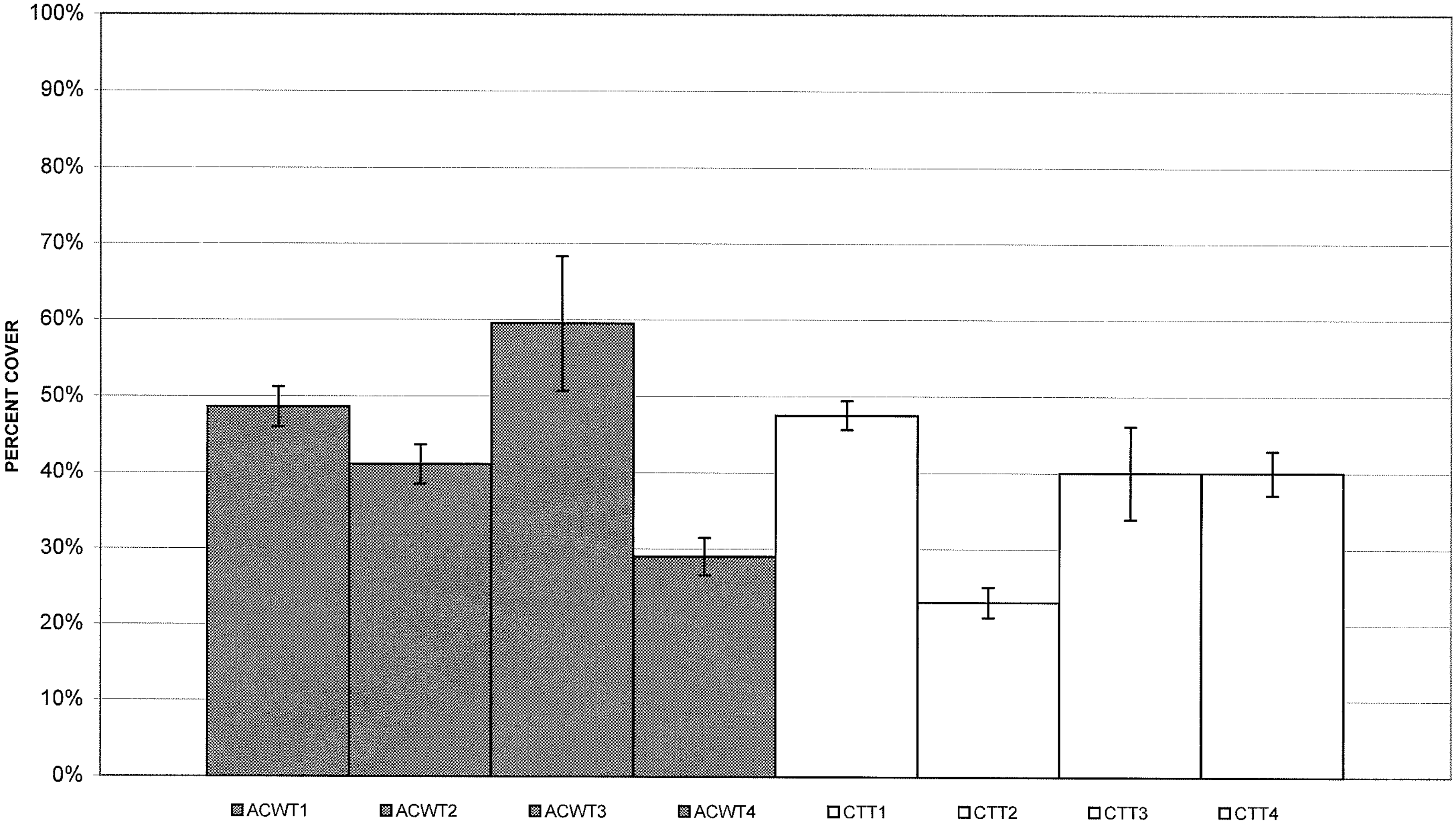
FIGURE 8-21
MEAN LIVE STANDING CROP
2008 RESTORATION SITE TRANSECT DATA



CT = Commercial Township Site
TR = The Rocks
CS = Cedar Swamp
ACW = Alloway Creek Site

- Error bar represents +/- one Standard Error of the Mean.

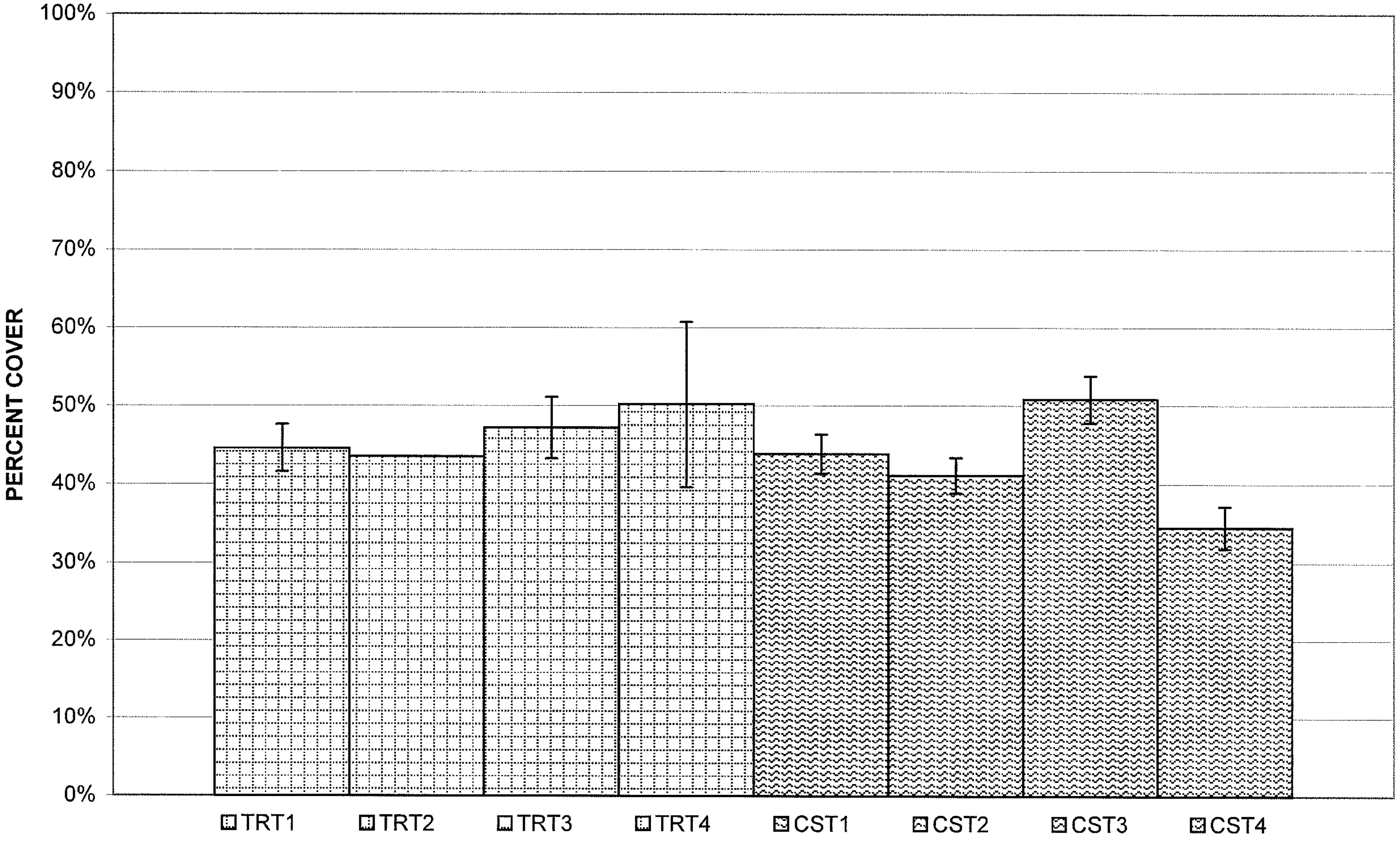
FIGURE 8-22
2008 MEAN PERCENT COVER by TRANSECT
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
NEW JERSEY WETLAND RESTORATION SITES



CT=Commercial Township
ACW = Alloway Creek
T1 = Transect

(a) Includes *S. cynosuroides* dominated quadrats.
- Error bar represents +/- one Standard Error of the Mean.

FIGURE 8-23
2008 MEAN PERCENT COVER by TRANSECT *SPARTINA ALTERNIFLORA* DOMINATED QUADRATS (a) DELAWARE WETLAND RESTORATION SITES

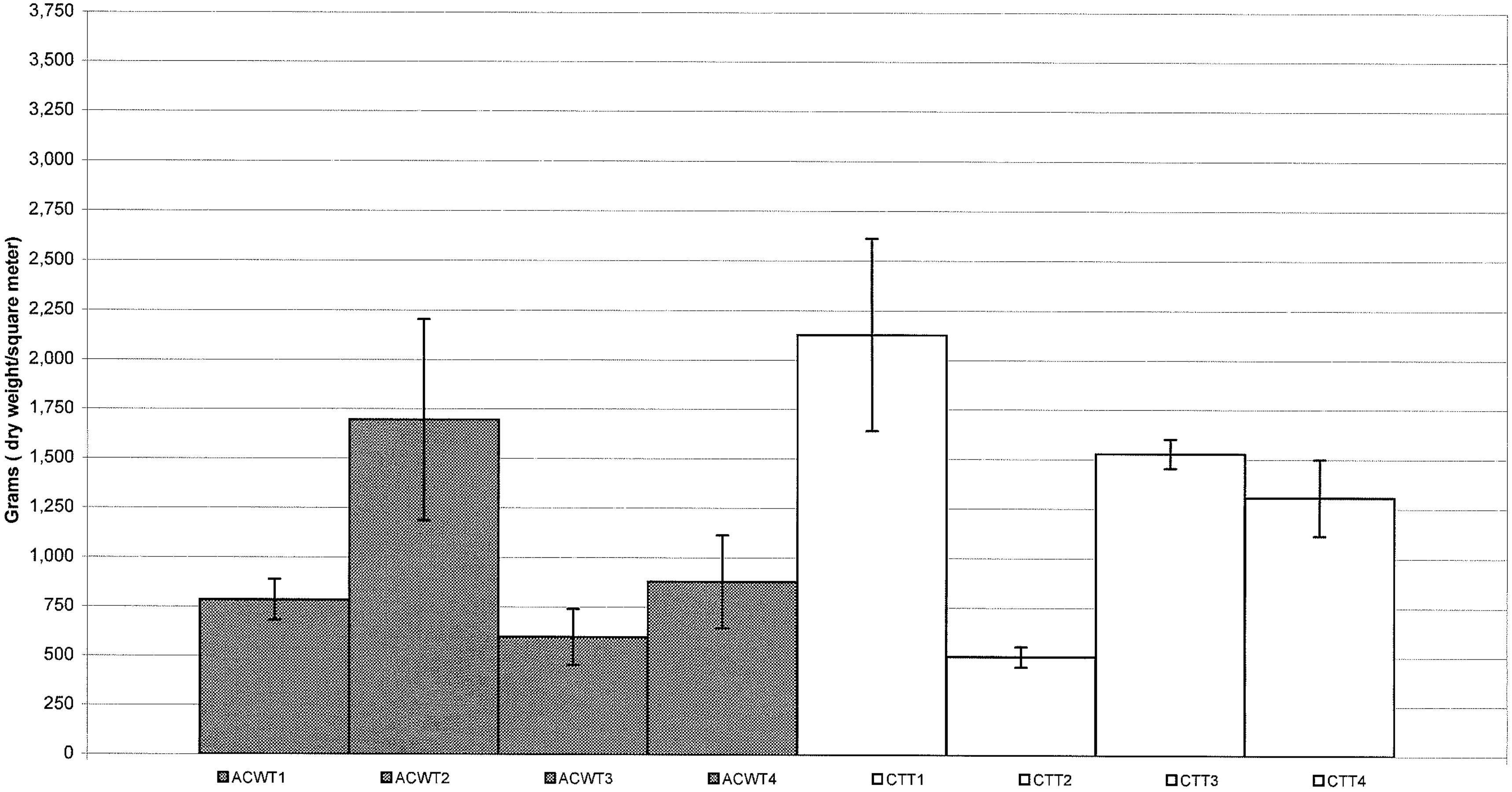


(a) Includes S. cynosuroides dominated quadrats.
Error bar represents +/- one Standard Error of the Mean.

TR = The Rocks
CS = Cedar Swamp

T1 =Transect 1

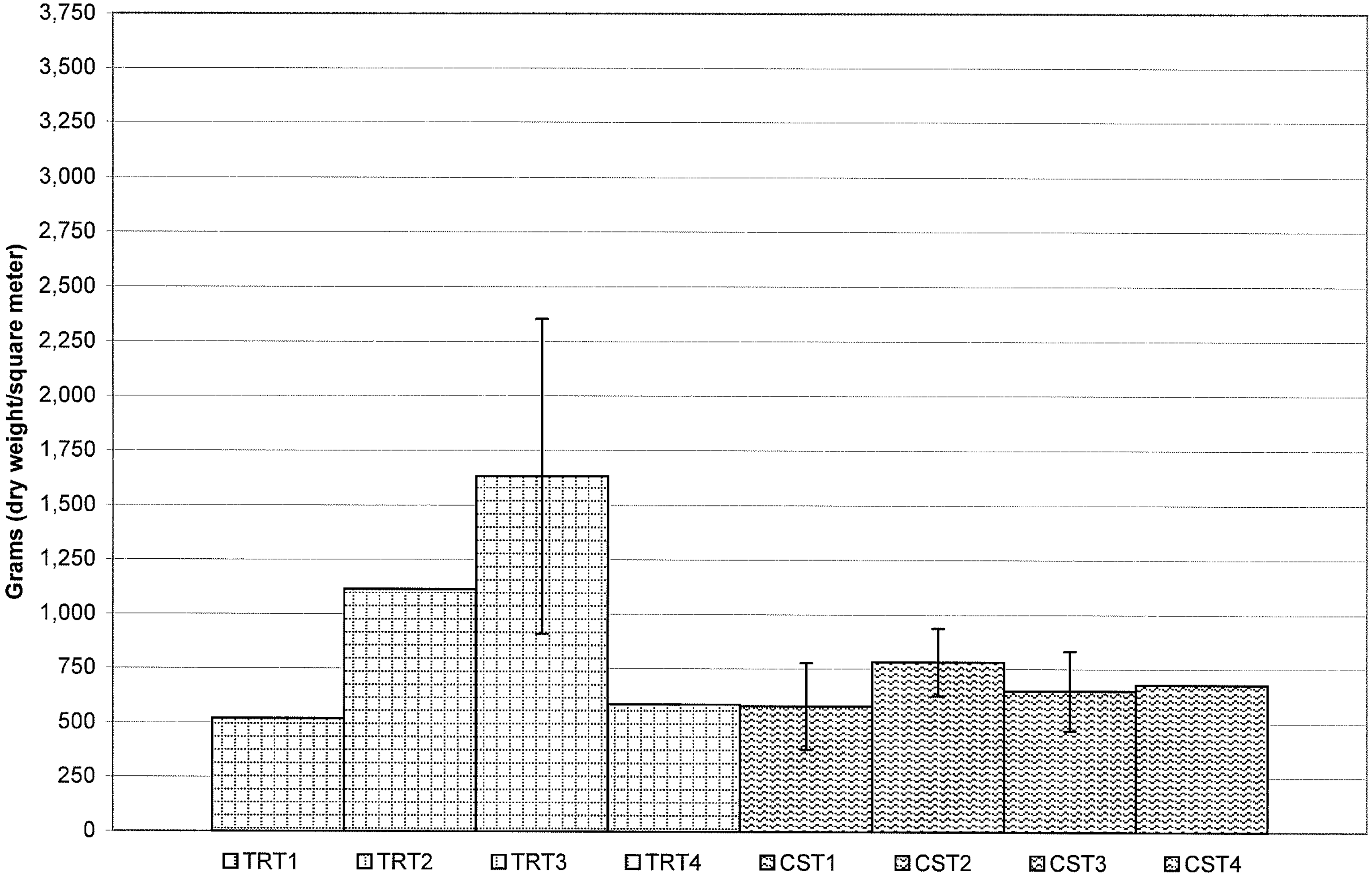
FIGURE 8-24
2008 MEAN LIVE STANDING CROP by TRANSECT
SPARTINA ALTERNIFLORA DOMINATED QUADRATS (a)
NEW JERSEY WETLAND RESTORATION SITES



CT=Commercial Township
ACW = Alloway Creek
T1 = Transect

(a) Includes *S. cynosuroides* dominated quadrats.
Error bar represents +/- one Standard Error of the Mean.

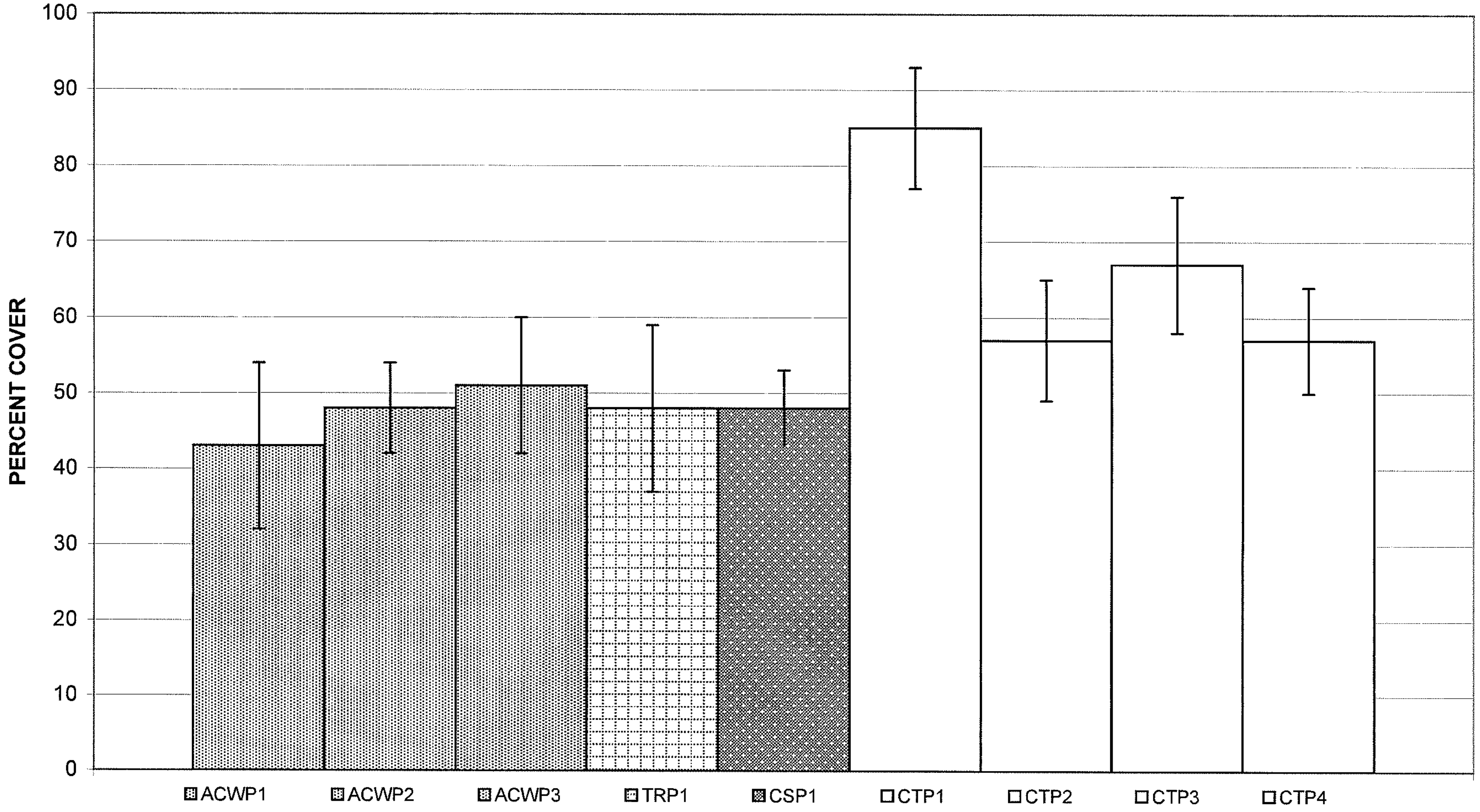
FIGURE 8-25
2008 MEAN LIVE STANDING CROP by TRANSECT *SPARTINA ALTERNIFLORA* DOMINATED QUADRATS (a) DELAWARE WETLAND RESTORATION SITES



(a) Includes S. cynosuroides dominated quadrats.
Error bar represents +/- one Standard Error of the Mean.

TR = The Rocks
CS = Cedar Swamp
T1 =Transect 1

FIGURE 8-26
2008 MEAN PERCENT COVER 60x60 METER PLOTS WETLAND RESTORATION SITES



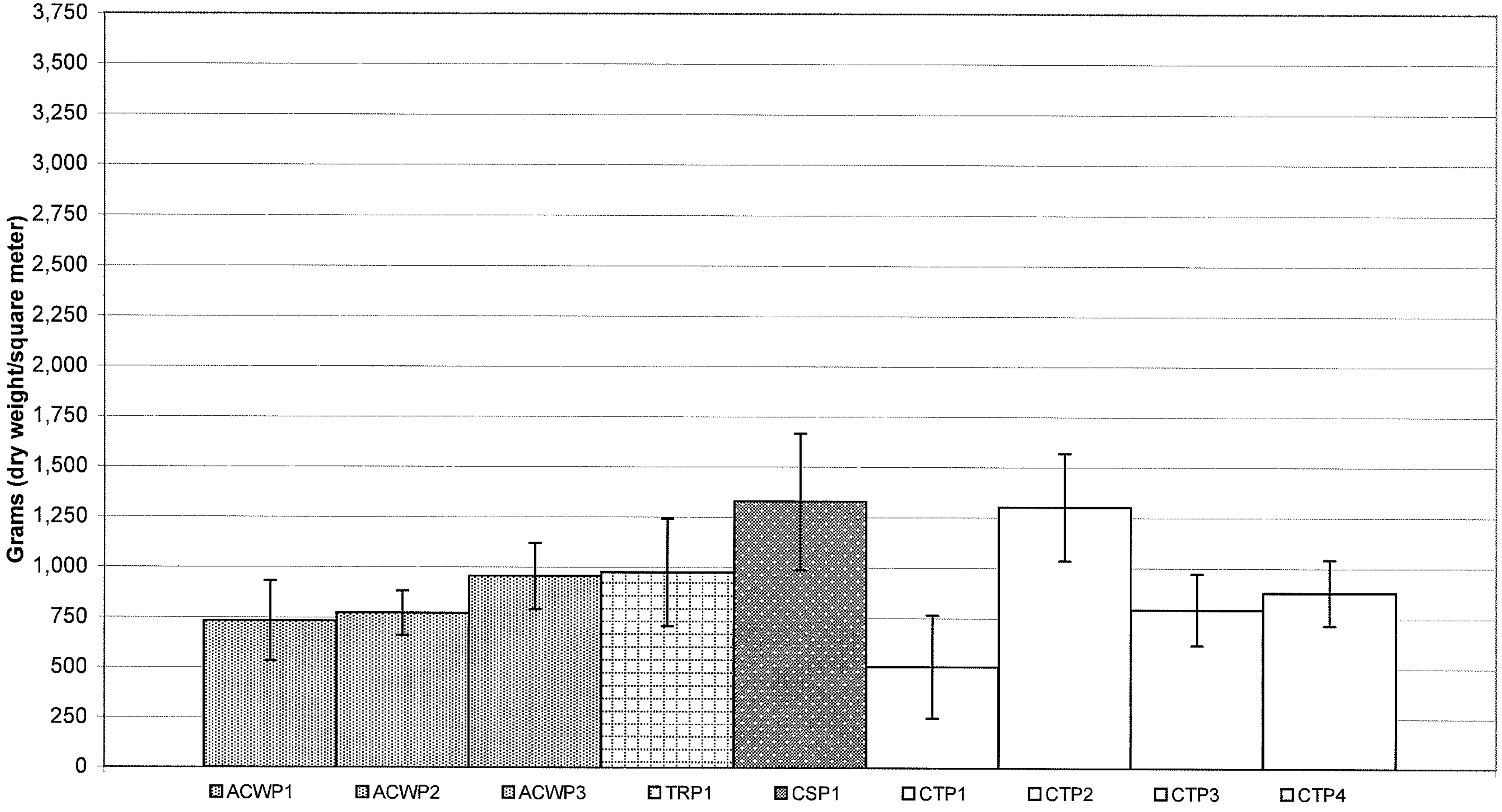
Error bar represents +/- one Standard Error of the Mean.

CT=Commercial Township
CS = Cedar Swamp
ACW = Alloway Creek Site

TR = The Rocks

P1 = Plot 1

FIGURE 8-27
2008 MEAN LIVE STANDING CROP 60x60 METER PLOTS
WETLAND RESTORATION SITES



CT=Commercial Township TR = The Rocks
CS = Cedar Swamp
ACW = Alloway Creek Site P1 = Plot 1

Error bar represents +/- one Standard Error of the Mean.

Appendix A
Macrophyte Field Data Sampling Data Sheets

EXHIBIT A-1
VEGETATION TRANSECT DATA SHEET
PSEG EEP DETRITAL MONITORING

Site:_______________ _____________ **Transect:** ____________ **Date:** ___________________

Investigators:___________________________________ **Compass Reading:**___________________

Weather Conditions:___________________________________

Pole #1
Pole #2
Pole #3
Pole #4
Pole #5

Notes:

Community type (No.) / Segment No.	**Start - End (m)**	**Length (m)**	**Return Start - End (m)**	**Selected Clip Plots (dist from segment) / Selected Ocular Plots (dist from end)**

Total number of vegetation communities = _________

Total number of 0.25 m^2 clip plots (number of vegetation communities X 2) = _________

Total number of 0.25 m^2 ocular quadrats (number of clip plots X 3; up to 22) = _________

Total transect length = ________ meters

Dominant Plant Community	**No. Community Segments**	**Selected Community Segment / length (m)**		**Segment No. / Distance to quadrat (m)**	

EXHIBIT A-2
CLIP QUADRAT DATA SHEET
PSEG EEP DETRITAL MONITORING

Site:______________ ________ **Photo No.:**_________ **Date:** ____________________

Investigators: ____________________ Weather Conditions: ____________________

Transect:_____________ **Quadrat:** ___________ **Distance (m):** ____________

Side of transect (L or R):__________________ Water Depth (cm): ____________________

Notes:

Species	Percent Cover	Height (cm)	Flowering (Y/N)	Number of Bags			
				Live	Dead	Litter	Sort
Total Percent Cover							

EXHIBIT A-3

OCULAR QUADRAT DATA SHEET
PSEG EEP VEGETATION MONITORING

Date: _______________ **Site:** __________________ **Transect:** _______________ **Investigators:** _________________

Quadrat No.	Distance from end (m)	Total % Cover	Species {% cover / height (cm) / flowering (y/n)}														
			% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__	% / ht. /__

Note: Locate odd number quadrats on the left side of the transect and even number quadrats on the right side.

EXHIBIT A-4

VEGETATION PLOT DATA SHEET
PSEG EEP VEGETATION MONITORING

Site:______________________________ **Date:** _________

Investigators:___________________ Weather Conditions:____________________________

Plot:___________________

Notes:

Quadrat ID	Distance north (m)	Distance east (m)	Species {% cover / height (cm) / flowering (y/n)}																	
																	Number of Bags			
			% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	% / ht ./__	Live	Dead	Litter	Sort

EXHIBIT A-5
LAB DATA SHEET FOR CLIP QUADRAT VEGETATION
PSEG EEP VEGETATION MONITORING

Quadrat ID	Date	Species	Live (g)	Dead Standing (g)	Litter (g)

Species abbreviations

AA = arrow arum - *Pelatandra virginica*
AC = water hemp - *Amaranthus cannabinus*
BJ = Blue joint - *Calamagrostis canadenis*
DS = spike grass - *Distichlis spicata*
JG = black grass - *Juncus gerardii*
PA = common reed - *Phragmites australis*
PP = salt marsh fleabane - *Pluchea purpurascens*
PUNC = dotted smartweed - *Polygonum punctatum*
PV = Switch grass - *Panicum virgatum*
SA = smooth cordgrass - *Spartina alterniflora*
SC = big cordgrass - *Spartina cynosuroides*
SO = Three square - *Scirpus olneyi*
SP = salt hay grass - *Spartina patens*
SR = salt marsh bulrush - *Scirpus robustus*
SS = seaside goldenrod - *Solidago sempervirens*
SV = soft stem bulrush - *Scirpus validus*
TA = narrow-leaf cattail - *Typha angustifolia*
TL = broad leaf cattail - *Typha latifolia*
WM = walter's millet - *Echinochloa walteri*