# Continuing trophic studies on constructed "restored" oyster reefs

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## Introduction

*Historical perspective*

Oyster reefs (*Crassostrea virginica*) developed in recent geological time as the current Chesapeake Bay was inundated by rising sea level, indeed, there is general consensus that oyster reefs were once the dominant feature for much of the Bay, contributing both biological and geological structures. Oysters dominated trophic interactions and enhanced overall system water quality while providing physical structure facilitating the development of complex benthic communities. By early Colonial times, oyster reefs had become significant geological and biological features of the Bay and were also major intertidal navigation hazards. Continuing harvest pressure since Colonial times has resulted in the transformation and degradation of the oyster reefs to subtidal "footprints" of former reefs that maintain drastically reduced populations of oysters. Reef degradation has been exacerbated by companion environmental degradation and a historical lack of consideration for water quality and natural resource management.

The past three decades have been defined by decline in the fishery production and the oyster resource under the added insult of two protistan parasites, *Perkinsus marinus* ("Dermo") and *Haplosporidium nelsoni* ("MSX"). Since the disease organisms are active throughout most of the growing range of the oyster there have been few sanctuaries in which to plant oysters or in which naturally occurring oysters could be found in appreciable quantities. Indeed, these parasites have effectively eliminated oysters from many sections of the Bay. The native oysters have developed neither tolerance nor absolute resistance to these diseases, and do not exhibit any recovery in disease endemic areas in Virginia. The oyster fishery is in severe decline and there is a recognized and urgent need to restore the oyster resource: not just for the commercial fishery, but also to provide both the benthic filter feeder and structural foundation for reef communities that are so pivotal to the ecology of the Bay.

*Current status of related oyster reef restoration activities*

Oyster reef restoration has begun in the Virginia portion of the Chesapeake Bay as a collaborative effort between the Shellfish Replenishment Program of the Virginia Marine Resources Commission

(VMRC) and the Virginia Institute of Marine Science (VIMS). It is timely to examine trophic interactions on restored oyster reefs and use these interactions as an indicator of the success of restoration efforts. Quantitative assessment methods for oyster reef communities are challenging and must incorporate temporal, tidal, and structural attributes of these systems in order to accurately characterize these habitats. We promote the philosophy that current oyster restoration efforts in the Bay may be gauged with respect to the overall demographic and ecological health of existing reef communities. Larval and adult forms of oysters, a suite of other benthic species (ranging from attached filter feeders through detrital feeders to benthic predators such as crabs), intermediate fish species (e.g., gobies and blennies), and apex predatory species (e.g., striped bass, bluefish, weakfish, and spotted sea trout) interact to form the complex trophic structures responsible for creation and maintenance of the stable climax reef community observed historically. Any holistic approach to assessment of restoration must be cognizant of all "the players" in the trophic interactions.

To accurately assess oyster restoration efforts, it is necessary to either establish a "baseline" for comparison or have access to historical data characterizing oyster demographics and ecology. We have access to such a database of oyster information and are currently involved in several monitoring programs which contribute directly to the maintenance of this archive. Restored reef data sets may be compared to extensive historical data sets from productive areas within Virginia waters, most notably the James River. Current and historical maps of oyster aerial densities for all public oyster grounds in Virginia waters are also available. Thus, any data resulting from these restoration efforts can be placed in both historical and geographical context with little difficulty. Integration of these data sets provides context and perspective for oyster reef restoration efforts which, to our knowledge, cannot be duplicated.

To date our activities in reef restoration through active construction and subsequent monitoring and manipulative studies have focused on the Piankatank River (Figure 1). The initial reef, Palace Bar Reef, was constructed in May of 1993 as a joint venture between VMRC and VIMS. Since that time, three more reefs have been constructed in the Piankatank resulting in an available "time series" of reefs with respect to development to a mature standing stock of oysters and associated benthic organisms. It is important to note that these reefs were not initially seeded with oysters. All recruitment is from natural settlement originating from other typical "flat" reefs or rocks in the same river - the location of

the Piankatank relative to other known oyster resources strongly suggests this system is isolated with respect to recruitment. These reef restoration projects offer an unparalleled opportunity to document the development of "natural" reef communities on three dimensional structures against a background of typical "flat" reefs or rocks.

The Piankatank River is an excellent site to develop an oyster reef restoration program in that it has not supported a commercial oyster fishery for over a decade; however, it has been the site of a successful seed oyster program, and remains the site of an active blue crab pot fishery and a recreational rod and line fishery. A limited number of typical "flat" oyster rocks in the Piankatank have had applications of shell on a regular basis by VMRC with subsequent harvest of the settled seed after one or two summers of exposure (the summer being the period of oyster settlement) prior to transfer to public oyster bars elsewhere in Virginia. The shell deployment and harvest data are documented by VMRC, the temporal and spatial nature of settlement is documented by a continuing program at VIMS. Oyster spat (juvenile and newly settled oysters) counts of up to 1000 individuals per bushel of shell are commonplace in seed oyster dredging from these maintained and managed areas. The footprints of the former reefs are well documented from both historical sources (Baylor Surveys), recent surveys (Haven and co-workers in the early 1980's, all material on file at both VIMS and VMRC), and continuing work by the VMRC staff. The reefs are not uniform in shape, this is clearly site specific and related to local circulation. The lack of a continuing commercial presence focused on oysters, the proven history of the site as one of good oyster settlement, the comparatively pristine environment at the site (there is essentially no industrial and very little agricultural development in the Piankatank watershed - even residential density is low), and the strongly supportive attitude of waterfront residents to environmentally sound management (illustrated by the support of the local residents through an environmentally oriented group called S.T.O.P - Save the Old Piankatank) combine to make this a unique and attractive site for continuing study.

Prior to the beginning of this study in 1996, little attention had been given to the trophic interaction of oysters with either fishes or benthic predators such as crabs on restored reefs. The relationship between oyster reefs and small intermediate reef fishes such as gobies and blennies is obvious in that oysters dominate the reef communities, and gobies (*Gobiosoma ginsburgi* and *G. bosc*) and blennies

(*Hypsoblennius hentzi* and *Chasmodes bosquianus*), which are some of the most abundant fish species in the Chesapeake Bay, are abundant in reef communities. Gobies and blennies are major food fishes for larger pelagic predatory species (*Morone saxitilis, Pomatomus saltatrix, Cynoscion regalis, Cynoscion nebulosus*) which potentially use reef communities as both nesting and nursery areas. It is reasonable to suggest a relationship between the developmental stage of a reef (maturity with respect to development of a stable oyster community over time, an index of the success of the restoration/rehabilitation process), the development of a goby population ( and other "food" fish populations), and the abundance of major predatory finfishes.

We have examined and continue to examine this relationship through field studies focusing on the oyster (predominantly oyster larvae) - intermediate fish (predominantly larval goby/blenny) relationship (Harding, In review; Harding and Mann, In review 1) as well as the intermediate fish-apex predator fish relationship (Harding and Mann, In review 2). A significant portion of this effort has been directed towards water column processes (e.g., predation on oyster veligers by larval intermediate fishes (Harding, In review), predation on adult intermediate fishes by apex fish predators (Harding and Mann, In review 2; In review 3)), as directly related to the benthic community.

The dependent relationship between oyster reefs and crabs is equally obvious. Crabs, notably the blue crab, *Callinectes sapidus*, are well documented as predators on oysters, especially the smaller size classes. As oyster communities develop to include dense seasonal populations of rapidly growing recent recruits there is an expectancy of intensive blue crab predatory activity. We have examined blue crab abundance and population structure in proximity to the oyster reef over time.

*Summary of previous research activities on Palace Bar Reef, Piankatank River, Virginia*

In 1996, we conducted an intensive seasonal reef sampling program with U.S. E.P.A. Bay Program support. During this intensive Piankatank reef sampling program samples were collected over a twenty-two week period extending from May through September 1996. Mann and Harding (1997) provide an overview of this program and the resulting data types are summarized in Table 1.

Our 1996 sampling program also incorporated two thirty-six hour sampling stations (June and August 1996). These were conducted at the oldest of the Piankatank reefs, Palace Bar Reef, on the full

moon to assess the diurnal variability of the reef community. Zooplankton and gill net samples were collected at three hour intervals corresponding to ebb, flood, and slack stages of the tide. Samples from these stations describe oyster-intermediate fish and apex predatorintermediate fish predator-prey interactions. Information from the 1996 field studies suggested that diurnal variability in the make up of the "user" fish community on the reefs was considerable and not completely represented by daytime sampling alone (Mann and Harding, 1997; Harding and Mann, In review 2; Harding and Mann, In review 3).

Field work during 1997 focused on diurnal variation in reef habitat use by both benthic and apex predators. These continuing oyster reef studies expanded sampling spatially to include a gradient of bottom types from three dimensional shell reef to two dimensional "oyster rock" to sand flat regions in proximity to both. Given the simultaneous sampling of non-reef and reef habitat, quantitative comparisons of bottom and community use by fish at each location are possible.

*Relevance of this project to the Aquatic Reef Restoration Program*

Restored oyster reefs are unique sites for examining oyster reef development and parallel development of associated communities within the Chesapeake Bay. The combination of Piankatank reef sites provides an unprecedented opportunity to quantitatively track the chronological development and maturation of "natural" reef sites of differing stages of maturity in a relatively undisturbed setting.

## Objectives

**The long term goal of our oyster reef community restoration research program is the understanding of reef function from an ecological community perspective (e.g. food web impacts)**. In this program we specifically:

1. Build on existing oyster reef restoration database with continued monitoring efforts across all trophic levels.
2. Combine monitoring efforts with sampling of upper trophic levels in reef communities of differing maturity levels.
3. Synthesize oyster community and trophic data into models of oyster reef community interactions.

4. Use data - based models of community interaction to assess restoration efforts and management strategies.

## Study Design

*Site Description*

Field studies were focused on Palace Bar Reef, Piankatank River, Virginia (N 37° 31'41.69", W 76° 22' 25.98"; Figure 1) in 1996 and 1997. Palace Bar Reef is an intertidal oyster reef (depth range of 1-3 m) adjacent to the historic Palace Bar oyster grounds. Approximately 70% of the reef (0.63 ha) is composed of oyster shell, while the remaining area (0.27 ha) is crushed clam shell (see Bartol and Mann, 1997). This reef is constructed on the footprint of ancient reefs and is located in an area protected from commercial oyster fishing and other perturbations. There is a substantial oyster settlement database and a continuing program of reef study for the Piankatank site to provide supplemental information to the proposed community restoration program.

In 1997, oyster reef trophic monitoring efforts were expanded to include two off-reef sites within the Piankatank River (Figure 1). The Ginney Point site (N 37° 31' 52.78", W 76° 24' 08.40") is located on a natural oyster shell flat (Figure 1). The Roane Point site (N 37° 31' 37.48," W 76° 22' 39.63") includes a sand bar south and inshore of Palace Bar Reef (Figure 1).

We have both continuing long-term monitoring programs in the Piankatank River and focused efforts on reef biology. We maintain a program to describe temporal and spatial settlement of oysters (using shellstring substrates deployed for weekly intervals) in the Virginia subestuaries of the Chesapeake Bay, including the Piankatank River, throughout the summer months from June through late September. Dredge surveys are conducted in Spring and Fall throughout the Piankatank system. Diver surveys of selected reefs are completed in Spring and Fall. General patent tong surveys are completed in selected areas in the Fall for quantitative oyster stock assessment.

## Methods and Results

Continuing VIMS-sponsored oyster monitoring studies have been combined with information on general community structure with the trophic levels directly above the oysters (intermediate fishes

(e.g. gobies and blennies) and their pelagic and benthic apex predators (e.g., striped bass, weakfish, bluefish, and blue crabs) to provide a more complete picture of oyster reef community function and restoration benefits to the overall ecosystem. The additional community and trophic information has been collected by pelagic adult fish sampling, plankton surveys, and crab pot deployments sponsored by the U.S. E.P. A. Chesapeake Bay Program.

*Sampling schedule*

Oyster reef community monitoring efforts during 1997 were designed to describe diurnal, tidal, and site - specific patterns of habitat use by reef community predators. Trophic monitoring samples were collected during nine 36 hour sampling stations focusing on the three sites described above (Table 2). Stations coincided with either the full or new moon; sampling intervals during the stations coincided with changes in tidal stage (Table 3). Field schedules from all of these 36 hour stations are included in Appendix 1.

Oyster monitoring data (shell strings) and reef monitoring physical data (water temperature, salinity, and dissolved oxygen measurements) were collected weekly.

*Current sample status*

A summary of all reef monitoring samples collected with U.S. E.P.A. Chesapeake Bay program support during both 1996 and 1997 field seasons is given in Table 4. The bongo and gut samples listed as archived have been preserved and are awaiting processing. These samples and the plankton samples will be analyzed and included in the annual report for the 1998 reef monitoring proposal that continues and expands the work described in this report and Mann and Harding (1997).

*Oyster monitoring data*

VIMS maintains an oyster monitoring program which provides data for oyster spat (shellstring program), small, and market-size oyster (annual dredge survey) abundance estimates. An extensive historic data set for both spatfall and adult abundance is available for Palace Bar (site of the primary study reef), Piankatank River. These data provide baseline information regarding the status of the Piankatank oyster populations in relation to Chesapeake Bay oyster populations. The trends observed

in both spatfall (Figure 2) and adult abundance (Figure 3) around Palace Bar Reef follow the general decline observed in the Virginia oyster fishery in recent years.

*Physical oceanographic data*

Water temperature, salinity, and dissolved oxygen measurements were made weekly at all three study sites from May through mid - September 1997. There were no significant differences between sites for water temperature, salinity, or oxygen data (ANOVA, $p < 0.05$); therefore data were combined (Figure 4). Water temperature and salinity data from 1997 were compared to 1996 data (Mann and Harding, 1997). Salinities, but not water temperatures, were significantly different between 1996 and 1997 (ANOVA, $p < 0.05$). Water temperatures and salinities during 1996 and 1997 were similar to those observed from 1993-95 at these sites (Figure 4; R. Mann, unpublished data). Dissolved oxygen values were at or near saturation values for measured field temperatures and salinities throughout the season.

*Pelagic predator surveys*

Relative abundance and distribution: Adults and juveniles of larger pelagic species were sampled using multi-panel experimental gill nets (one 30.5 m x 1.8 m and two 30.5 m x 3.0 m nets all with one 7.6 m panel each of stretch mesh monofilament of 57.2, 63.5, 73.0, and 76.2 mm). Gill nets were deployed such that the entire water column was sampled (e.g. the smallest net at the shallowest site) and were retrieved at three hour intervals corresponding with changes in tidal stage (See Harding and Mann, In review 2). Benthic fishes, resident on the reef, were sampled using nesting substrates deployed for another study (Harding and Mann, In review 1). Twenty - one fish species representing 15 families were collected during 1997 across all three sites (Table 5; Harding and Mann, In review 2). If pelagic fish data from the 1996 and 1997 field seasons are combined, 31 species of finfishes representing 25 families were collected on or adjacent to Palace Bar Reef, Piankatank River, Virginia (Table 6; Harding and Mann, In review 2).

The four most abundant non-menhaden pelagic fishes collected at all three of the sites are recreationally and commercially valuable and were also the four most abundant non-menhaden

fishes collected on Palace Bar Reef during 1996: Atlantic croaker (*Micropogonias undulatus*), bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and spot (*Leiostomus xanthurus*). Abundance patterns of these fishes varied seasonally and diurnally (Tables 7-15) . Abundance of each of these fishes varied seasonally (Figure 5).

Dietary analyses: As with 1996 samples, the entire digestive tracts of all pelagic fishes samples including all gut contents were collected and field preserved for subsequent laboratory quantitative gut content analyses. These analyses provide information on multi-species interactions and trophic relationships within and around the reef communities. Dietary analyses are in progress for all species observed during 1997 but are most complete for bluefish (*Pomatomus saltatrix;* Figure 6) and striped bass (*Morone saxatilis;* Table 16). Teleost fishes are dominant prey items for both of these species. Intermediate reef fishes (e.g., gobies and blennies) are found more frequently in the guts of bluefish caught on Palace Bar Reef than at either of the other sites (Harding and Mann, In review 3).

*Benthic predators: Blue crabs*

Abundance: Blue crab abundance information for all three study sites was obtained with baited crab pots (fishery independent data - 2' x 2' pots with a 2" cull ring) deployed in conjunction with 36 hour stations. Crab abundance increases as temperature increases seasonally from May through August (Figure 4, Figure 7).

Abundance patterns: males vs. females: Plots of male and female blue crab abundance over time indicate clear differences in habitat use by the sexes over time (Figure 8). It is important to note that all of these abundance data are relative and may have been influenced by commercial crabbing in the area which varied in intensity with the seasons e.g., the commercial crabbing presence was most noticeable immediately adjacent to the reef in June and July 1997.

## Current status and connections with continuing research

The combination of the VIMS historic data archives and the abundant trophic data collected at Palace Bar Reef during 1996 and 1997 with EPA support places us in a unique position: we have the necessary monitoring data to establish a baseline of oyster reef community structure. The 1997 field season expanded our focus to include comparisons with local non-reef sites while maintaining monitoring efforts at the Palace Bar Reef site. The end product of the 1996 and 1997 field seasons is two years of intensive reef baseline data coupled with one year of parallel intensive data from a local flat oyster rock and a local sand-bar; an ideal scenario for establishing oyster reef impacts on the local biological landscape. Given the quantity of data involved in this project, our major limiting factors revolve around sample processing and analyses (i.e. time and money to do both properly). Both processing and analyses are currently underway and have been in progress since 1996. When all of these data are processed and analyzed, we will be able to quantitatively and qualitatively describe the development and function of oyster reef trophic structure at an unprecedented level of detail.

The 1997 field season provides comparative data from on-reef and off-reef sites across seasonal, diurnal, and tidal scales. The combination of these sites and scales and the focus on multiple trophic predator-prey relationships enables a better understanding of community dynamics than has been previously possible. The major benefit of this work is an understanding of the quantitative relationship between oyster reef community food chain levels in an ecological framework dependent upon the oyster (as both a physical habitat and a major prey item) as present on restored oyster reefs and typical "flat" oyster rocks.

Oyster reef restoration for the express purpose of oyster enhancement and water quality improvement may also contribute significantly to provision of habitat for blue crab predation, and to the success of recreational finfish species (probably more so than finfish reef enhancement alone in that oyster reefs provide a viable food chain to support the fishes). Dedicated oyster and finfish reef development will continue in the Bay, probably at accelerated rates in future years. It is fundamental that we understand the processes that dictate the success or failure of these activities, and maximize the

benefit of such activities for fisheries enhancement and environmental rehabilitation (that is oyster resource rehabilitation).

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Table 1: Summary of data types collected on/around Palace Bar Reef, Piankatank River,Virginia during intensive seasonal sampling with U.S. E.P.A. Chesapeake Bay Program support .

| Sample type | n | Targeted trophic level | Duration of sampling |
|---|---|---|---|
| Plankton tows | 198 | Oysters - Intermediate fishes | May - October 1996 |
| Bongo tows | 48 | Oysters - Intermediate fishes | May - October 1996 |
| Fish traps | 120 | Intermediate fishes | May - September 1996 |
| Quadrat counts | 9 | Intermediate fishes | May - September 1996 |
| Crab pots | 72 | Intermediate benthic predators | May - September 1996 |
| Gill nets | 42 | Apex pelagic predators | May - September 1996 |
| Trawls | 22 | Apex and benthic predators | May - September 1996 |
| Shell strings | 32 | Oysters | June - October 1996 |

Table 2: Summary of all biological samples collected on the Piankatank River during the 1997 field season with U.S. E.P.A. Chesapeake Bay Program support.

| Trophic Level | Type of Sample | No. of samples | Processing status |
|---|---|---|---|
| Apex predators | Gill net deployment | 255 sets | In progress |
| Benthic predators | Crab pot deployment | 162 pots | Completed |

Table 3: Summary of all gill net collections of non-menhaden species completed on the Piankatank River during the 1997 field season.

| Sampling dates | Moon phase | Total no. of nonmenhaden fishes collected | Processing status |
|---|---|---|---|
| May 22-23, 1997 | Full | 257 | In progress |
| June 5-6, 1997 | New | 205 | In progress |
| June 19-20, 1997 | Full | 185 | In progress |
| July 2-3, 1997 | New | 140 | In progress |
| July 17-18, 1997 | Full | 238 | In progress |
| Aug. 4-5, 1997 | New | 69 | In progress |
| Aug. 18-19, 1997 | Full | 67 | In progress |
| Sept. 2-3, 1997 | New | 212 | In progress |
| Sept. 15-16, 1997* | Full | 83 | In progress |

Table 4: Sample status for all of the Piankatank reef monitoring samples collected during both 1996 and 1997 with Bay Program support.

| **Trophic Level** | **Year** | **Type of Sample** | **# of Samples** | **Processing status** |
|---|---|---|---|---|
| Oysters-Intermediate fishes | 1996 | Zooplankton tows | 198 | Under analysis |
| | 1997 | Zooplankton tows | 120 | Under analysis |
| Oysters-Intermediate fishes | 1996 | Bongo tows | 48 | In progress |
| Apex predators | 1996 | Gill net deployment | 20 sets | Completed |
| | 1997 | Gill net deployment | 270 sets | In progress |

Table 5: Fishes collected during 1997 with gill nets, crab pots, and nest substrates in the Piankatank River, Virginia. This table is from Harding and Mann (In review 2).

| Fish species | Ginney Point | Roane Point | Palace Bar Reef |
|---|---|---|---|
| American eel | | | X |
| Atlantic croaker | X | X | X |
| Atlantic menhaden | X | X | X |
| Black Sea bass | X | | |
| Blueback herring | X | X | X |
| Bluefish | X | X | X |
| Butterfish | | | X |
| Carp | | X | |
| Cownose ray | | | X |
| Hogchoker | X | | X |
| Naked goby | | | X |
| Oyster toadfish | | | X |
| Silver perch | X | X | X |
| Skilletfish | | | X |
| Speckled trout | X | X | X |
| Spot | X | X | X |
| Striped bass | X | X | X |
| Striped blenny | | | X |
| Summer flounder | X | | |
| Weakfish | X | X | X |

Table 6: Family, common, and scientific names with species status for all fish species observed in the Piankatank River,Virginia during 1996-97. This table is modified from Harding and Mann (In review 2).

| Family | Common name | *Scientific name* | Recreationally or commercially valuable species |
|---|---|---|---|
| Anguillidae | | | |
| | American eel | *Anguilla rostrata* | X |
| Batrachoididae | | | |
| | Oyster toadfish | *Opsanus tau* | |
| Blennidae | | | |
| | Striped blenny | *Chasmodes bosquianus* | |
| Bothidae | | | |
| | Summer flounder | *Paralichthyes dentatus* | X |
| Clupeidae | | | |
| | Atlantic menhaden | *Brevoortia tyrannus* | X |
| | Blueback herring | *Alosa aestivalis* | X |
| Engraulidae | | | |
| | Bay anchovy | *Anchoa mitchilli* | |
| Ephippidae | | | |
| | Spadefish | *Chateodipterus faber* | |
| Gadidae | | | |
| | Spotted hake | *Urophycis regia* | |
| Gobiesocidae | | | |
| | Skilletfish | *Gobiesox strumosus* | |
| Gobidae | | | |
| | Naked goby | *Gobiosoma bosc* | |
| Haemulidae | | | |
| | Pigfish | *Orthopristis chrysoptera* | |
| Labridae | | | |
| | Tautog | *Tautoga onitis* | X |

| | | | |
|---|---|---|---|
| Myliobatidae | | | |
| | Cownose ray | *Rhinoptera bonasus* | |
| Percichthyidae | | | |
| | Striped bass | *Morone saxatilis* | X |
| Pomatomidae | | | |
| | Bluefish | *Pomatomus saltatrix* | X |
| Rachycentridae | | | |
| | Cobia | *Rachycentron canadium* | X |
| Sciaenidae | | | |
| | Atlantic croaker | *Micropogonias undulatus* | X |
| | Silver perch | *Bairdiellal chyrsoura* | |
| | Speckled trout | *Cynoscion nebulosus* | X |
| | Spot | *Leiostomus xanthurus* | |
| | Weakfish | *Cynoscion regalis* | X |
| Scombridae | | | |
| | Spanish mackerel | *Scomberomorus maculatus* | X |
| Serranidae | | | |
| | Black Sea bass | *Centropristis striata* | X |
| Soleidae | | | |
| | Hog choker | *Trinectes maculatus* | |
| Sparidae | | | |
| | Pinfish | *Lagodon rhomboides* | |
| Stromateidae | | | |
| | Butterfish | *Peprilus triacanthus* | |
| | Harvest fish | *Peprilus alepidotus* | |
| Syngnathidae | | | |
| | Lined seahorse | *Hippocampus erectus* | |
| Tetradontidae | | | |
| | Northern puffer | *Spheroides maculatus* | |
| Triglidae | | | |
| | Northern searobin | *Prionotus carolinus* | |

Table 7: Summary of fishes caught with gill nets at Piankatank River, VA sites on May 22-23, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/22/97 | Full | 1330 | Ebb | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | X | | X | X | | | | | | | | | | |
| | | 1940 | SF | 1 | X | | X | | | | | | | | | | | |
| | | | | 2 | | X | X | X | | | | | | | | | | |
| | | | | 3 | X | | X | X | | | | | | | | | | |
| | | 2230 | Flood | 1 | X | X | X | X | X | | | | | | | | | |
| | | | | 2 | X | X | X | X | X | X | | X | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | X | | | |
| 5/23/97 | Full | 0222 | SE | 1 | X | X | X | X | X | X | | | | | | | | |
| | | | | 2 | | | X | X | X | | X | | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | | | | |
| | | 0600 | Ebb | 1 | X | | | X | | | | | | | | | | |
| | | | | 2 | X | | | X | X | | | | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | | | | |
| | | 0920 | SF | 1 | X | | | X | | | | | | | | | | |
| | | | | 2 | X | | | | | | | | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | | | | |
| | | 1130 | Flood | 1 | | | | | | | | | | | | | | |
| | | | | 2 | X | | | | | | | X | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1440 | SE | 1 | X | X | | | | | | | | | | | | |
| | | | | 2 | | | | X | | | | | | | | X | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| | | 1710 | Ebb | 1 | X | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |

Table 8: Summary of fishes caught with gill nets at Piankatank River, VA sites on June 5-6, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/5/97 | New | 1340 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | | X | | X | | | | | | | | | | |
| | | 1658 | Ebb | 1 | | X | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | X | | | X | | | | | | | | | | |
| | | 2000 | SF | 1 | X | X | X | | | | | | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| | | 2300 | Flood | 1 | | X | X | X | X | | | | | | | | | |
| | | | | 2 | X | X | X | X | X | | | | | | | | | |
| | | | | 3 | | | X | X | X | | | | | | | | | |
| 6/6/97 | New | 0250 | SE | 1 | X | | X | X | X | | | | | | | | | |
| | | | | 2 | | | X | X | | | X | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| | | 0610 | Ebb | 1 | X | X | | X | | | | X | X | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | | | | X | | | | | |
| | | 0950 | SF | 1 | | X | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | X | | | | | | | | | | | | |
| | | 1140 | Flood | 1 | X | X | X | | | | | | | | | | | |
| | | | | 2 | | X | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1445 | SE | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | X | | | | | | | | | | |
| | | | | 3 | | X | X | | | | | | | | | | | |

Table 9: Summary of fishes caught with gill nets at Piankatank River, VA sites on June 19-20, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/19/97 | Full | 1230 | SE | 1 | X | X | X | | | | | | | | | | | |
| | | | | 2 | | X | | | | | | | | | | | | |
| | | | | 3 | X | X | | | | | | | | | | | | |
| | | 1540 | Ebb | 1 | | X | | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1840 | SF | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | X | | X | X | | | | | | | | | | |
| | | 2140 | Flood | 1 | | X | X | X | X | | | | | | | | | |
| | | | | 2 | X | X | X | X | X | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | | | | | | | | | |
| 6/20/97 | Full | 0115 | SE | 1 | | X | X | X | X | | | | | | | | | |
| | | | | 2 | X | X | X | X | X | | X | | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | | | | |
| | | 0436 | Ebb | 1 | | | X | X | X | | | | | | | | | |
| | | | | 2 | | X | X | X | X | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | | | | | | | | | |
| | | 0715 | SF | 1 | X | X | | X | X | | | | | | | | | |
| | | | | 2 | | | | X | X | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | | | | | | | | | |
| | | 1020 | Flood | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1320 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | X | | | | | | | | | | |

Table 10: Summary of fishes caught with gill nets at Piankatank River, VA sites on July 2-3, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/2/97 | New | 1120 | SE | 1 | | | X | | X | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1500 | Ebb | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1800 | SF | 1 | | X | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | X | X | X | | | | | | | | | | |
| | | 2119 | Flood | 1 | | | X | X | X | X | | | | | | | | |
| | | | | 2 | | | X | X | X | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | X | | | | | | | | |
| 7/3/97 | New | 0030 | SE | 1 | X | X | X | X | X | X | | X | | | | | | |
| | | | | 2 | | | X | X | X | | | | | | | | | |
| | | | | 3 | X | | X | X | X | | | | | | | | | |
| | | 0400 | Ebb | 1 | | X | X | X | X | | | | | | | | | |
| | | | | 2 | | | X | X | X | | | | | | | | | |
| | | | | 3 | | | X | X | X | | | | | | | | | |
| | | 0650 | SF | 1 | | X | X | | X | | | | | | | | | |
| | | | | 2 | | | | | X | | | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| | | 0945 | Flood | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1240 | SE | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | X | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |

Table 11: Summary of fishes caught with gill nets at Piankatank River, VA sites on July 17-18, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/17/97 | Full | 1100 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | X | | X | | | | | | | | | | | |
| | | 1415 | Ebb | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| | | 1720 | SF | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | X | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| | | 2030 | Flood | 1 | | | | X | X | X | | | | | | | | |
| | | | | 2 | X | | | | | X | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| 7/18/97 | Full | 0010 | SE | 1 | | X | X | X | X | | X | | | | | | | |
| | | | | 2 | | | X | X | X | | X | | | | | | | |
| | | | | 3 | X | X | X | X | X | X | | | | | | | | |
| | | 0320 | Ebb | 1 | | X | X | X | X | | X | | | | | | | |
| | | | | 2 | | | X | | X | | | X | | | | | | |
| | | | | 3 | | | X | X | X | | X | | | | | | | |
| | | 0630 | SF | 1 | | X | X | X | X | | X | | | | X | | | |
| | | | | 2 | | X | X | X | X | | | | | | | | | |
| | | | | 3 | | | X | X | X | X | | | | | | | | |
| | | 0950 | Flood | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | X | X | | | | | | | | | |
| | | 1210 | SE | 1 | | X | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | X | | | | | | | | | |

Table 12: Summary of fishes caught with gill nets at Piankatank River, VA sites on August 4-5, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/4/97 | New | 1127 | Flood | 1 | | | X | | X | | | | X | | | | | |
| | | | | 2 | | | X | | | | | | X | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1420 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1740 | Ebb | 1 | | | X | | X | | | | X | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |
| | | 2045 | SF | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | | | X | X | X | | | | | | | | | |
| | | 2350 | Flood | 1 | | X | X | | X | | | X | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | | | X | | | X | | | | | | |
| 8/5/97 | New | 0315 | SE | 1 | | | X | | X | X | | X | | | | | | |
| | | | | 2 | | X | X | | X | | | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| | | 0630 | Ebb | 1 | | | X | X | X | | | | | | | | | |
| | | | | 2 | | | X | X | | X | | | | | | | | |
| | | | | 3 | | | X | X | X | | | | | | | | | |
| | | 0930 | SF | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | X | X | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1200 | Flood | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |

Table 13: Summary of fishes caught with gill nets at Piankatank River, VA sites on August 18-19, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/18/97 | Full | 1415 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1630 | Ebb | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | X | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 2020 | SF | 1 | | | | X | | | | | | | | | | |
| | | | | 2 | | | | X | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | X | |
| | | 2300 | Flood | 1 | | | X | X | | | | X | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| 8/19/97 | Full | 0230 | SE | 1 | | X | X | X | | X | | | | | | | | |
| | | | | 2 | | | | X | | X | | | | | | | | |
| | | | | 3 | | | | X | X | | | X | | | | | | |
| | | 0530 | Ebb | 1 | | | X | X | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | X | X | | | | | | | | | |
| | | 0815 | SF | 1 | | | | X | | | | | | | | | | |
| | | | | 2 | | X | | | | | | | | | | | | |
| | | | | 3 | | | | X | | | | | | | | | | |
| | | 1115 | Flood | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1430 | SE | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |

Table 14: Summary of fishes caught with gill nets at Piankatank River, VA sites on September 2-3, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE).

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/2/97 | New | 1410 | SE | 1 | | | X | X | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | | X | | | | | | | | | | |
| | | 1730 | Ebb | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 2030 | SF | 1 | X | X | X | X | | | | X | | | | | | |
| | | | | 2 | | | X | X | | | | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| | | 2340 | Flood | 1 | | X | X | X | X | X | | X | | | | | | X |
| | | | | 2 | X | X | X | X | X | | | | | | | | | |
| | | | | 3 | X | X | X | X | X | | | | | | | | | |
| 9/3/97 | New | 0230 | SE | 1 | | X | X | X | X | X | | X | | | | | | |
| | | | | 2 | | | | X | | | | | | | | | | |
| | | | | 3 | | X | X | | X | X | | X | | | | | | |
| | | 0600 | Ebb | 1 | X | | X | X | | X | | X | X | | | | | |
| | | | | 2 | | X | X | X | X | X | | | X | | | | | |
| | | | | 3 | | X | X | X | | | | | | | | | | |
| | | 0925 | SF | 1 | X | X | | X | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | X | | | | | | | X | | | |
| | | 1245 | Flood | 1 | | | | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | | | | | | | | | | | | |
| | | 1645 | SE | 1 | | X | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | X | | | | | | | | | | |

Table 15: Summary of fishes caught with gill nets at Piankatank River, VA sites on September 15-16, 1997 during the 36 hour sampling station. Three sites were sampled: Palace Bar Reef (1), Roane Point (2), and Ginney Point (3). Site descriptions are provided in the text. Sampling was conducted on one of four tidal stages: Ebb, Slack onto Flood (SF), Flood, and Slack onto Ebb (SE). This station was not completed due to the presence of non-*Pfisteria* lesions on fishes.

| Date | Moon Phase | Time | Tidal stage | Site | Striped bass | Bluefish | Croaker | Spot | Menhaden | Weakfish | Sea trout | Silver perch | Herring | Shad | Hog choker | Carp | Summer flounder | Butter fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/15/97 | Full | 1200 | SE | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | | |
| | | 1542 | Ebb | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | | | | | | | | | | | | |
| | | | | 3 | | X | X | X | | | | | | | | | | |
| | | 1830 | SF | 1 | | | X | | | | | | | | | | | |
| | | | | 2 | | | X | | | | | | | | | | | |
| | | | | 3 | | | X | | | | | | | | | | X | |
| | | 2140 | Flood | 1 | | X | | X | | X | | X | | | | | | |
| | | | | 2 | | | X | X | X | | | | | | | | | |
| | | | | 3 | | X | X | X | X | | | | | | | | | |
| 9/16/97 | Full | 0100 | SE | 1 | X | X | X | X | X | X | | X | | | | | | |
| | | | | 2 | | X | | X | | | | X | | | | | | |
| | | | | 3 | | | X | | X | | | | | | | | | |

Table 16: Preliminary diet summary for striped bass caught during the first four thirty-six hour gill netting stations on the Piankatank River calculated from guts processed to date. The “Teleost” category refers to gut contents not indentifiable beyond this level.

| Date | Site | n | Mean TL (mm) | 1° prey/ Diet % | 2° prey/ Diet % | 3° prey/ Diet % |
|---|---|---|---|---|---|---|
| 22-23 May 97 | PBR | 25 | 322 | Polychaete/39 | Gobiidae/38 | Teleost/15 |
| | RP | 4 | 278 | Polychaete/53 | Teleost/19 | Mysid/15 |
| | GP | 28 | 273 | Polychaete/90 | Mysids/5 | Teleost/2 |
| 5-6 June 97 | PBR | 7 | 270 | Mysid/66 | Polychaete/26 | Gobiidae/3 |
| | RP | 0 | - | - | - | - |
| | GP | 10 | 269 | Polychaete/96 | Amphipod/33 | Teleost/1 |
| 19-20 June 97 | PBR | 11 | 285 | Mysid/93 | Polychaete/6 | Gobiidae/1 |
| | RP | 3 | 254 | Mysid/100 | | |
| | GP | 14 | 251 | Mysid/51 | Polychaete/40 | Xanthid/5 |
| 2-3 July 97 | PBR | 0 | - | | | |
| | RP | 0 | - | | | |
| | GP | 9 | 281 | Polychaete/50 | Gobiidae/25 | Teleost/25 |

Figure 1: Map of the Piankatank River in relation to the Chesapeake Bay showing sampling locations. Palace Bar Reef (C.) was sampled in 1996 and 1997. Sites at Ginney Point (A.) and Roane Point (B.) were established in 1997 to provide data for nonreef habitats. This figure is taken from Harding and Mann (In review 1).

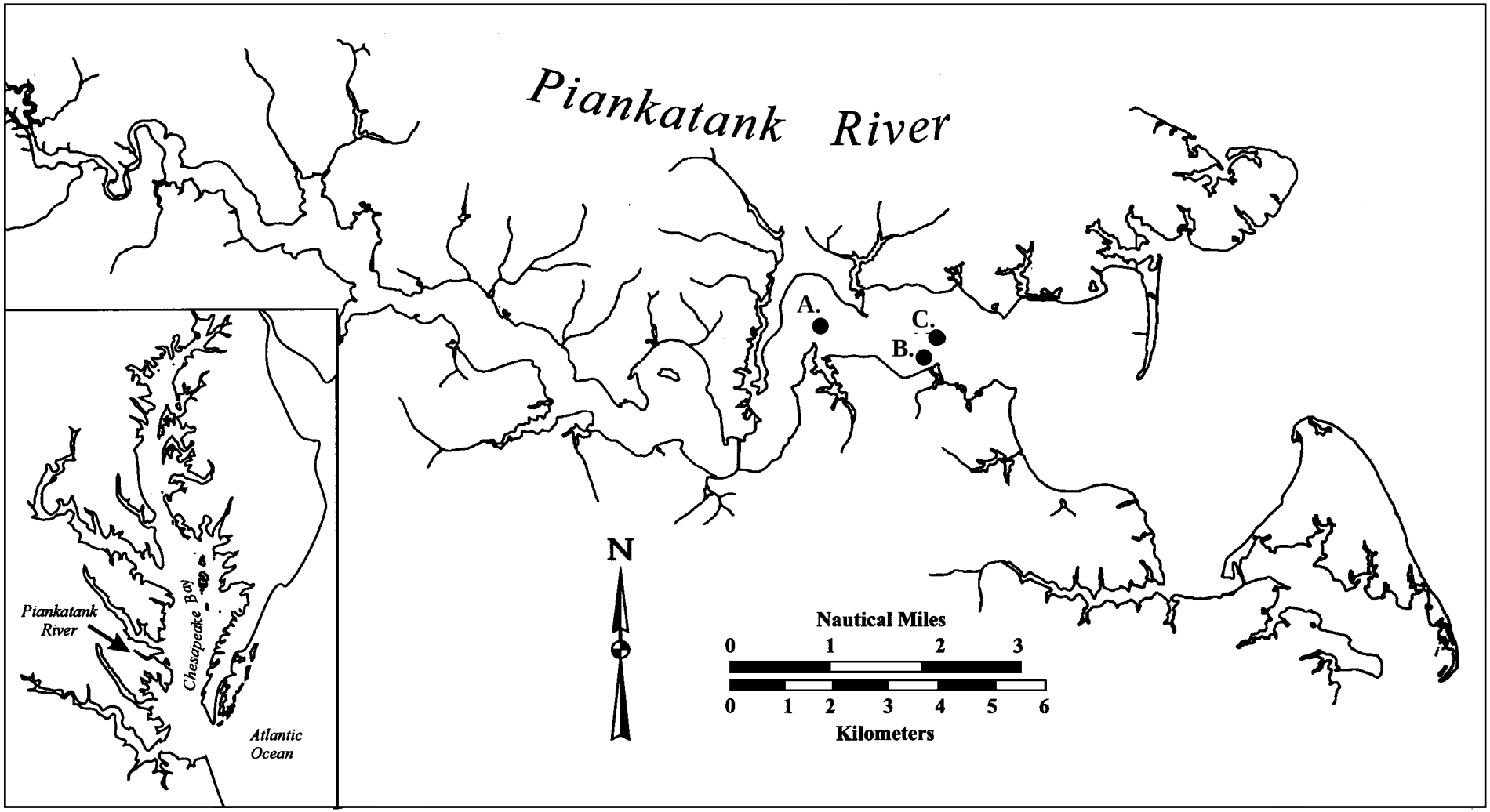

Piankatank River
A.
B.
C.
N
Nautical Miles
0 1 2 3
0 1 2 3 4 5 6
Kilometers
Piankatank River
Chesapeake Bay
Atlantic Ocean

Figure 2: Average annual spatfall for 1967-97 (± standard error) recorded at Palace Bar Piankatank River, Virginia. Data provided courtesy of the VIMS Molluscan Ecology program.

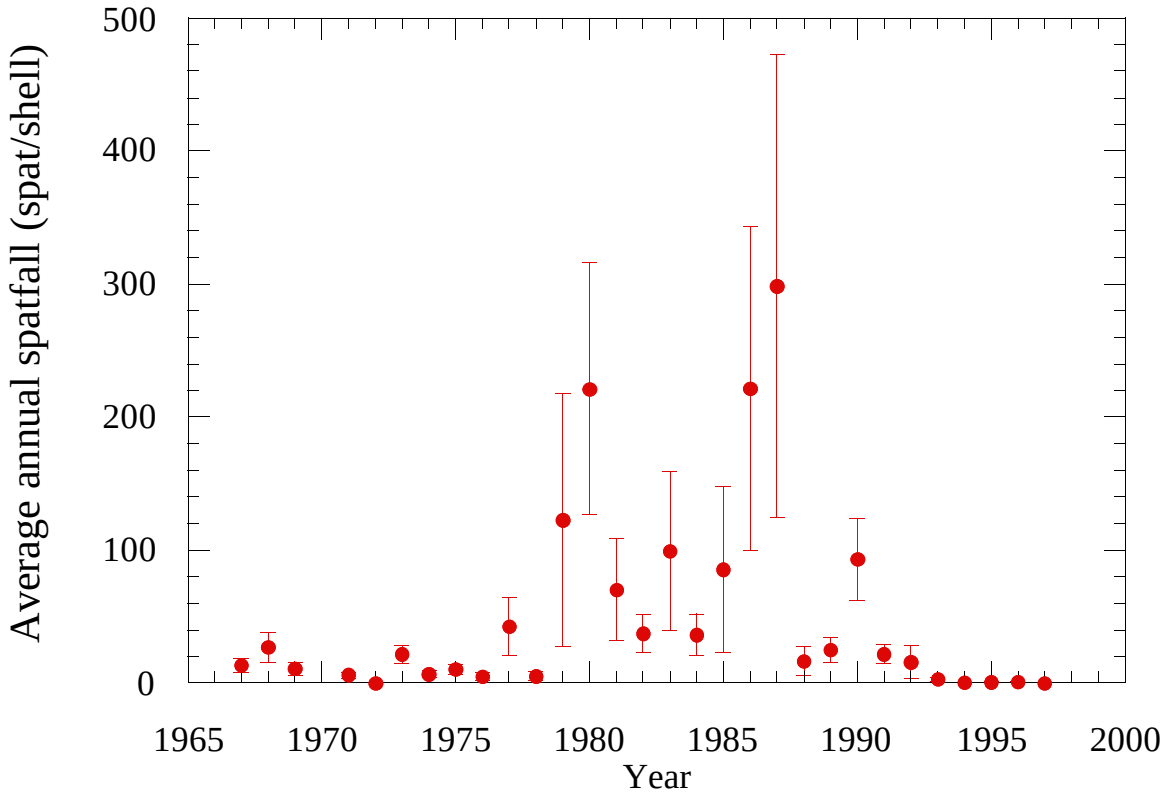

Average annual spatfall (spat/shell)
500
400
300
200
100
0
1965
1970
1975
1980
1985
1990
1995
2000
Year

Figure 3: Average annual oyster abundance (1946-97) recorded through dredge surveys of Palace Bar Piankatank River, Virginia. Data for both small and market oysters are presented courtesy of the VIMS Molluscan Ecology program.

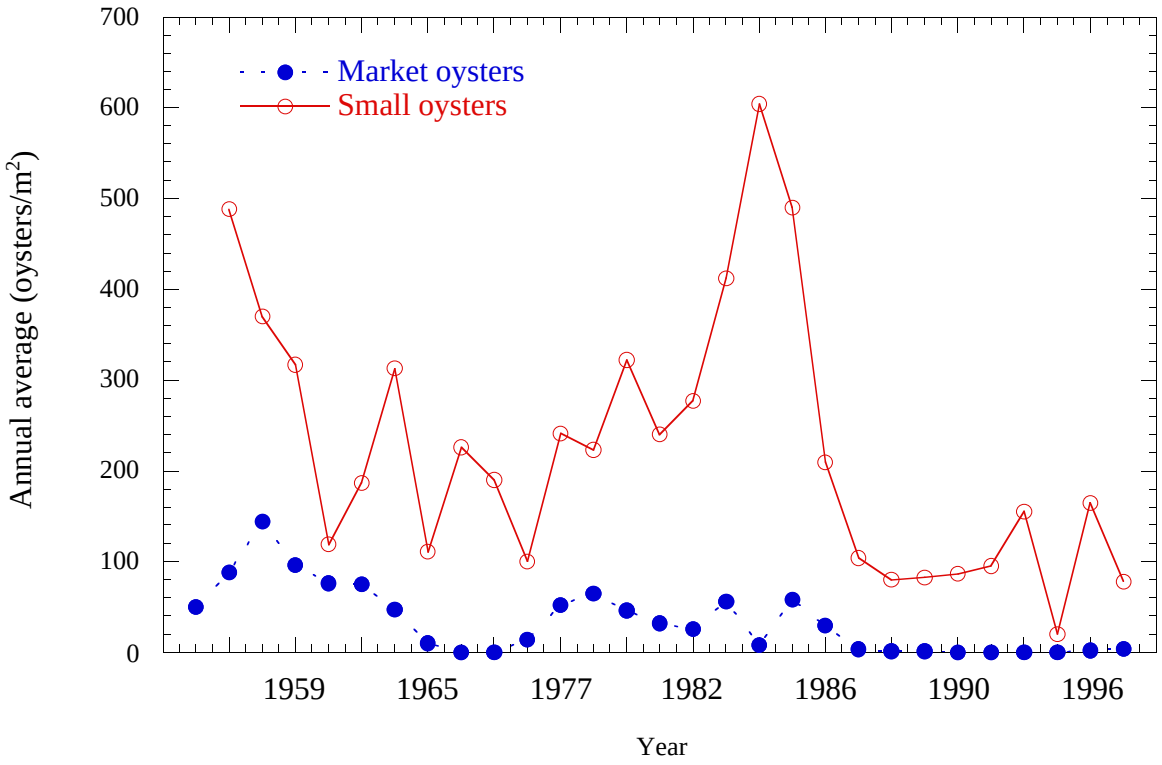

Market oysters
Small oysters
Annual average (oysters/m2)
700
600
500
400
300
200
100
0
1959
1965
1977
1982
1986
1990
1996
Year

Figure 4: Mean salinity and water temperature values (± std. error) for Ginney Point and Palace Bar Reef Piankatank River, Virginia from May to October in 1996 and 1997. Data from these two sites were averaged since there was no siginficant difference in temperature or salinity measurements between sites (ANOVA, $p < 0.05$). Reference mean values for salinity (‰, A.) and temperature (°C, B.) data from 1993-95 are plotted with a solid line (± standard error). Data from 1996 and 1997 are indicated by lines with symbols (± standard error). This figure is taken from Harding and Mann (In review 1).

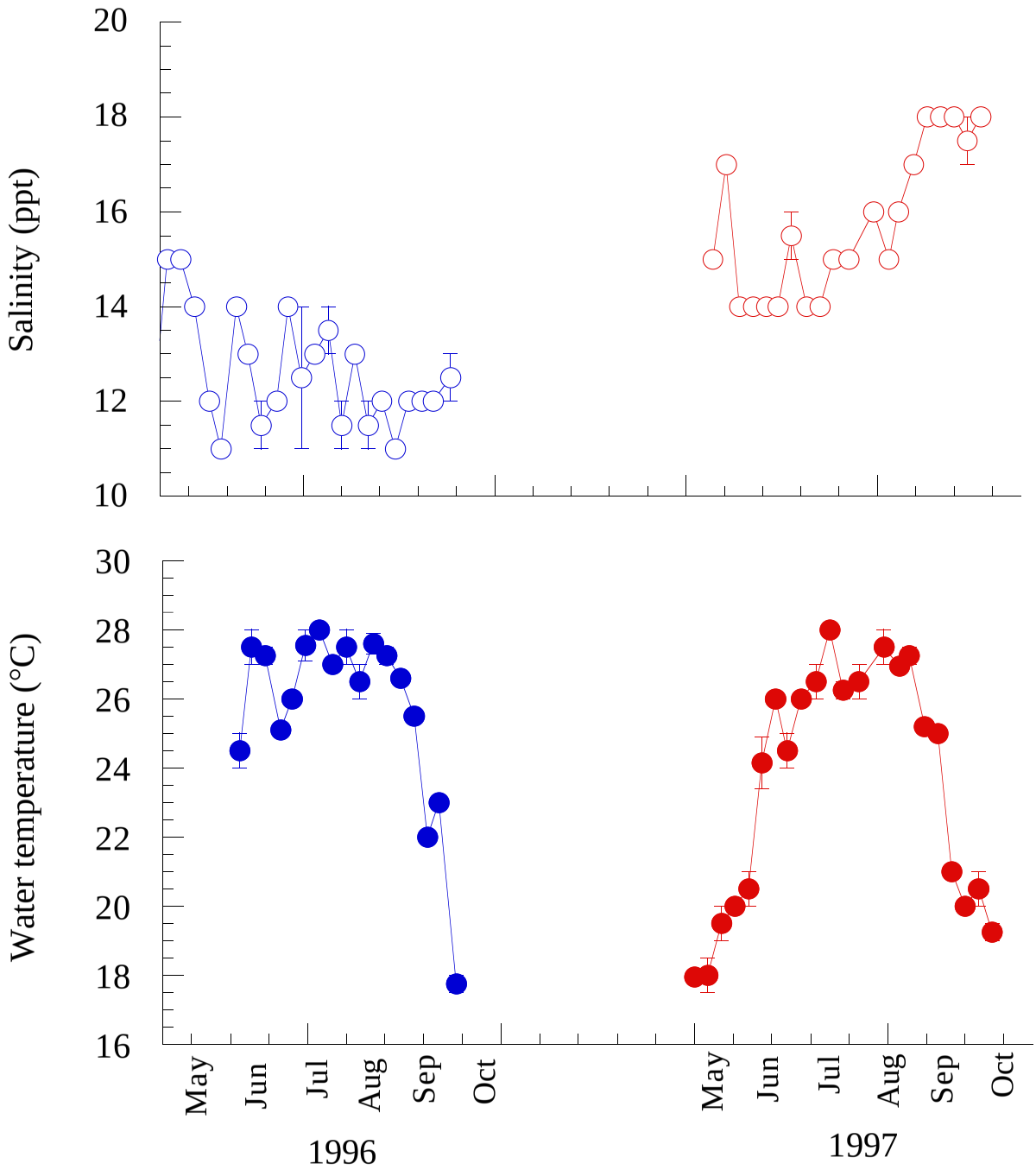
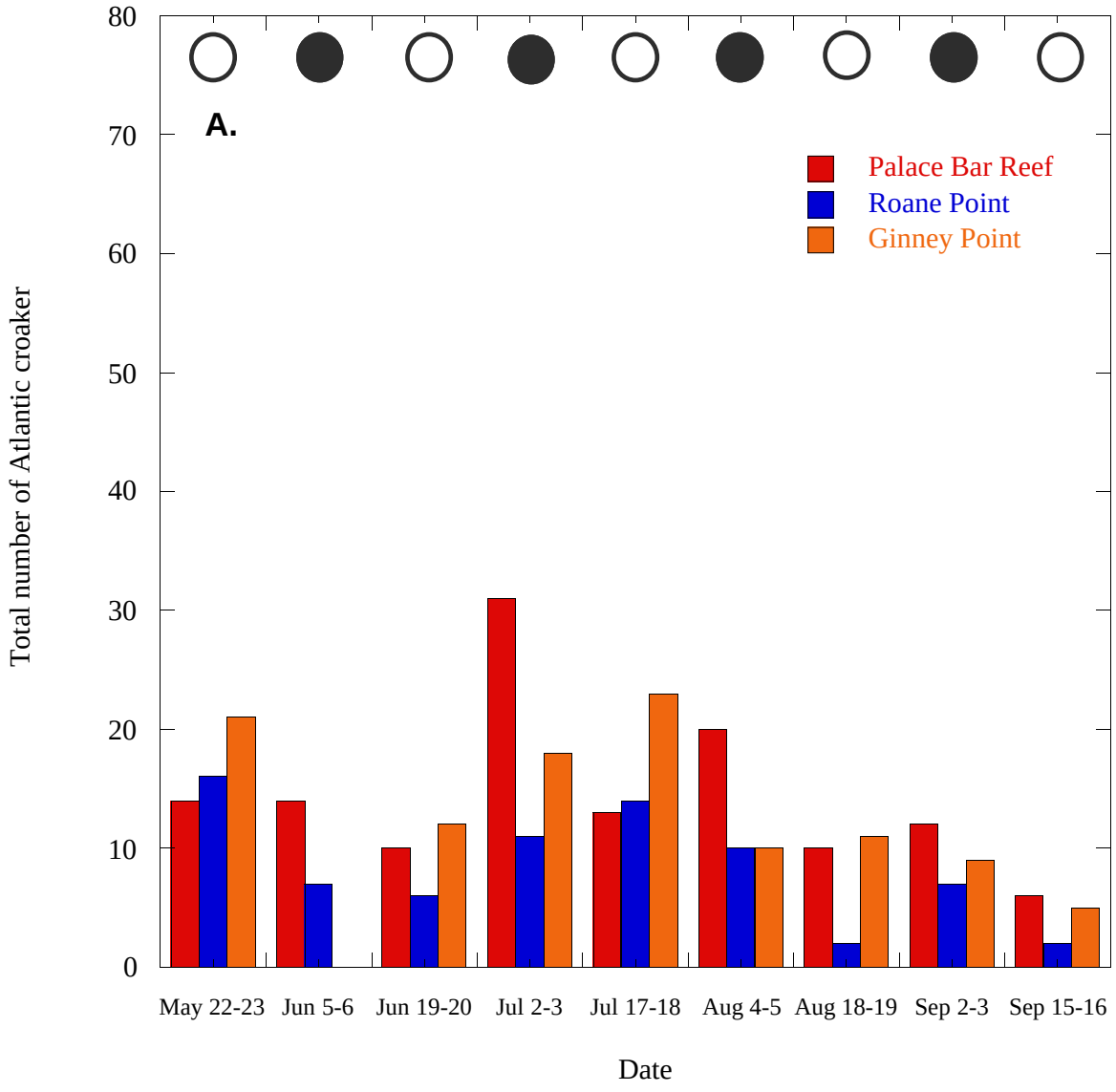
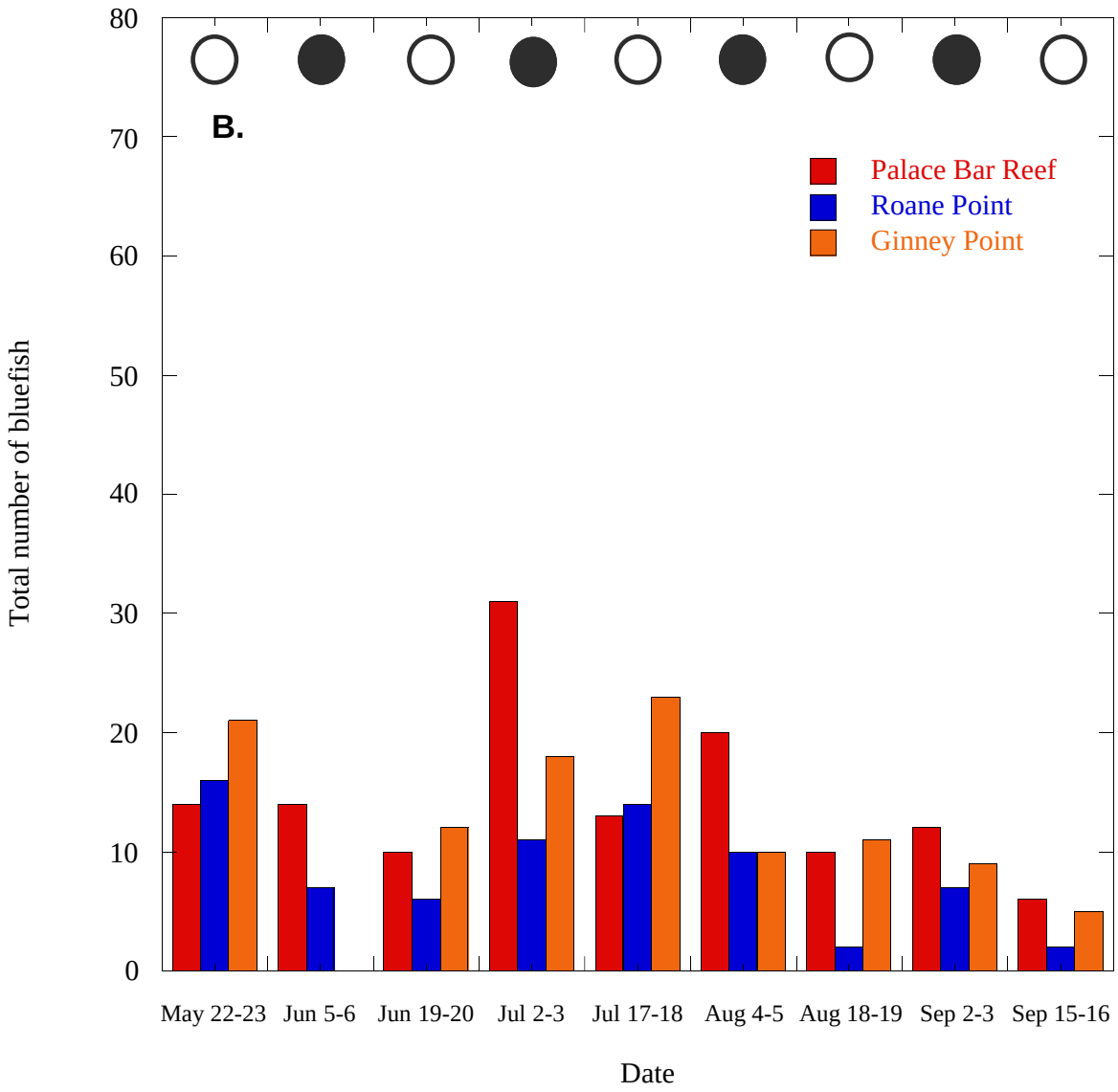
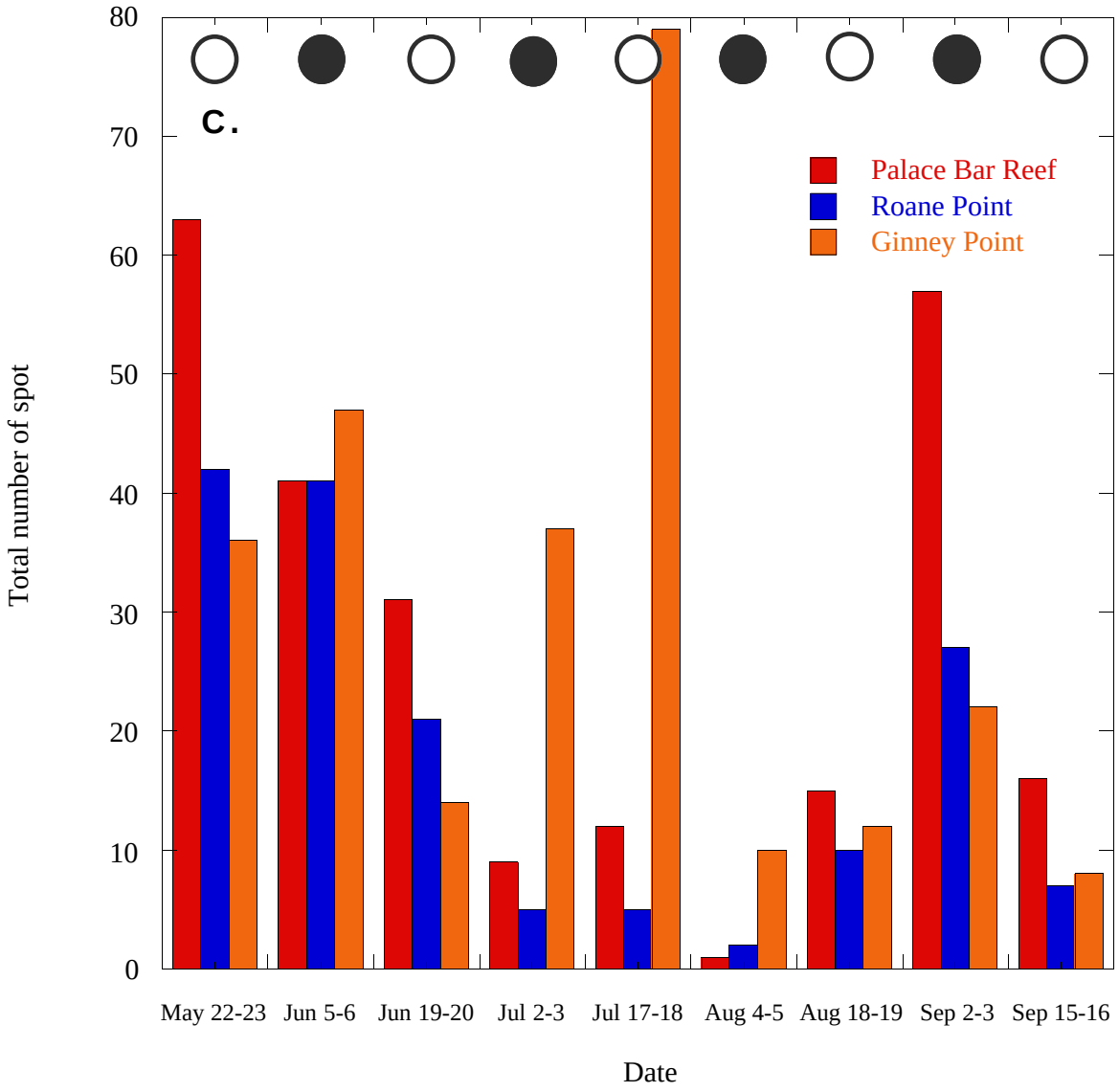

Salinity (ppt)
20
18
16
14
12
10
Water temperature (°C)
30
28
26
24
22
20
18
16
May
Jun
Jul
Aug
Sep
Oct
1996
May
Jun
Jul
Aug
Sep
Oct
1997

Figure 5: Total abundance of the four most common pelagic fishes caught by gill netting on the Piankatank River, Virginia during the 1997 36 hour stations. Total number of fish captured during each station are presented by site for (A.) Atlantic croaker, (B.) Bluefish, (C.) Spot and (D.) Striped bass. Open circles indicate sampling stations on the full moon; closed circles represent stations completed on the new moon.


A.
Palace Bar Reef
Roane Point
Ginney Point
Total number of Atlantic croaker
0
10
20
30
40
50
60
70
80
May 22-23
Jun 5-6
Jun 19-20
Jul 2-3
Jul 17-18
Aug 4-5
Aug 18-19
Sep 2-3
Sep 15-16
Date


B.
Palace Bar Reef
Roane Point
Ginney Point
Total number of bluefish
0
10
20
30
40
50
60
70
80
May 22-23
Jun 5-6
Jun 19-20
Jul 2-3
Jul 17-18
Aug 4-5
Aug 18-19
Sep 2-3
Sep 15-16
Date


C.
Palace Bar Reef
Roane Point
Ginney Point
Total number of spot
0
10
20
30
40
50
60
70
80
May 22-23
Jun 5-6
Jun 19-20
Jul 2-3
Jul 17-18
Aug 4-5
Aug 18-19
Sep 2-3
Sep 15-16
Date

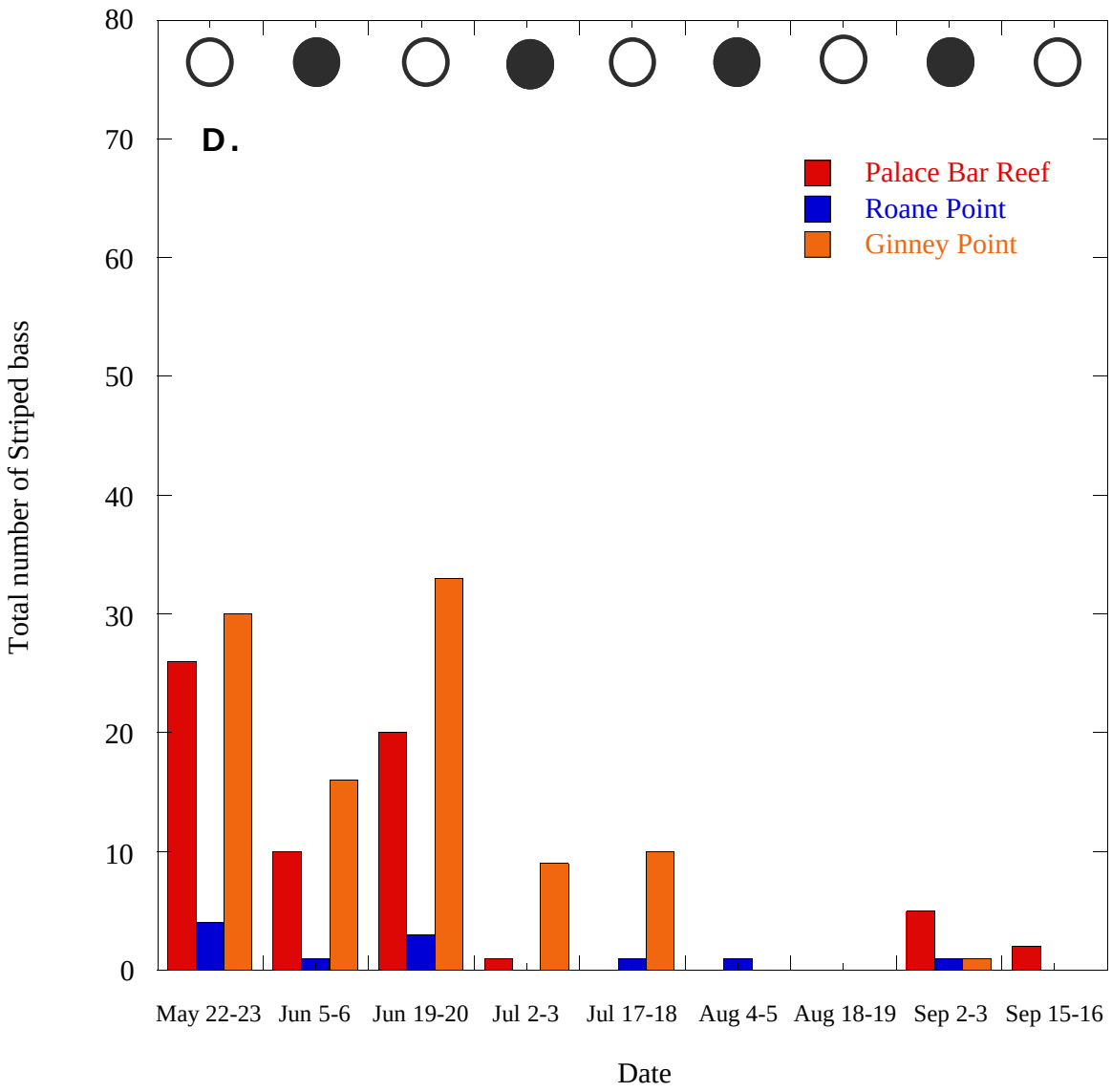

D.
Palace Bar Reef
Roane Point
Ginney Point
Total number of Striped bass
0
10
20
30
40
50
60
70
80
May 22-23
Jun 5-6
Jun 19-20
Jul 2-3
Jul 17-18
Aug 4-5
Aug 18-19
Sep 2-3
Sep 15-16
Date

Figure 6: Summary of bluefish gut contents for fishes collected at Piankatank River sampling sites during the 1996 and 1997 field seasons. This figure is from Harding and Mann (In review 3).

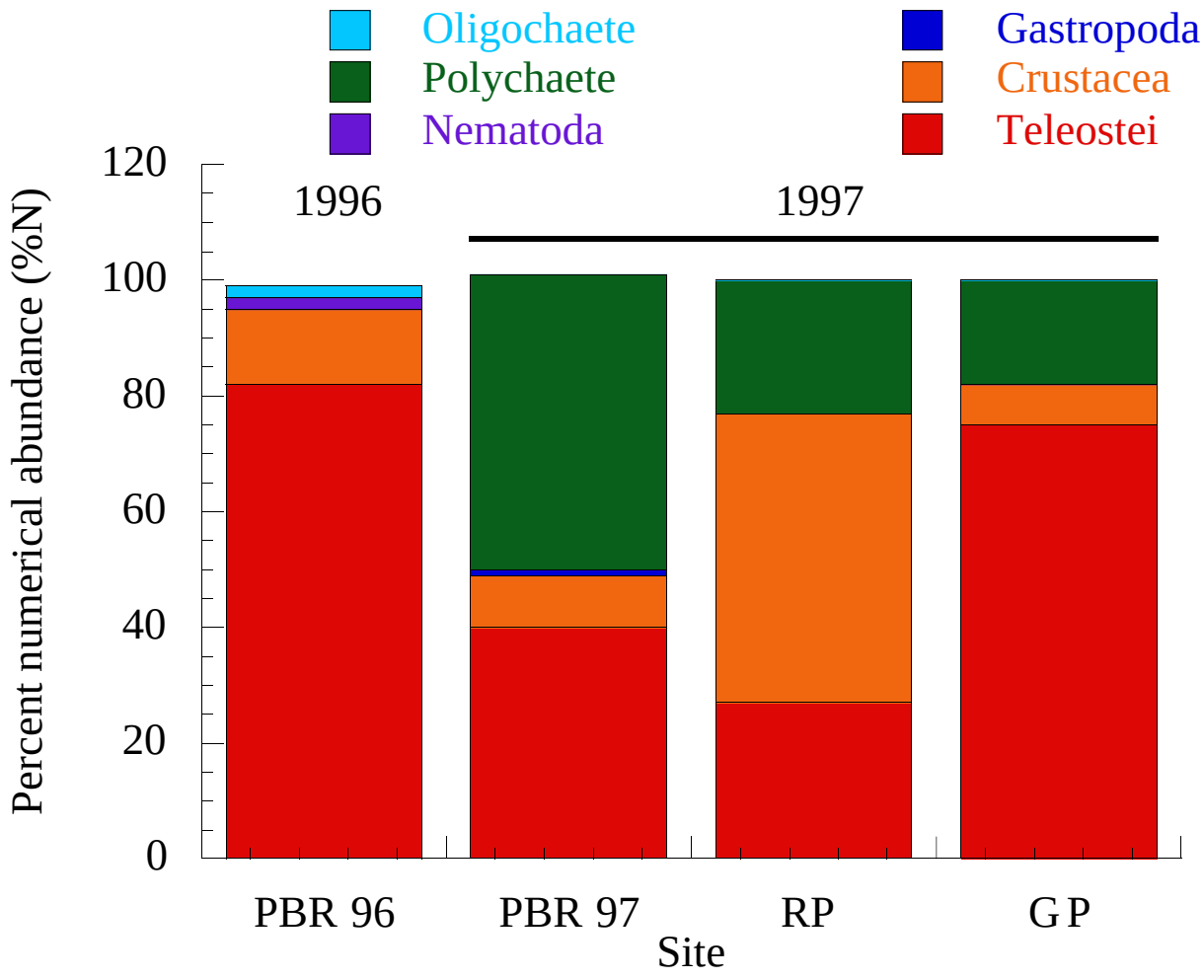

Oligochaete
Polychaete
Nematoda
Gastropoda
Crustacea
Teleostei
1996
1997
Percent numerical abundance (%N)
120
100
80
60
40
20
0
PBR 96
PBR 97
RP
G P
Site

Figure 7: Total blue crab abundance by site during the 1997 field season for the Piankatank River, VA.

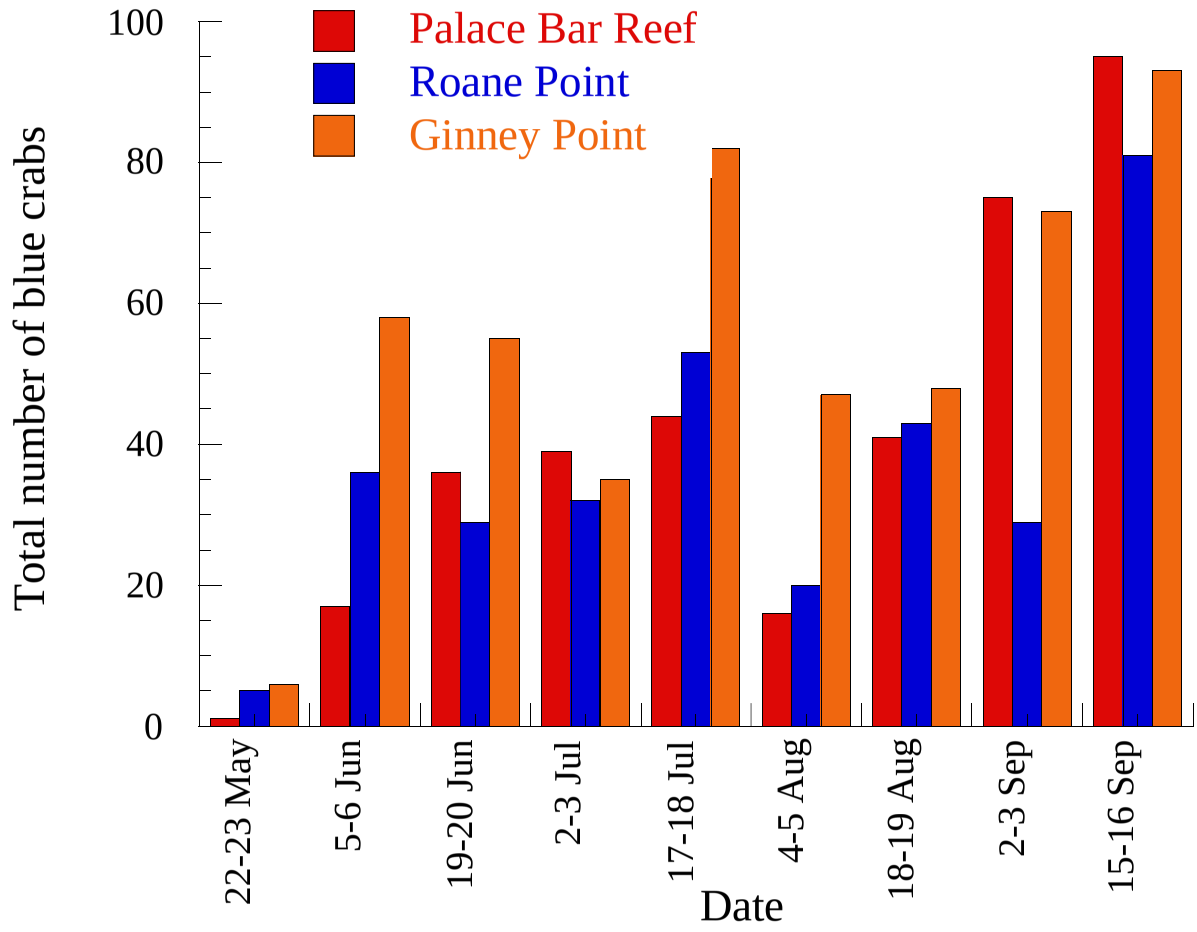
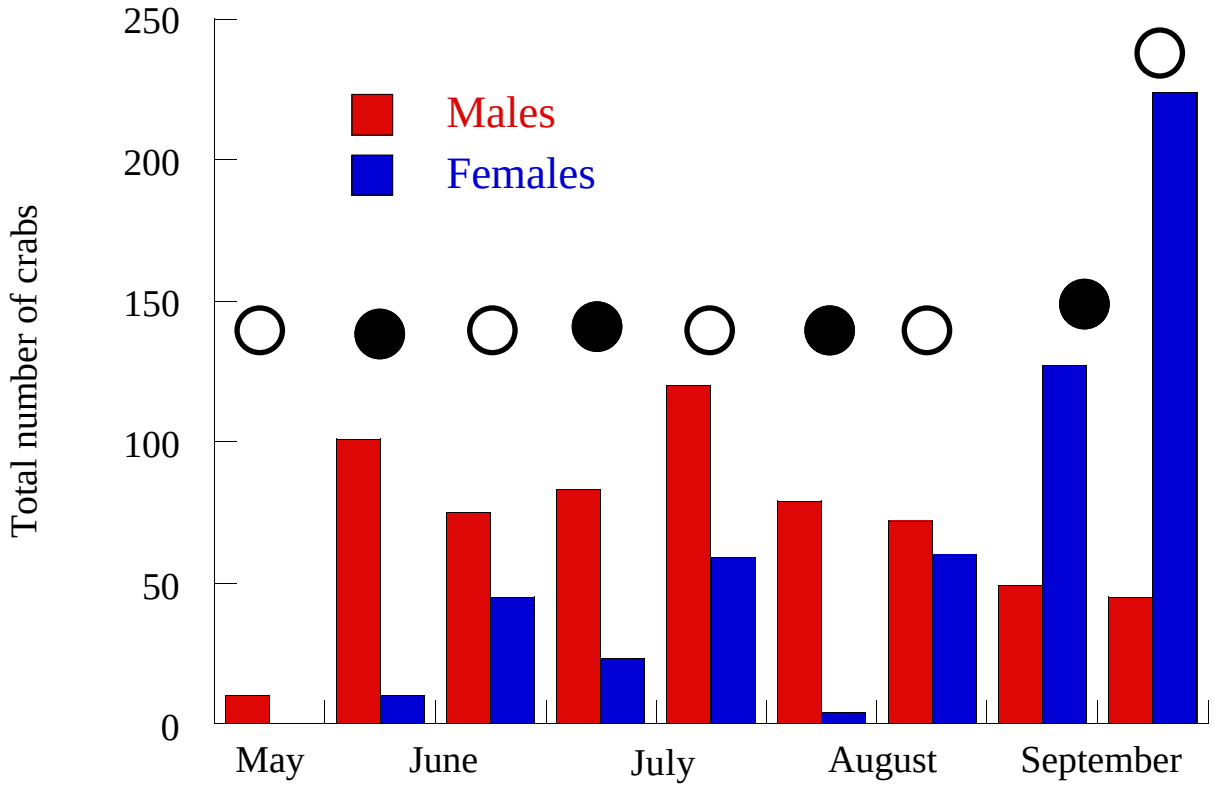

Palace Bar Reef
Roane Point
Ginney Point
Total number of blue crabs
100
80
60
40
20
0
22-23 May
5-6 Jun
19-20 Jun
2-3 Jul
17-18 Jul
4-5 Aug
18-19 Aug
2-3 Sep
15-16 Sep
Date

Figure 8: Total abundance of blue crabs by sex for all three Piankatank River, Virginia study sites. Open circles indicate sampling conducted on the full moon; closed circles represent new moon sampling dates.


250
200
150
100
50
0
Total number of crabs
Males
Females
May
June
July
August
September

## Appendix 1

## Field schedules for 1997 Piankatank River 36 hour sampling stations

36 hour sampling stations
Piankatank River
May 22-23 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 22 May | 0700 | | Crew 1 assembles @ VIMS |
| | 0730 | | Crew 1 leaves VIMS |
| | 0830 | | Launch @ Harcum |
| | 0900 | | Set RP crab pots |
| | 0930 | | Set GP crab pots |
| | 1000 | | Set PBR crab pots |
| | | | Take oxygen @ PBR |
| | 1040 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 1115 | | Take oxygen @ RP, GP |
| | 1200 | | Lunch |
| | 1350 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1600 | | Crew change @ Harcum |
| | 1655 | Max Ebb | GNC #2/set #3 |
| | 1830 | | Pizza pick-up/water refill |
| | 1915 | | Glo stick deployment |
| | 1955 | Slack onto Flood | GNC #3/set #4 |
| Sunset | 2014 | | |
| | 2258 | Max Flood | GNC #4/set #5 |
| 23 May | 0100 | | Crew change @ Admiral's |
| | 0222 | Slack onto Ebb | GNC #5/set #6 |
| | 0544 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0551 | | |
| | 0750 | | Crew change @ Harcum |
| | 0830 | Slack onto Flood | GNC #7/set #8 |
| | 1125 | Max Flood | GNC #8/set #9 |
| | 1300 | | Lunch |
| | 1430 | Slack onto Ebb | GNC #9/set #10 |
| | 1730 | Max Ebb | GNC #10 |
| | 1900 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
June 5-6 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 5 June | 0700 | | Crew 1 assembles @ VIMS |
| | 0730 | | Crew 1 leaves VIMS |
| | 0830 | | Launch @ Harcum |
| | 0900 | | Set RP crab pots |
| | 0930 | | Set GP crab pots |
| | 1000 | | Set PBR crab pots |
| | | | Take oxygen @ PBR |
| | 1048 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 1115 | | Take oxygen @ RP, GP |
| | 1200 | | Lunch |
| | 1350 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1600 | | Crew change @ Harcum |
| | 1702 | Max Ebb | GNC #2/set #3 |
| | 1830 | | Pizza pick-up/water refill |
| | 1915 | | Glo stick deployment |
| | 2002 | Slack onto Flood | GNC #3/set #4 |
| Sunset | 2024 | | |
| | 2309 | Max Flood | GNC #4/set #5 |
| 6 June | 0100 | | Crew change @ Admiral's |
| | 0220 | Slack onto Ebb | GNC #5/set #6 |
| Sunrise | 0545 | | |
| | 0551 | Max Ebb | GNC #6/set #7 |
| | 0750 | | Crew change @ Harcum |
| | 0830 | Slack onto Flood | GNC #7/set #8 |
| | 1133 | Max Flood | GNC #8/set #9 |
| | 1300 | | Lunch |
| | 1440 | Slack onto Ebb | GNC #9/set #10 |
| | 1747 | Max Ebb | GNC #10 |
| | 1900 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
June 19-20 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 19 June | 0700 | | Crew 1 assembles @ VIMS |
| | 0730 | | Crew 1 leaves VIMS |
| | 0830 | | Launch @ Harcum |
| | 0930 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 0930 | | Set PBR, RP, GP crab pots |
| | 1230 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1345 | | Lunch |
| | 1542 | Max Ebb | GNC #2/set #3 |
| | 1730 | | Crew change @ Harcum |
| | 1840 | Slack onto Flood | GNC #3/set #4 |
| | 2000 | | Glostick deployment |
| Sunset | 2030 | | |
| | 2149 | Max Flood | GNC #4/set #5 |
| 20 June | 0030 | | Crew change @ Admiral's |
| | 0115 | Slack onto Ebb | GNC #5/set #6 |
| | 0436 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0545 | | |
| | 0715 | Slack onto Flood | GNC #7/set #8 |
| | 0845 | | Crew change @ Harcum |
| | 1015 | Max Flood | GNC #8/set #9 |
| | 1145 | | Lunch |
| | 1330 | Slack onto Ebb | GNC #9/set #10 |
| | 1630 | Max Ebb | GNC #10 |
| | 1800 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
July 2-3 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 2 July | 0600 | | Crew 1 assembles @ VIMS |
| | 0630 | | Crew 1 leaves VIMS |
| | 0745 | | Launch @ Harcum |
| | 0852 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 0900 | | Set PBR, RP, GP crab pots |
| | 1120 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1200 | | Lunch |
| | 1506 | Max Ebb | GNC #2/set #3 |
| | 1700 | | Crew change @ Harcum |
| | 1800 | Slack onto Flood | GNC #3/set #4 |
| | 1945 | | Glostick deployment |
| Sunset | 2031 | | |
| | 2119 | Max Flood | GNC #4/set #5 |
| 3 July | 0000 | | Crew change @ Admiral's |
| | 0030 | Slack onto Ebb | GNC #5/set #6 |
| | 0402 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0550 | | |
| | 0630 | Slack onto Flood | GNC #7/set #8 |
| | 0900 | | Crew change @ Harcum |
| | 0942 | Max Flood | GNC #8/set #9 |
| | 1130 | | Lunch |
| | 1230 | Slack onto Ebb | GNC #9/set #10 |
| | 1555 | Max Ebb | GNC #10 |
| | 1730 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
July 17-18 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 17 July | 0600 | | Crew 1 assembles @ VIMS |
| | 0630 | | Crew 1 leaves VIMS |
| | 0745 | | Launch @ Harcum |
| | 0806 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 0900 | | Set PBR, RP, GP crab pots |
| | 1110 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1200 | | Lunch |
| | 1422 | Max Ebb | GNC #2/set #3 |
| | 1645 | | Crew change @ Harcum |
| | 1720 | Slack onto Flood | GNC #3/set #4 |
| | 1945 | | Glostick deployment |
| Sunset | 2026 | | |
| | 2030 | Max Flood | GNC #4/set #5 |
| | 2330 | | Crew change @ Admiral's |
| 18 July | 0010 | Slack onto Ebb | GNC #5/set #6 |
| | 0322 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0559 | | |
| | 0630 | Slack onto Flood | GNC #7/set #8 |
| | 0830 | | Crew change @ Harcum |
| | 0900 | Max Flood | GNC #8/set #9 |
| | 1130 | | Lunch |
| | 1210 | Slack onto Ebb | GNC #9/set #10 |
| | 1516 | Max Ebb | GNC #10 |
| | 1730 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
August 4-5 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 4 August | 0630 | | Crew 1 assembles @ VIMS |
| | 0700 | | Crew 1 leaves VIMS |
| | 0745 | | Launch @ Harcum |
| | 0830 | Slack onto Flood | Gill net set #1 (PRB, RP, GP) |
| | 0900 | | Set PBR, RP, GP crab pots |
| | 1127 | Max Flood | Gill net Check #1/Set #2 |
| | 1200 | | Lunch |
| | 1435 | Slack onto Ebb | GNC #2/set #3 |
| | 1700 | | Crew change @ Harcum |
| | 1745 | Max Ebb | GNC #3/set #4 |
| | 1945 | | Glostick deployment |
| Sunset | 2011 | | |
| | 2040 | Slack onto Flood | GNC #4/set #5 |
| | 2340 | Max Flood | GNC #5/set #6 |
| 5 August | 0130 | | Crew change @ Admiral's |
| | 0315 | Slack onto Ebb | GNC #6/set #7 |
| Sunrise | 0614 | | |
| | 0616 | Max Ebb | GNC #7/set #8 |
| | 0845 | | Crew change @ Harcum |
| | 0910 | Slack onto Flood | GNC #8/set #9 |
| | 1130 | | Lunch |
| | 1200 | Max Flood | GNC #9/set #10 |
| | 1510 | Slack onto Ebb | GNC #10 |
| | 1730 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
August 18-19 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 18 August | 0800 | | Crew 1 assembles @ VIMS |
| | 0830 | | Crew 1 leaves VIMS |
| | 1000 | | Launch @ Harcum |
| | 1030 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 1100 | | Set PBR, RP, GP crab pots |
| | 1245 | | Lunch |
| | 1335 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1648 | Max Ebb | GNC #2/set #3 |
| | 1825 | | Crew change @ Harcum |
| | 1900 | | Glostick deployment |
| | 1940 | Slack onto Flood | GNC #3/set #4 |
| Sunset | 1954 | | |
| | 2247 | Max Flood | GNC #4/set #5 |
| 19 August | 0200 | | Crew change @ Admiral's |
| | 0215 | Slack onto Ebb | GNC #5/set #6 |
| | 0522 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0625 | | |
| | 0820 | Slack onto Flood | GNC #7/set #8 |
| | 1000 | | Crew change @ Harcum |
| | 1115 | Max Flood | GNC #8/set #9 |
| | 1300 | | Lunch |
| | 1430 | Slack onto Ebb | GNC #9/set #10 |
| | 1742 | Max Ebb | GNC #10 |
| | 1900 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
September 2-3 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 2 September | 0900 | | Crew 1 assembles @ VIMS |
| | 0930 | | Crew 1 leaves VIMS |
| | 1030 | | Launch @ Harcum |
| | 1100 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 1130 | | Set PBR, RP, GP crab pots |
| | 1245 | | Lunch |
| | 1410 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1615 | | Crew change @ Harcum |
| | 1722 | Max Ebb | GNC #2/set #3 |
| | 1900 | | Glostick deployment |
| Sunset | 1933 | | |
| | 2020 | Slack onto Flood | GNC #3/set #4 |
| | 2300 | | Crew change @ Admiral's |
| | 2330 | Max Flood | GNC #4/set #5 |
| 3 September | 0240 | Slack onto Ebb | GNC #5/set #6 |
| | 0541 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0638 | | |
| | 0715 | | Crew change @ Harcum |
| | 0840 | Slack onto Flood | GNC #7/set #8 |
| | 1150 | Max Flood | GNC #8/set #9 |
| | 1300 | | Lunch |
| | 1500 | Slack onto Ebb | GNC #9/set #10 |
| | 1800 | Max Ebb | GNC #10 |
| | 1930 | | Boat recovery @ Harcum |

36 hour sampling stations
Piankatank River
September 15-16 1997

PBR = Palace Bar Reef
RP = Roane Point
GP = Ginney Point

| Date | Time | Tidal stage | Event |
|---|---|---|---|
| 15 September | 0730 | | Crew 1 assembles @ VIMS |
| | 0745 | | Crew 1 leaves VIMS |
| | 0830 | | Launch @ Harcum |
| | 0900 | Max Flood | Gill net set #1 (PRB, RP, GP) |
| | 1000 | | Set PBR, RP, GP crab pots |
| | 1150 | | Lunch |
| | 1220 | Slack onto Ebb | Gill net Check #1/Set #2 |
| | 1540 | Max Ebb | GNC #2/set #3 |
| | 1750 | | Crew change @ Harcum |
| | 1820 | Slack onto Flood | GNC #3/set #4 |
| | 1900 | | Glostick deployment |
| Sunset | 1914 | | |
| | 2130 | Max Flood | GNC #4/set #5 |
| 16 September | 0030 | | Crew change @ Admiral's |
| | 0100 | Slack onto Ebb | GNC #5/set #6 |
| | 0410 | Max Ebb | GNC #6/set #7 |
| Sunrise | 0649 | | |
| | 0705 | Slack onto Flood | GNC #7/set #8 |
| | 0900 | | Crew change @ Harcum |
| | 1000 | Max Flood | GNC #8/set #9 |
| | 1130 | | Lunch |
| | 1315 | Slack onto Ebb | GNC #9/set #10 |
| | 1630 | Max Ebb | GNC #10 |
| | 1745 | | Boat recovery @ Harcum |