Biological Status of Sanctuary Waters of the Hudson River Park in New York

Final Project Report

for the

Hudson River Park Trust

by

Mark B. Bain, Marcia S. Meixler,
and Geof E. Eckerlin

Cornell University
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March 2006

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Cover images (top down): Anne Gallagher Ernst, Ted Treska, Geof Eckerlin,
Andrea Parmenter, Jeremy Dietrich, and the Hudson River Park waters.

Bain, M. B., M. S. Meixler, and G. E. Eckerlin. 2006. Biological status of sanctuary waters of the Hudson River Park in New York. Final Project Report by Cornell University to the Hudson River Park Trust, New York.

Summary -- The Hudson River Park occupies the western waterfront of Manhattan (New York, NY) from the Battery to 59th Street and provides water oriented recreation, public access, and an estuary sanctuary for protection of fish, wildlife, and their habitats. Almost immediately following 9/11 the sanctuary waters of the Hudson River Park were dredged to allow large barge access to the shore at Pier 25 for World Trade Center debris removal. Objectives of this study were: (1) to assess the impact of dredging on fish, benthic macroinvertebrates, and habitat; (2) to monitor the redevelopment of an aquatic community in the dredged area; and (3) to characterize the status of the aquatic communities in a range of sanctuary habitats. Without pre-dredging data, we needed to rely on a comparison of dredged versus undredged sites over time to infer impacts and environmental status.

Physicochemical and biological sampling was conducted monthly from June 2002 (end of debris barging) through June 2004 at eight sites along the Hudson River Park. Fish were captured with a 6-m wide otter trawl deployed four times at each site. Benthic macroinvertebrates were sampled using a Ponar grab (0.053 m^2 area) deployed two times at each site. A total of 35,869 fish of 41 species and 78,925 benthic organisms of 145 taxa were collected. The dredged site was not different from the other sites in the abundance and diversity of fish over the study period. Despite high abundance and diversity of aquatic life in the Park, we found that fish and invertebrate assemblages were dominated by inappropriate organisms. The current Park biota is overwhelmingly dominated by fish that primarily occupy open coastal waters, and benthic invertebrates tolerant of pollution and environmental stress. The nature of fish and invertebrate communities in the Hudson River Park make detection of dredging impacts difficult.

Habitat modifications in the Hudson River Park could promote a more proper shoreline fish fauna. Dedicating one or more inter-pier areas to shallow, vegetated fish habitat would enhance the abundance of fishes expected in shoreline waters of estuaries. Habitat enhancements in the Park to improve the invertebrate assemblage does not appear feasible. These organisms are constrained by water and sediment quality problems at the scale of the upper harbor. Local actions seem unlikely to correct this, but improvements in harbor water and sediment quality are underway.

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Introduction

New York was the busiest seaport in the world through much of the 1900s. The major shipping facilities were located along the Hudson River waterfront on the west side of Manhattan. The Hudson River waterfront declined as a primary port for New York with changes in shipping technology and increasing vessel sizes. By the 1970s, shipping effectively ended on Manhattan's waterfront and alternative uses for the area were considered. The Hudson River Park Trust was created in the 1990s as a state and city partnership to redevelop the waterfront as a park area supporting public uses. From the Battery to 59th Street, the Hudson River Park now provides water oriented recreation, public access, and a designated estuarine sanctuary for protection of fish, wildlife, and their habitats.

Almost immediately following the destruction of the World Trade Center, sanctuary waters of the Hudson River Park were dredged to allow large barge access to the shore at Pier 25 for building debris removal. While the 9/11 attack and the need for recovery of lower Manhattan justified altering sanctuary waters, the potential adverse consequences of dredging were considered by Park leaders. Within a month of 9/11, a study was planned to assess impacts on aquatic life and define recovery actions for the sanctuary waters. This report presents the findings of the post-dredging study, and it provides an assessment of the status of aquatic life in the Hudson River Park.

Dredging impacts on aquatic life have been well studied and are generally predictable. Dredging causes acute stress to aquatic organisms due to physical destruction of habitats and degraded water quality from suspension of sediments and high turbidity. Long-term impacts are a consequence of altered habitats that are usually deeper, devoid of cover and refugee structure, and dominated by new substrate material. We hypothesized an initial response to dredging would result in diminished fish and benthic macroinvertebrate numbers and diversity, followed by a redevelopment of a community using the new deeper and less structured habitat.

Fish inhabiting dredged sites can be expected to reflect disturbance and environmental stress through changed species composition and abundance. Fish respond to changed habitats through their selection of occupation locations, and their mobility often results in rapid response to local disturbance. Benthic macroinvertebrates also respond to habitat disturbance and change but in a different manner. Invertebrates occur in much higher species numbers than fish and this diversity of species will generally cover a broader range of environmental requirements and stress tolerances. High potential diversity makes invertebrate community composition very indicative of environmental conditions. Also, invertebrates are typically less mobile than fish so their occurrence in a habitat often reflects conditions over many weeks or months. Both fish and invertebrates are routinely used for impact detection and environmental quality monitoring (Plafkin et al. 1989, Gibson et al. 2000).

Working with fish and benthic macroinvertebrates, our study objectives were to: (1) assess the impact of dredging on the biota and habitat of the Hudson River Park estuarine sanctuary; (2) monitor the redevelopment of an aquatic community in the dredged area; and (3) characterize the status of the aquatic communities in a range of sanctuary habitats. Without pre-dredging data, we needed to rely on a comparison of dredged versus unimpacted sites over time to infer impacts and environmental status. Finally, the findings are used to recommend strategies for enhancing the habitats and biota of the Hudson River Park.

Methods

The Hudson River Park includes the shoreline waters (to maximum pier line; 305 m [1000 ft.]) of the west side of Manhattan between Battery City and 59th Street. Physicochemical and biological sampling was conducted monthly from June 2002 through June 2004 at eight sites along the Hudson River Park (Figure 1). Sampling started soon after debris barging ended at pier 25, and continued for 25 months. Sampling sites were chosen to include the dredged site (pier 25, Figure 2) and seven similar undredged sites (piers 26, 32, 49, 52,

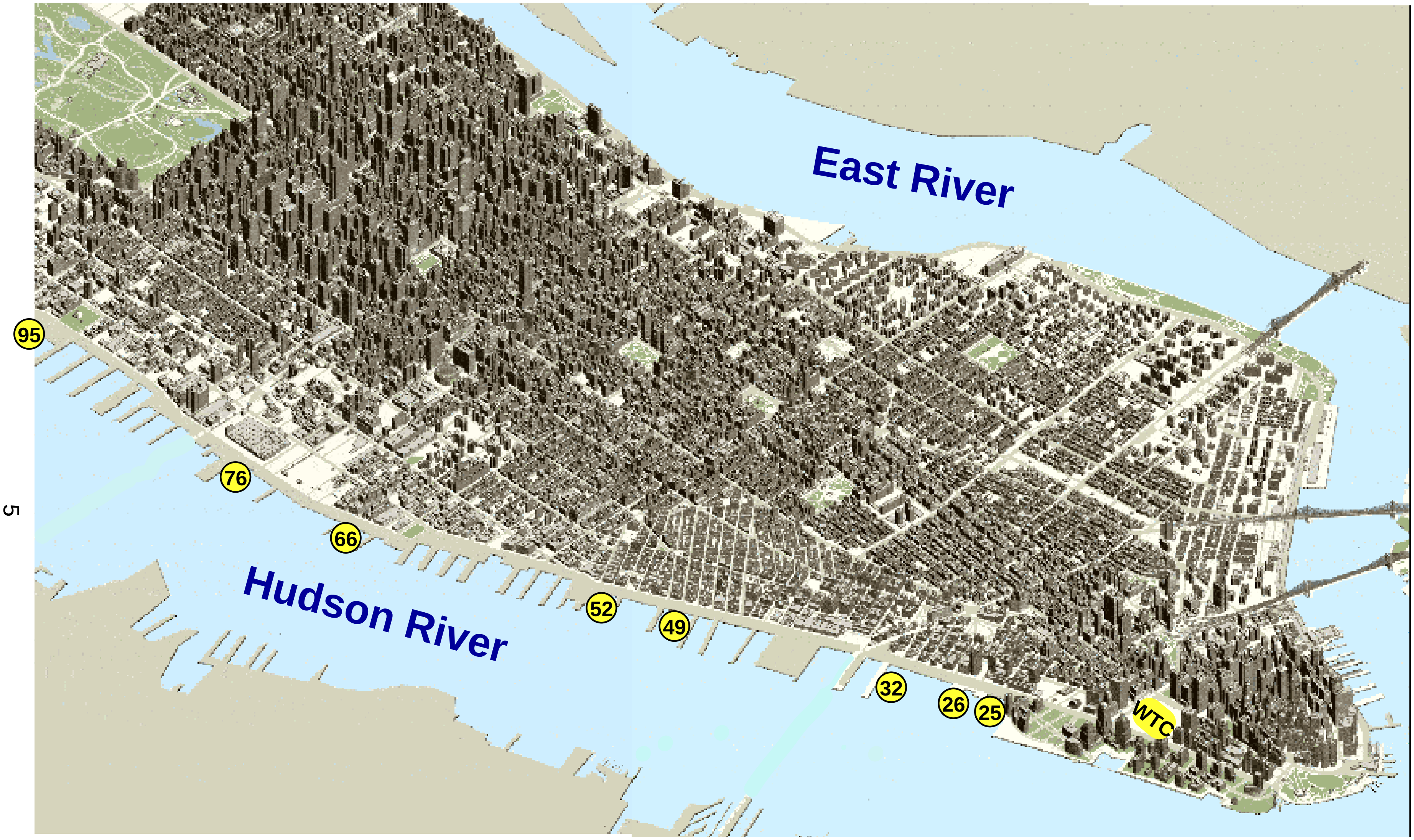


Figure 1. Location of study sites named after pier numbers along the Hudson River shoreline of Manhattan Island. The former location of the World Trade Center (WTC) is shown with site 25 being the location of debris barge docking.

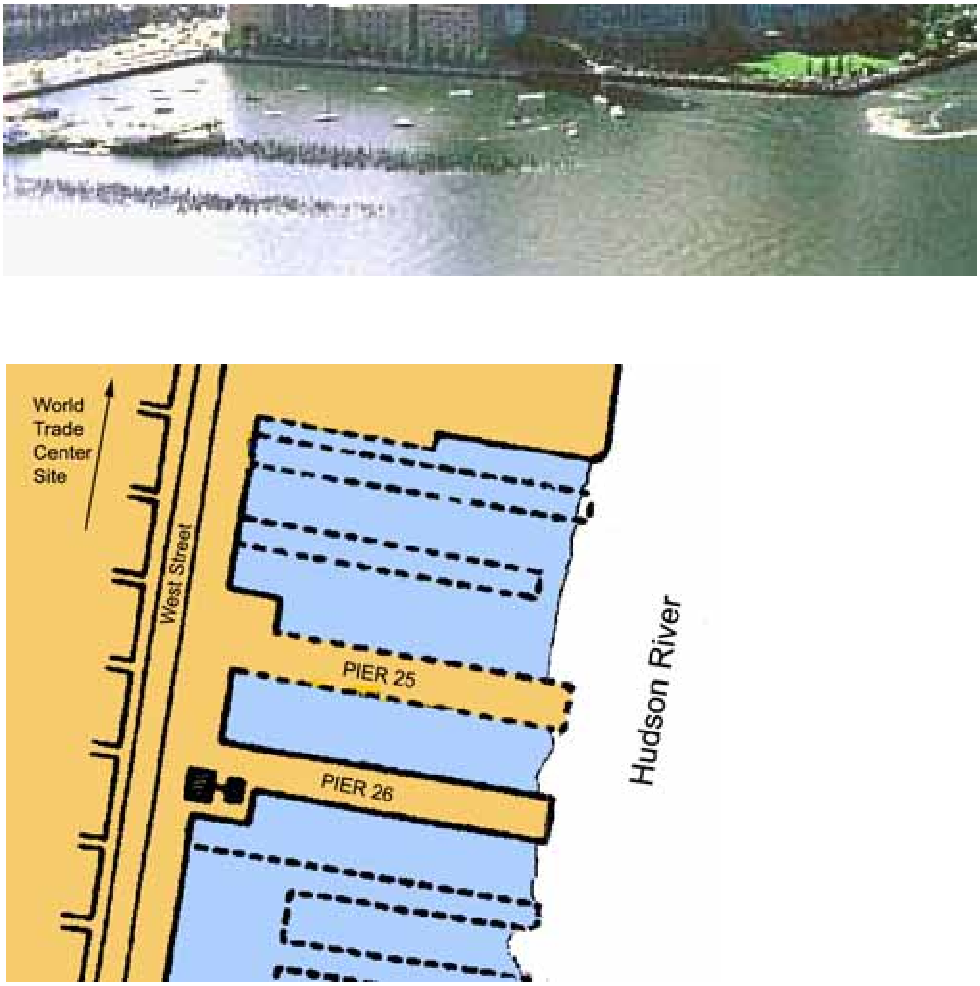


Figure 2. Photograph and navigation map of the dredged area adjacent to pier 25. Dashed pier outlines indicate locations of former piers (blue) and abandoned piers with a visible piling field (yellow). Pier 26 is shown as intact on the navigation map but was without a deck at the time of the photograph (2001). Dredging was concentrated on the abandoned piers not visible in the photograph but shown on the navigation map.

66, and 95). The sampling area at each site was between the shore and the outer extent of piers. Appendix A includes detailed images of study sites showing the area sampled, and navigation maps with location of current and past piers (commonly associated with piling fields and submerged pier structure debris).

Prior to biological sampling, we measured surface and bottom water properties at each site. Salinity and water temperature were recorded using a YSI model 30/50 S-C-T meter. Dissolved oxygen was measured with a YSI model 51 meter. Position and water depth were recorded from a Raytheon model RC425 chart plotter and depth finder.

Fish were captured using a 6-m wide otter trawl with 5-cm stretch mesh netting and a 0.6-cm stretch mesh cod end liner. The trawl was dropped close to the shoreline and pulled by the 8.5-m research vessel Acipenser toward the Hudson River channel. Trawls were performed four times at each site per month. Captured fish were identified to species, enumerated, and measured (TL in mm) in the field. Fish were released unless identification was not possible without laboratory inspections. These fish were preserved in 10% buffered formalin and later keyed to species. There were some deviations from the sampling plan: December 2002 and February 2003 had equipment failures and thick ice; gear problems reduced trawl numbers at some sites in September 2003, January 2004 and March 2004; and sampling at pier 76 was discontinued after November 2003 because of repeated entanglement of trawling gear in submerged obstructions.

Benthic macroinvertebrates were sampled using a Ponar grab (0.053 m^2 area) deployed two times at each site per month. Samples were fixed with 10% buffered formalin in the field. Upon returning to the lab, samples were rinsed through sieves with mesh sizes of 0.50 mm, 2.0 mm, and 4.75 mm, stained with Rose Bengal (84% dye content), sorted, enumerated, and identified (Jeremy Dietrich, Cornell University) to the most complete taxonomic level allowed by 40X magnification. Hudson River benthic invertebrate specialists Anne Gallagher, United States Geological Survey (Troy NY), and Dr. Bob Cerrato, State University of New York at Stony Brook, confirmed identities of select invertebrate samples.

Analysis of the physical, chemical, and biological data were conducted to identify variations among sites and through time. A two-way repeated measures analysis of variance (ANOVA) was generally used to test for site and time interactions. Tests of the hypothesis that the dredged site 25 differed from the seven other undredged sites was done by computing the 95% confidence interval about the mean (n = 7) for each parameter (fish catch rate and species richness, invertebrate density and richness) of interest and comparing the observed value for site 25. We sought evidence for a persistent pattern of low values at site 25 by inspected plots of the 25 month series of confidence intervals and site 25 observations.

The quality status of the Hudson River Park fish community was assessed as a whole (sites pooled) over the study period (months pooled). A target fish community for the Hudson River Park was derived from a database developed by the National Oceanic and Atmospheric Administration’s Estuarine Living Marine Resources (ELMR) Program (Stone et al. 1994, Nelson and Monaco 2000) beginning in the late 1980s. Data on all juvenile and adult fishes were retrieved for Barnegat Bay (NJ), the Connecticut River (CT), Long Island Sound (CT, NY), Narragansett Bay (RI), and New Jersey Inland Bays (NJ) in a salinity range of 0.5 to 25 ppt. Values were retrieved for life stage and species relative abundance (not present, rare, common, abundant, and highly abundant) by month. An overall expected abundance value for a species was computed by summing mean monthly abundance values for the juvenile and adult life stage and averaging across the five estuarine systems. These expected abundance values were then ranked to provide a list of fish expected to inhabit the Hudson River Park in order from the most dominant to rare species. Fish species ranks were converted to expected target fish community proportions. Expected proportions were computed by converting species ranks to reciprocals (1/rank), summing these in decimal form, and dividing the reciprocal rank (decimal) by the sum of all reciprocal ranks. The methods follow the target community specification technique of Bain and Meixler (2006a) which has been used to define target fish communities associated with quality environments in northeast rivers (Bain and Meixler 2006b, Meixler and Eleria 2006). The theoretical basis for this technique is the linear log-log relations widely documented in many fields (reviewed in Mandelbrot 1983, Bak 1996, Ricklefs and Miller 2000, Solè and Goodwin 2000).

We employed target community modeling (Bain and Meixler 2000a) as a means of evaluating biotic conditions in the Hudson River over time. The target community model is an inference approach used to set a numeric biotic baseline for environmental planning. It provides a benchmark for assessing comparability and allows users to identify the nature of departures. The target fish community developed from the ELMR database was compared to the observed fish community of the Hudson River Park. Species displaying major deviations from the target community in their abundance were grouped into underrepresented and over-represented species. The biology of these fishes were compiled to identify common habitat and water quality requirements by group. Species biology was summarized from Hardy (1978), Smith (1985), Jenkins and Burkhead (1993), Collette and Klain-MacPhee (2002), Froese and Pauly (2005), and sources noted on species biology summaries in Appendix B.

Our assessment of invertebrate community quality used a multi-metric benthic index of biotic integrity (B-IBI) developed for the New York/New Jersey Harbor (Weisberg, et al. 1998). Community quality metrics were those for mesohaline mud: species richness, abundance (#/m^2), abundance of pollution-indicative taxa (%), abundance of pollution-sensitive taxa (%), and abundance of carnivores/omnivores (%). Pollution-sensitive and pollution-indicative taxa classifications were found in Weisberg et al. (1998). Feeding modes were assigned using literature descriptions of feeding behavior (Gilbert and Suchow 1977, Lopez and Cheng 1983, Oakden 1984, Hughes and Drewett 1985, Young and Cameron 1989, Chalermwat et al. 1991, New York Department of Environmental Conservation 1991, Morgan 1992, Chester 1993, Rhodes and Thompson 1993, Thomas 1993, Beninger and St. Jean 1997, Kaag et al. 1997, Bostrom and Matilla 1999, Ingalls et al. 2000, Bricelj et al. 2001, Rouse and Pleijel 2001, Whitman et al. 2001, Riisgard and Seerup 2003, Silliman et al. 2003, Valentine et al. 2002, Brown 2004, Connor et al. 2004, Dyrynda 2004, Gulf of Maine Biogeographic Information System 2004, The International Commission for the Scientific Exploration of the Mediterranean Sea 2004, Marine Biological Association 2004, Marine Biological Laboratory 2004, Museum of Paleontology 2004, Museum Victoria 2004, Ping 2004, Ramel 2004, Science

Daily 2004, Shimek 2004, Soil & Water Conservation Society of Metro Halifax 2004, Taylor and Peck 2004, Todd 2004, UK Marine Special Areas Conservation 2004, University of Michigan Museum of Zoology 2004). Each metric was assigned a value of 5, 3, or 1 depending on whether its value approximated, deviated slightly from, or deviated greatly from conditions expected at high quality reference sites, respectively (Table 1). Values from all five metrics were averaged for each site. Sites with averaged values under three were classified as stressed, as their metrics on average were less than those at the poorest reference sites. A monthly series of stress frequency in all samples (n=16) was plotted by month to identify trends in the quality of invertebrate communities through the study period.

Results

Water depth differed among sites (ANOVA, $p \leq 0.0001$) with site 25 having the highest average depth (5.2 m, 17.0 feet, Table 2). This site also had the highest minimum measured water depth (3.2 m, 10.4 feet) and almost the highest maximum water depth (6.6 m, 21.8 feet). The greater depths at site 25 can be attributed to the dredging of this site. Prior to September 2001 the site had submerged pier pilings (Figure 2) and other debris including cars removed in the dredging operation. The other sites ranged from 3.9 m (12.7 feet) to 1.8 m (5.8 feet) mean depth with the most northern sites being the shallowest (Table 2). Measurements were taken throughout the tidal cycle that has a mean range of 1.8 m (4.53 feet).

We saw no differences among sites in water temperatures (ANOVA, $p = 1.0$) with either surface or bottom measurements. Surface waters were slightly warmer (paired t-Test, mean difference 0.14 C, $p = 0.0049$)) than bottom waters across all sites. As expected, there were strong seasonal differences in water temperature (Figure 3) with the lowest mean temperature in February (lowest recording = 0 C) and the highest in August (highest = 25.9 C) of each study year.

Salinity was found to vary (ANOVA, $p \leq 0.0001$) among study sites in bottom waters only. Bottom water salinity was consistently higher at the downstream sites (south sites, site 25 mean 18.55 ppt) than the upstream sites (site 95 mean

Table 1. Benthic invertebrate community metrics and scoring criteria for the multi-metric benthic index of biotic integrity (B-IBI) developed for the New York/New Jersey Harbor (Weisberg, et al. 1998).

Metric	1 point	3 points	5 points
Number of species	14 or fewer	25-20	More than 20
Abundance (#/ m2)	Low (<1500) or very high (>20,000)	Relatively low (1500-3000) or Relatively high (20,000-20,000)	Moderate (3,000 - 10,000)
Proportion of pollution tolerant taxa	More than 40%	10 to 40%	Less than 10%
Proportion of pollution sensitive taxa	Below 3%	3 to 15%	Greater than 15%
Proportion of carnivore and omnivore taxa	Below 4%	4 to 15%	Greater than 15%

Table 2. Water depths measured during sampling between the shoreline and the end of the pier zone at each study site between June 2002 and July 2004. Measurements were not standardized relative to tidal cycle which has a mean range of 1.38 m (4.53 feet).

Site	N	Mean depth (m)	Minimum depth (m)	Maximum depth (m)
25	21	5.2	3.2	6.6
26	24	3.9	2.8	6.7
32	25	3.7	2.8	4.7
49	26	3.8	2.9	4.9
52	26	3.7	2.6	4.8
66	25	2.5	1.8	3.3
76	27	2.6	1.7	4.5
95	23	1.8	1.1	3.9

12.77 ppt). This was expected as the heavier salty water enters the river with upstream tidal movements. On average bottom water had a salinity of 15.84 ppt and a range of 5.9 to 25.9 ppt through the study period. Surface water salinity (mean 13.9) ranged from 5.8 to 25.2 ppt. As expected, salinity varied seasonally although the pattern was not as clear as temperature (Figure 3).

We saw no differences among sites in dissolved oxygen (ANOVA, $p \geq 0.999$) with either surface or bottom measurements. However, on average bottom waters were slightly lower (paired t-Test, $p = 0.0014$) in dissolved oxygen (mean difference 0.15 mg/l) than surface waters across all sites. There were strong seasonal differences in water temperature corresponding with variations in air temperature and biological activity (Figure 3). Dissolved oxygen concentrations in bottom waters were often adequate for aquatic life support (mean = 8.03 mg/l) but concentrations did drop to stressful levels (hypoxia, <4.0 mg/l) during late summer (minimum 3.75 mg/l, Figure 3). We expect that biological decomposition on and in the sediments consumed oxygen causing low levels in bottom waters. This same process would not affect surface waters in a well mixed environment like our study sites. Surface waters had slightly higher average (8.19 mg/l) oxygen levels in a range (4.1 to 14.0 mg/l) acceptable for aquatic life support.

During 24 sampling months, we made 158 trawl samples (625 trawls) at the eight study sites. A total of 35,869 fish and 41 species were recorded (Table 3). Trawl catches ranged from zero to 3,619 fish. The abundance of fish in trawl catches did not differ among sites (repeated measures ANOVA, $p = 0.28$, Figure 4) but did vary by sampling period (repeated measures ANOVA, $p \leq 0.0001$); there was no significant site and sampling period interaction. Peak catches occurred in the late summer and fall (Figure 5) when the abundance of bay anchovy accounted for most fish recorded in the study sites.

Species richness, or number of species recorded, ranged from 0 to 14 per trawl. As with fish abundance, there were no difference in species richness among the eight study sites (repeated measures ANOVA, $p = 0.92$, Figure 4). Species richness varied by sampling period (repeated measures ANOVA, $p \leq 0.0001$); there was no significant site and sampling period interaction. High

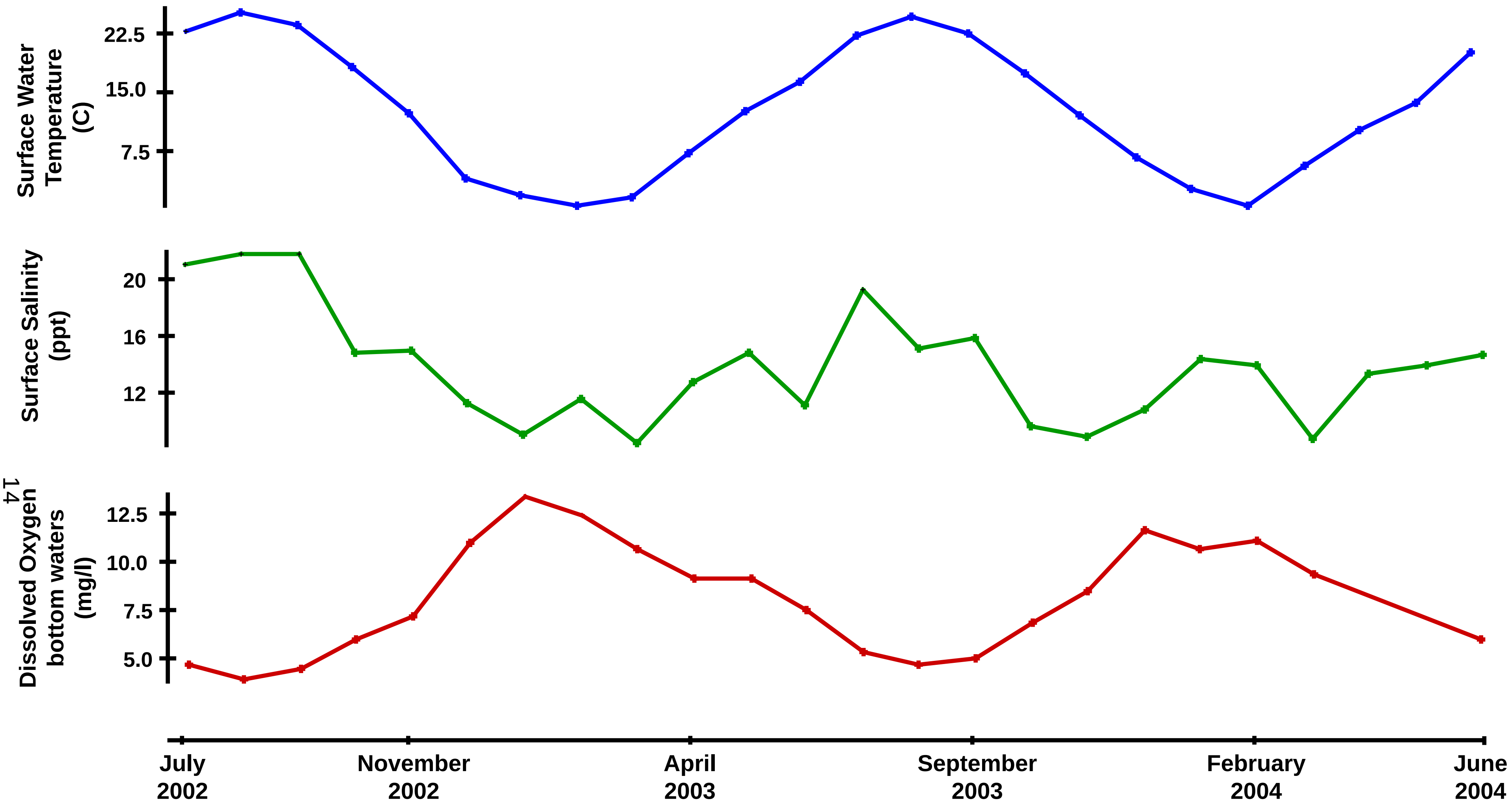


Figure 3. Mean surface water temperature, surface salinity, and bottom water dissolved oxygen during the study period. Plotted values are means of all study sites by month.

Table 3. Summary of captured fishes and their lengths

Name of fish		Number caught	Total length (mm)			
Common	Scientific		Min	Max	Middle 50%	Mean
Hogchoker	*Trinectes maculatus*	8	73	114	76-94	90
American eel	*Anguilla rostrata*	6	431	610	435-610	510
Atlantic silverside	*Menidia menidia*	6	81	107	86-93	93
Feather blenny	*Hypsoblennius hentzi*	1	-	-	-	-
Lookdown	*Selene vomer*	3	75	158	-	119
Shad, unidentified	*Alosa*	140	9	29	12-14	14
Blueback herring	*Alosa aestivalis*	850	25	237	58-76	68
Hickory shad	*Alosa mediocris*	12	27	321	69-222	172
Alewife	*Alosa pseudoharengus*	704	23	241	81-98	89
American shad	*Alosa sapidissima*	166	11	511	87-104	109
Atlantic menhaden	*Brevoorta tyrannus*	94	17	191	57-110	86
Atlantic herring	*Clupea harengus*	1903	4	215	46-57	52
Gizzard shad	*Dorosoma cepedianum*	21	101	210	147-170	158
Grubby	*Myoxocephalus aenaeus*	4	63	136	63-79	87
Bay anchovy	*Anchoa mitchilli*	29314	2	103	30-40	48
Striped anchovy	*Anchoa hepsetus*	186	9	111	80-89	83
Atlantic tomcod	*Microgadus microgadus*	397	17	224	34-68	61
Gobies, unidentified	*Gobiidae, Gobiosoma*	1	22	22	-	22
Seaboard goby	*Gobiosoma ginsburgi*	6	13	41	14-29	26
Cunner	*Tautogolabrus adspersus*	2	88	177	-	133
Goosefish	*Lophius americanus*	1	89	89	-	89
Silver hake	*Merluccius bilinearis*	8	58	174	62-82	88
Striped bass	*Morone saxatilis*	1328	7	1090	36-109	87
White perch	*Morone americana*	47	74	247	124-221	171
Gulf Stream flounder	*Citharichthys arctifrons*	4	60	72	60-68	66
Summer flounder	*Paralichthys dentatus*	20	10	347	294-330	290
Red hake	*Urophycis chuss*	4	58	133	58-91	88
Spotted hake	*Urophycis regia*	31	48	179	76-114	99
Winter flounder	*Pseudopleuronectes americanus*	82	36	266	89-153	122
Bluefish	*Pomatomus saltatrix*	82	19	423	121-198	150
Atlantic croaker	*Micropogonias undulatus*	68	7	53	12-20	12
Northern kingfish	*Menticirrhus saxatilis*	1	21	21	-	21
Spot	*Leiostomus xanthurus*	3	11	12	-	12
Weakfish	*Cynoscion regalis*	135	17	248	33-70	58
Windowpane	*Scophthalmus aquosus*	3	44	95	-	67
Rock sea bass	*Centropristis philadelphica*	1	76	76	-	76
Scup	*Stenotomus chrysops*	11	54	180	87-154	140
Butterfish	*Peprilus triacanthus*	159	11	246	22-139	81
Lined seahorse	*Hippocampus erectus*	2	65	105	-	85
Northern pipefish	*Syngnathus fuscus*	37	21	225	115-175	137
Northern searobin	*Prionotus carolinus*	13	19	41	23-32	29
Striped searobin	*Prionotus evolans*	3	34	294	-	130
Northern stargazer	*Astroscopus guttatus*	2	17	19	-	18

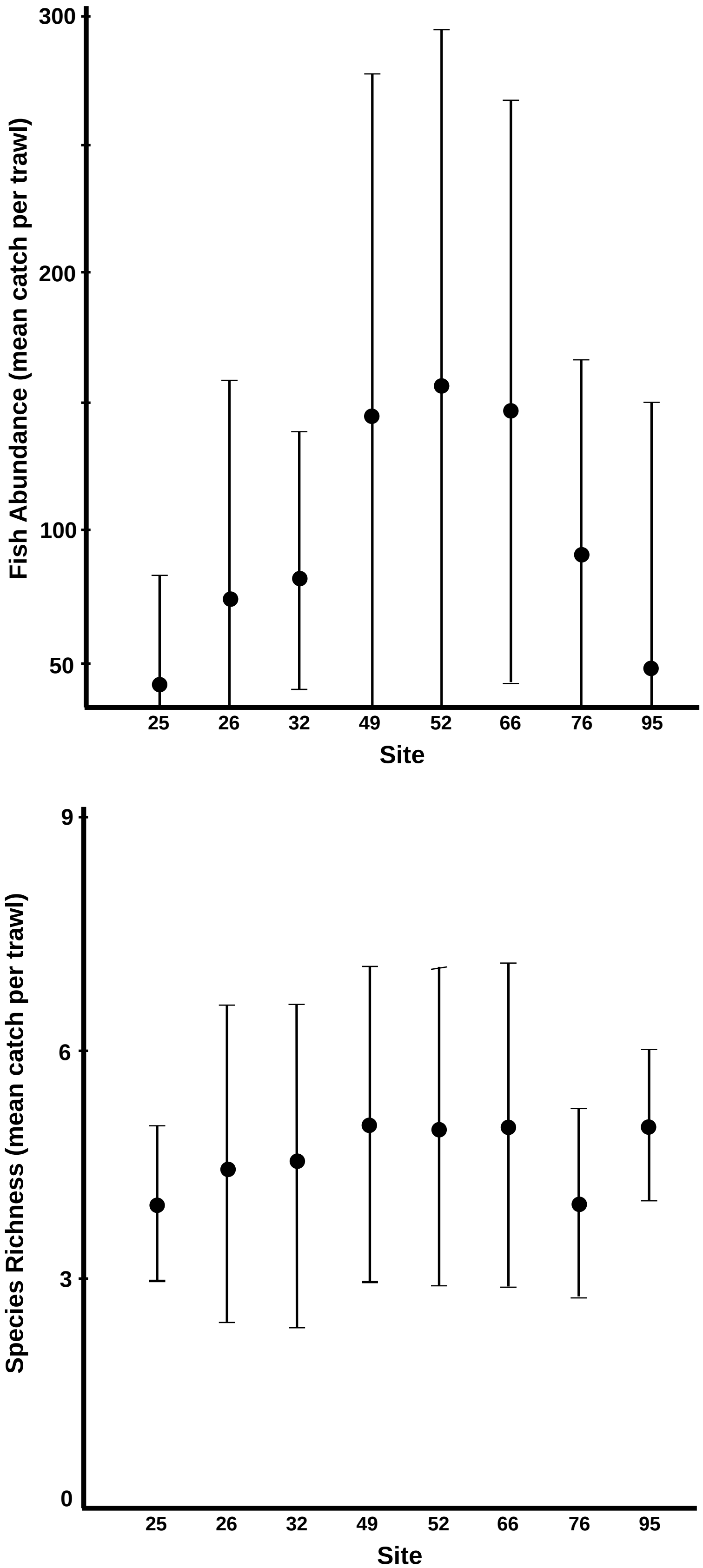


Figure 4. Abundance and richness of fish catch pooled by site over the period of study. Means and 95% confidence intervals are shown.

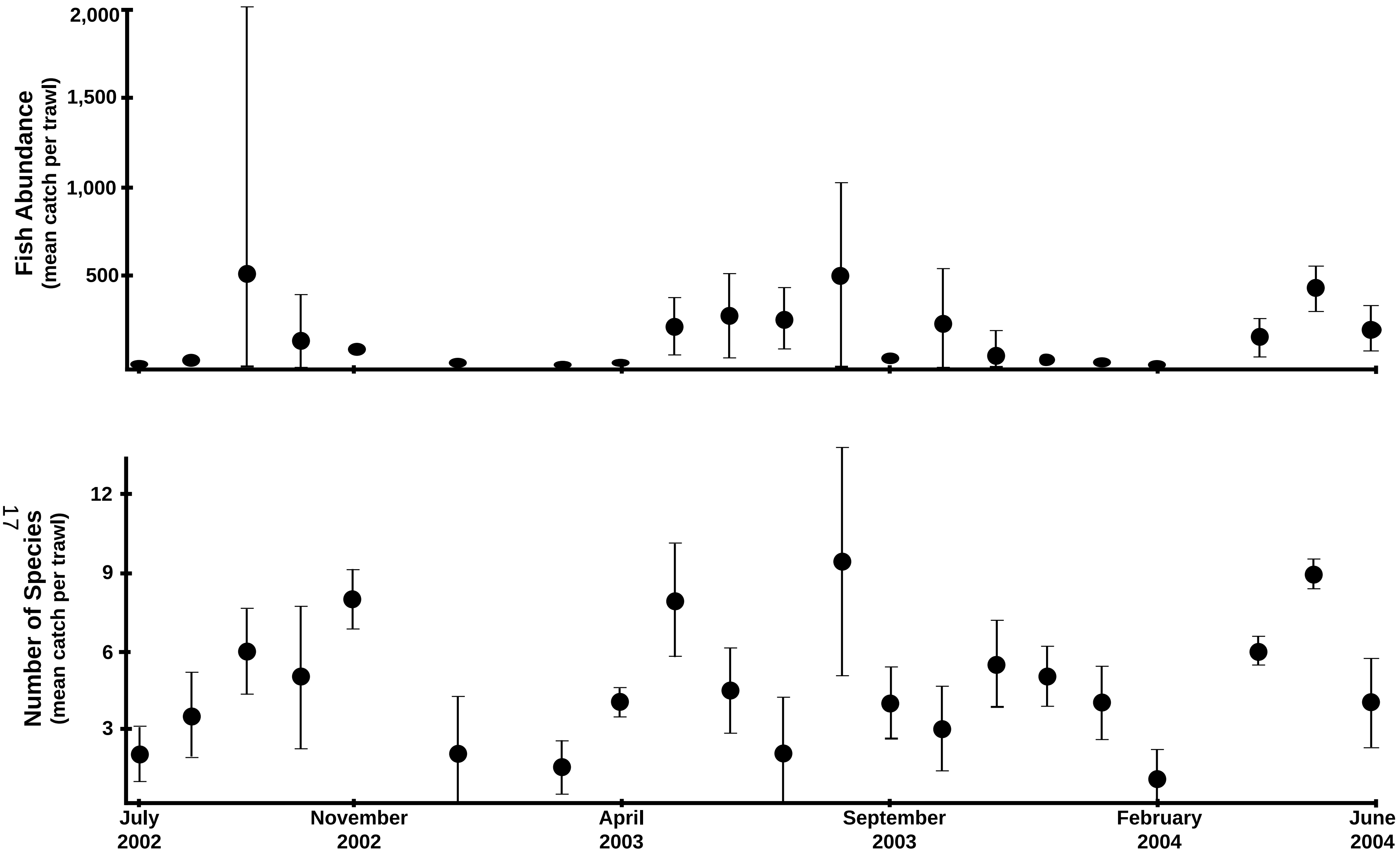


Figure 5. Abundance and richness of fish catch pooled by month over the period of study. Means and 95% confidence intervals are shown.

diversity periods tended to be in the fall and spring (Figure 5) when many species move through estuaries, although peaks were inconsistent across years.

The dredged site 25 did not appear distinct from the other sites on average or through time. Although lower numbers of fish were captured at site 25 in many months, the abundances of fish in trawls were often within the 95% confidence interval of the mean for the seven other sites (Figure 6). Species richness had a similar pattern even though the variability in recorded species richness had a different temporal pattern than fish abundances. Site 25 was sometimes below the 95 confidence interval for the mean of other seven sites, it was more often within the confidence interval (Figure 6). We therefore did not find adequate evidence to distinguish site 25 from the others on the basis of the number of fish caught or the number of species recorded.

The fish community in the Hudson River Park was assessed as a whole since no differences among sites were found. Seasonal changes were significant but pooling across the study period was done to eliminate this factor. The total fish community of 35,869 individuals in 41 species was plotted against a theoretical distribution for a balanced community (Figure 7) shaped by habitat and biotic interactions. The community recorded for the Hudson River Park is left compressed; that is, dominated by one overlay abundant species followed by rapidly declining numbers of other species. The Park fish fauna has too few common species and many species far more rare than expected for a balanced community. We therefore find clear evidence for a malformed community of fishes in the Park waters.

The comparison of the Hudson River Park fish fauna with an expected fauna for river-estuary systems in the Middle Atlantic Coast region (north and south of Hudson-Raritan Estuary) shows major deviations in species composition and relative abundances (Figure 8). Four species were captured in unexpectedly high numbers (Table 4) and many others were found in numbers below and sometimes far below anticipated abundances. The habitat and water quality conditions associated with these species (Table 5) indicate many underrepresented species use shallow, vegetated waters. Some of the underrepresented species prefer substrates with sand and some of these species are sensitive to water quality conditions. The characteristics of habitat and water quality associated with the overrepresented species appears very

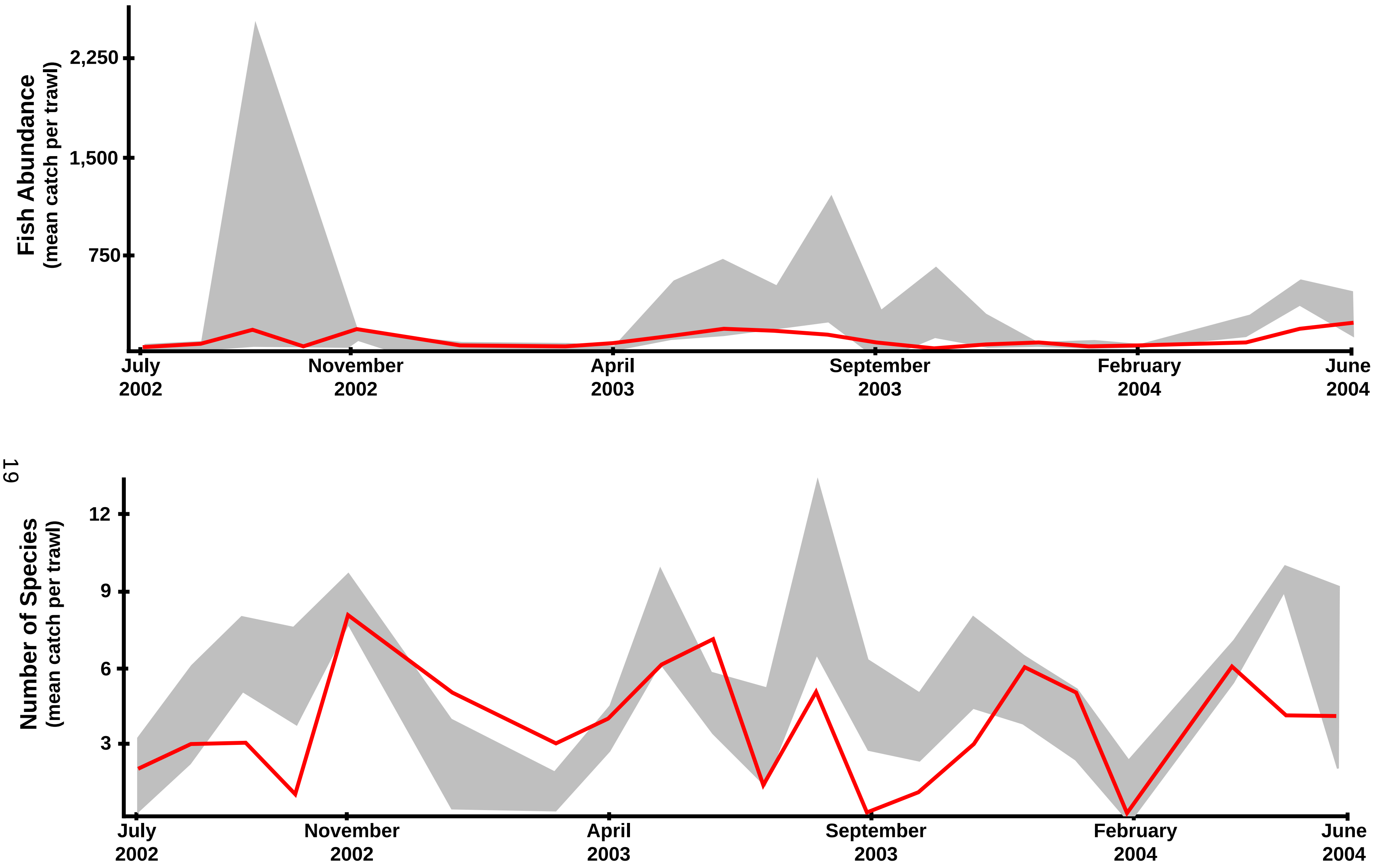


Figure 6. Abundance and richness of fish catch by month over the period of study for the 7 undredged sites (grey) and the dredged site 25 (red line). The grey shaded range is the 95% confidence range about the mean of 7 undredged sites. The red line is the mean for dredged site 25.

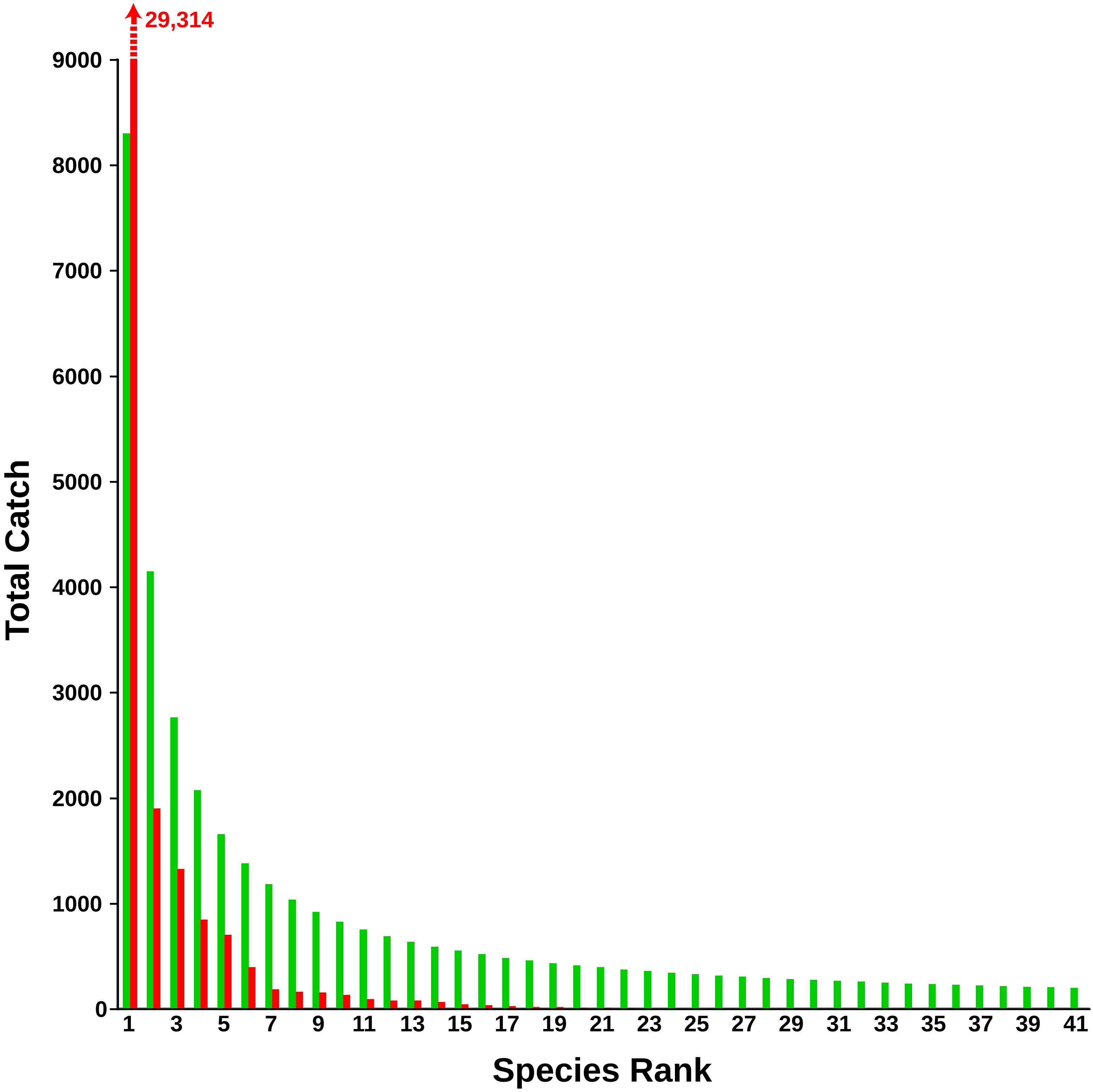


Figure 7. Distribution of fish by species in rank order from the most common fish to the least common. Observed fish numbers for the Hudson River Park (red) are contrasted with an expected distribution following a theoretical pattern for a balanced community.

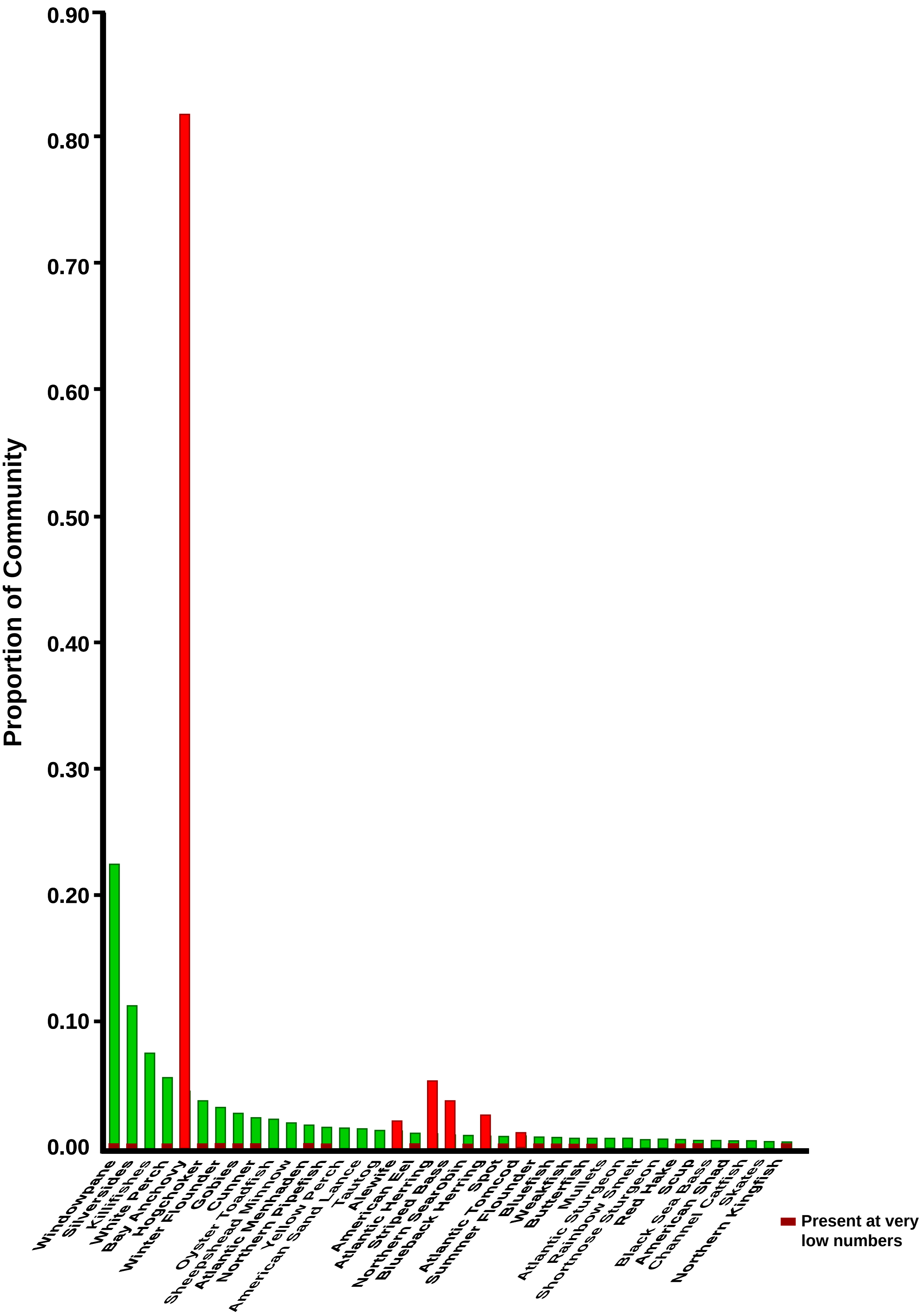


Figure 8. Distribution of fish by expected abundance rank (green) for communities in river-estuary systems along the US mid-Atlantic Coast. Observed community proportions for the Hudson River Park (red) include many species shown on the chart at enhanced levels to allow them to be seen.

Table 4. Composition of expected and observed fish communities for the Hudson River Park.

Name of fish		Expected		Observed		Status
Common	Scientific	Rank	Proportion	Total catch[1]	Proportion	relative to expectation
Windowpane	*Scophthalmus aquosus*	1	0.2243	3	0.0001	Very low
Silversides	*Atherinopsidae*	2	0.1121	6	0.0002	Very low
Killifishes	*Fundulidae*	3	0.0748	0	0.0000	Very low
White perch	*Morone americana*	4	0.0561	47	0.0013	Very low
Bay anchovy	*Anchoa mitchilli*	5	0.0449	29314	0.8173	*Very High*
Hogchoker	*Trinectes maculatus*	6	0.0374	8	0.0002	Low
Winter flounder	*Pseudopleuronectes americanus*	7	0.0320	82	0.0023	Low
Gobies	*Gobiidae, Gobiosoma*	8	0.0280	7	0.0002	Low
Cunner	*Tautogolabrus adspersus*	9	0.0249	2	0.0001	Low
Oyster toadfish	*Opsanus tau*	10	0.0224	0	0.0000	Low
Sheepshead minnow	*Cyprinodon variegatus*	11	0.0204	0	0.0000	Low
Atlantic menhaden	*Brevoorta tyrannus*	12	0.0187	94	0.0026	Low
Northern pipefish	*Syngnathus fuscus*	13	0.0173	37	0.0010	Low
Yellow perch	*Perca flavescens*	14	0.0160	0	0.0000	Low
American sand lance	*Ammodytes americanus*	15	0.0150	0	0.0000	
Tautog	*Tautoga onitis*	16	0.0140	0	0.0000	
Alewife	*Alosa pseudoharengus*	17	0.0132	761	0.0212	
American eel	*Anguilla rostrata*	18	0.0125	6	0.0002	
Atlantic herring	*Clupea harengus*	19	0.0118	1903	0.0531	High
Striped bass	*Morone saxatilis*	20	0.0112	1328	0.0370	High
Northern searobin	*Prionotus carolinus*	21	0.0107	13	0.0004	
Blueback herring	*Alosa aestivalis*	22	0.0102	919	0.0256	High
Spot	*Leiostomus xanthurus*	23	0.0098	3	0.0001	
Atlantic tomcod	*Microgadus microgadus*	24	0.0093	397	0.0111	
Summer flounder	*Paralichthys dentatus*	25	0.0090	20	0.0006	
Bluefish	*Pomatomus saltatrix*	26	0.0086	82	0.0023	
Weakfish	*Cynoscion regalis*	27	0.0083	135	0.0038	
Butterfish	*Peprilus triacanthus*	28	0.0080	159	0.0044	
Mullet	*Mugilidae*	29	0.0077	0	0.0000	
Atlantic sturgeon	*Acipenser oxyrinchus*	30	0.0075	0	0.0000	
Rainbow smelt	*Osmerus mordax*	31	0.0072	0	0.0000	
Shortnose sturgeon	*Acipenser brevirostrum*	32	0.0070	0	0.0000	
Red hake	*Urophycis chuss*	33	0.0068	4	0.0001	
Scup	*Stenotomus chrysops*	34	0.0066	11	0.0003	
Black sea bass	*Centropristis striata*	35	0.0064	0	0.0000	
American shad	*Alosa sapidissima*	36	0.0062	180	0.0050	
Channel catfish	*Ictalurus punctatus*	37	0.0061	0	0.0000	
Skate spp.	*Rajidae*	38	0.0059	0	0.0000	
Northern kingfish	*Menticirrhus saxatilis*	39	0.0058	1	0.0000	

1. Zero captures are shown because these species are known to inhabit the Hudson-Raritan Estuary system but were not captured in sampling.

Table 5. Brief descriptions of habitat and water quality attributes associated with species found in fewer or higher abundances than expected in the Hudson River Park. Empty entries indicate that comments were not found in common references that cover the biology of the species.

Species	**Habitat**	**Water Quality**
Underrepresented fishes		
Windowpane	Firm substrate with sand	Oxygen sensitive
Silversides	Marsh edges, Vegetation	
Killifishes	Marsh edges, Vegetation, protected	Thermal and oxygen hardy
White perch	Shallow waters	
Hogchoker	Shallow, soft bottom	Thermal and oxygen hardy
Winter flounder	Muddy sand to very coarse, vegetation	Thermal and oxygen sensitivity
Gobies	Still, shallow, vegetation or cover	
Cunner	Cover oriented; vegetation or structure	
Oyster toadfish	Shallow with debris and cover	
Sheepshead minnow	Shallow, vegetation	Thermal and oxygen hardy
Atlantic menhaden	Open waters	
Northern pipefish	Shallow, soft bottom, vegetation	Thermal tolerant
Yellow perch	Vegetated waters	Low salinity
Overrepresented fishes		
Bay anchovy	Open,shallow waters	Salinity and turbidity tolerant
Atlantic Herring	Open waters	
Striped bass	Oriented to prey; generalist	Salinity tolerant
Blueback herring	Open coastal waters	

different. All of these species use open waters. Three species are plantivorous fishes and the piscivorous, striped bass, uses habitat broadly but tends to be oriented to prey species; typically the open water fishes. Therefore, deviations from the expected fish fauna for the Park setting appears to be the replacement of shallow, shoreline, vegetated fishes with species that occupy open waters of bays and coastal environments.

A total of 145 benthic invertebrate taxa and 78,925 individuals were collected in 383 samples between July 2002 and June 2004. The common taxa recorded are shown in Table 6 and taxa constituting less than 1% of the total collection are listed in Appendix C. An illustrated key to benthic invertebrates of the Hudson River Park is provided in Appendix D. The invertebrate taxa collected include 63 polychaetes, 44 crustaceans, 38 molluscs (17 bivalves and 21 gastropods), 5 maxillopods, 2 pycnogonidans, oligocheates, ostracods and 1 each of several more rare taxa (leech, insect, ascidacean, cnidarian, nemata, porifera, and nemertea). Annelida and mollusca were the most abundant taxa comprising 66% and 29% of the pooled samples, respectively. The remaining 5% of the collections consisted of individuals in the phyla: arthropoda, chordata, cnidaria, nemata, nemertea and porifera. The four most common taxa were *Mediomastus spp*. (15%), *Mulinia lateralis* (13%), Oligochaeta (13%), and *Streblospio benedicti* (12%).

The density of invertebrates differed among sites (repeated measures ANOVA, $P \leq 0.0001$), through time ($P \leq 0.0001$) and the difference among sites varied through time ($P \leq 0.0001$). The dredged site 25 was similar to five of the other sites (Figure 9) with sites 52 and 95 being very high and low in density respectively. Results for the number of taxa (richness) of invertebrates generally followed the pattern of results for organism density. Differences among sites were marginal (repeated measures ANOVA, $P \leq 0.08$) with strong differences through time ($P \leq 0.0001$) and a significant site and time interaction ($P \leq 0.01$). Again, the dredged site 25 was similar to most other sites (Figure 9) with site 95 being below most sites in invertebrate taxa richness. Site 52 was high in taxa richness but not as clearly different from the other sites as seen with organism density.

Table 6. Common benthic invertebrate taxa recorded in the study with the proportion of all invertebrates collected.

Taxa	**Phylum**	**Class**	**Order**	**Family**	**Number recorded**	**Proportion**
Mediomastus spp.	Annelida	Polychaeta	Capitellida	Capitellidae	11,833	0.15
Mulinia lateralis	Mollusca	Bivalvia	Veneroida	Mactridae	10,488	0.13
Oligochaeta	Annelida	Clitellata			10,077	0.13
Streblospio benedicti	Annelida	Polychaeta	Spionida	Spionidae	9,129	0.12
Acteocina canaliculata	Mollusca	Gastropoda	Cephalaspidea	Cylichnidae	5,785	0.07
Leitoscoloplos spp.	Annelida	Polychaeta	Orbiniida	Orbiniidae	5,815	0.07
Capitellidae	Annelida	Polychaeta	Capitellida		2,494	0.03
Rictaxis punctostriatus	Mollusca	Gastropoda	Cephalaspidea	Acteonidae	2,255	0.03
Heteromastus sp.	Annelida	Polychaeta	Capitellida	Capitellidae	2,240	0.03
Spio setosa	Annelida	Polychaeta	Canalipalpata	Spionidae	2,194	0.03
Tellina agilis	Mollusca	Bivalvia	Veneroida	Tellinidae	1,570	0.02
Tharyx spp.	Annelida	Polychaeta	Spionida	Cirratulidae	1,491	0.02
Leucon americanus	Arthropoda	Malacostraca	Cumacea	Leuconidae	1,399	0.02
Ostracoda	Arthropoda				1,205	0.02
Pectinaria gouldii	Annelida	Polychaeta	Terebellida	Pectinariidae	999	0.01
Eteone sp.	Annelida	Polychaeta	Aciculata	Phyllodocidae	948	0.01
Orbiniidae	Annelida	Polychaeta	Ariciida		910	0.01
Hydrobia totteni	Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	872	0.01
Polydora ligni	Annelida	Polychaeta	Canalipalpata	Spionidae	865	0.01
Nassarius obsoletus	Mollusca	Gastropoda	Neogastropoda	Nassariidae	832	0.01
Leitoscoloplos fragilis	Annelida	Polychaeta	Ariciida	Orbiniidae	746	0.01
Spio sp.	Annelida	Polychaeta	Canalipalpata	Spionidae	372	0.01

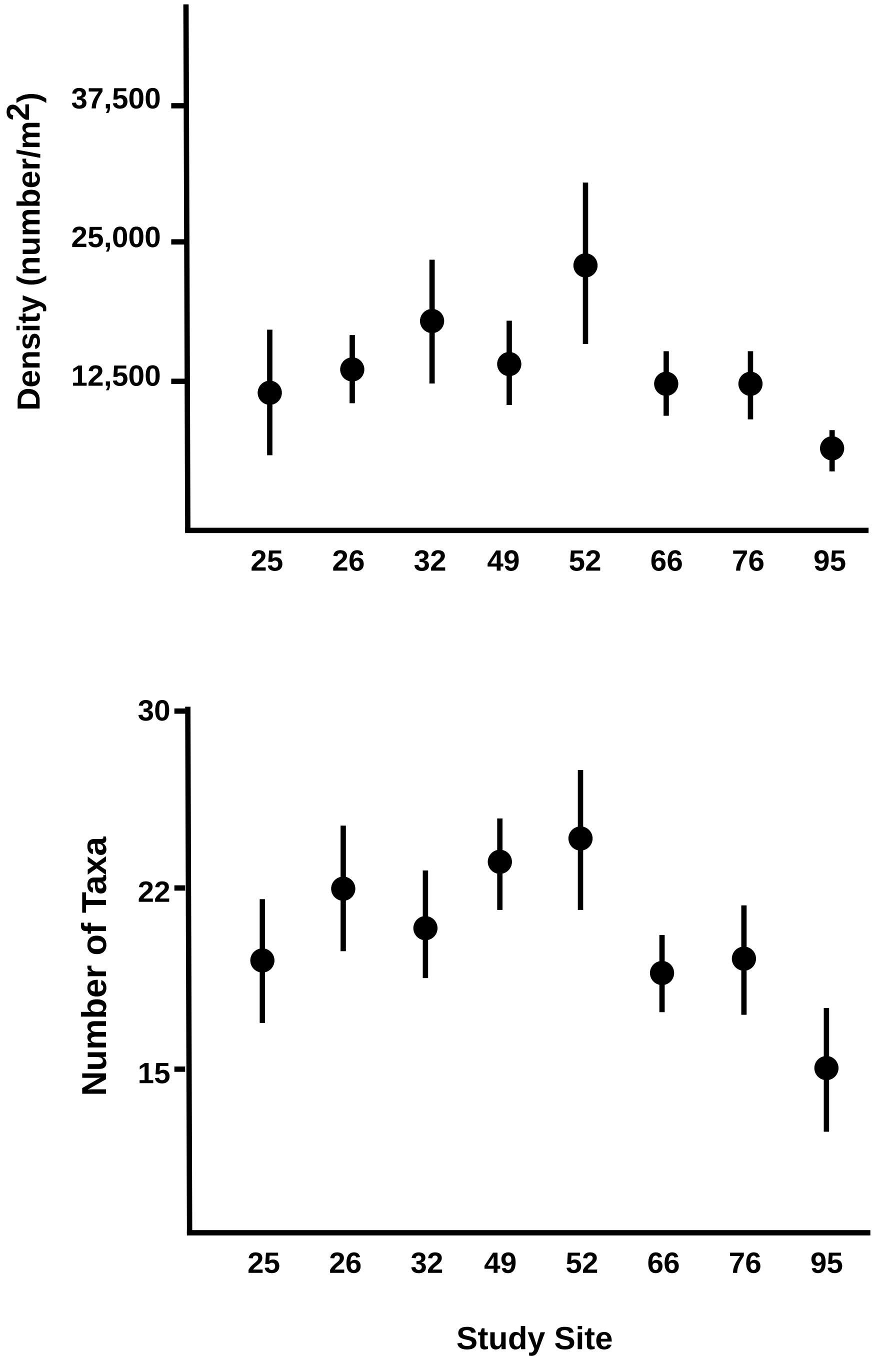


Figure 9. Abundance and richness of benthic invertebrates pooled by site over the period of study. Means and 95% confidence intervals are shown.

In general, the density of invertebrates at the dredged site 25 did not appear distinct from the other sites through the study period (Figure 10). Although invertebrate density was less at site 25 than the other undredged sites at the start of the study, density values were often within the 95% confidence interval of the mean for the seven other sites (Figure 10). Taxa richness had nearly the same pattern as organism density, and the pattern of variation at site 25 and the other sites was very similar throughout the study. Aside from possibly the first two months, we did not find adequate evidence to distinguish site 25 from the others on the basis of the number of invertebrates caught per sample or the number of taxa recorded.

The US Environmental Protection Agency Benthic Index of Biotic Integrity for the NY-NJ Harbor system detected at least some stressful conditions for invertebrates in the Hudson River Park in most months (Figure 11). Overall, 35% of our samples were classified as indicating a stressed invertebrate community. The annual pattern of stress frequency varied from most samples indicating stress to few with a gradual seasonal cycle. In the cold winter months, the number of samples classified as reflecting benthic environmental stress was lowest. Conversely, there was a general trend for most benthic invertebrate samples (16 per month) to indicate stress during the warm late summer months. The gradual change from high levels of stress to low and then back indicates changing invertebrate stress levels vary in response to gradually changing environmental conditions.

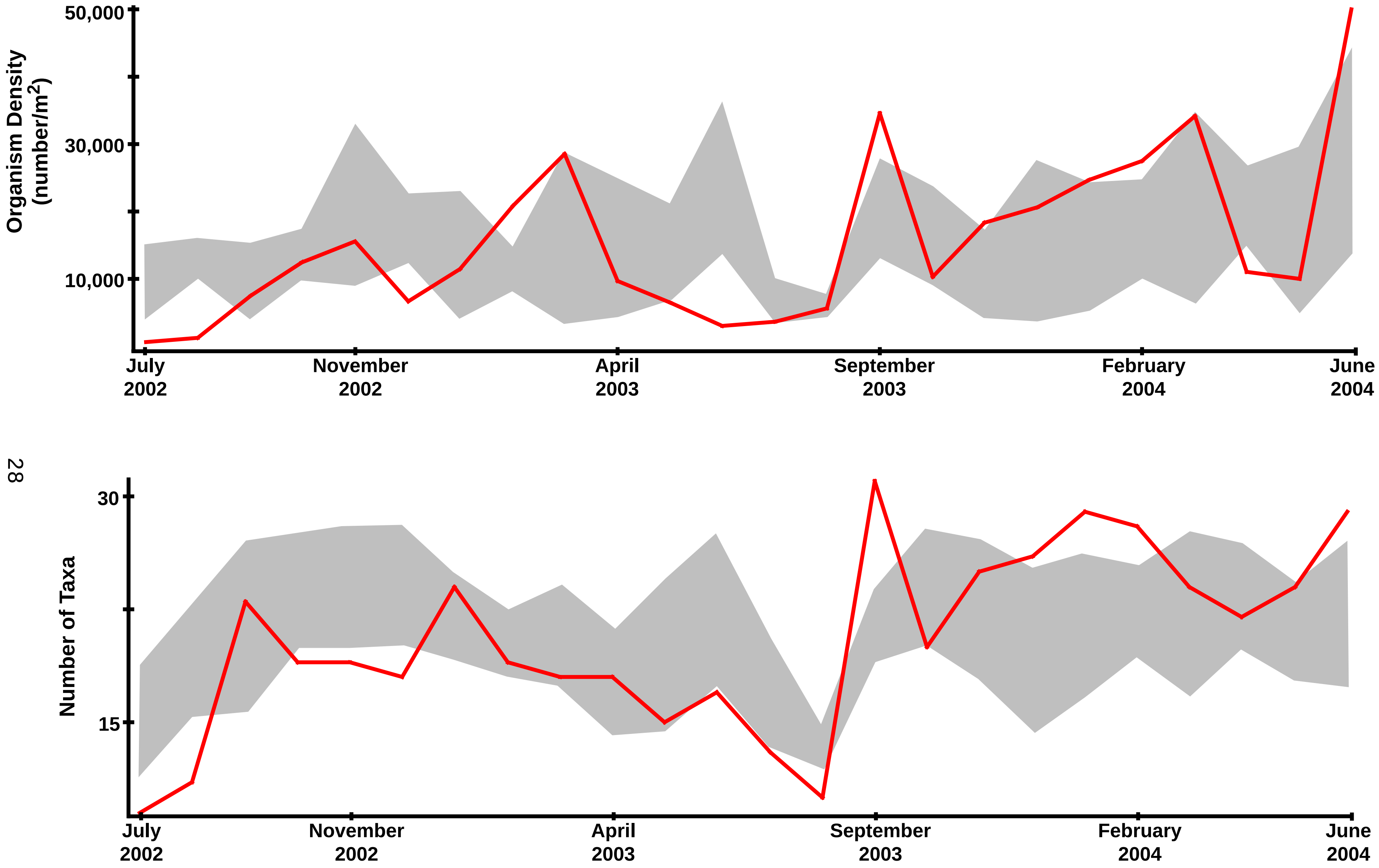


Figure 10. Density and richness of benthic invertebrates by month over the period of study for the 7 undredged sites (grey) and the dredged site 25 (red line). The grey shaded range is the 95% confidence range about the mean of 7 undredged sites. The red line is the mean for dredged site 25.

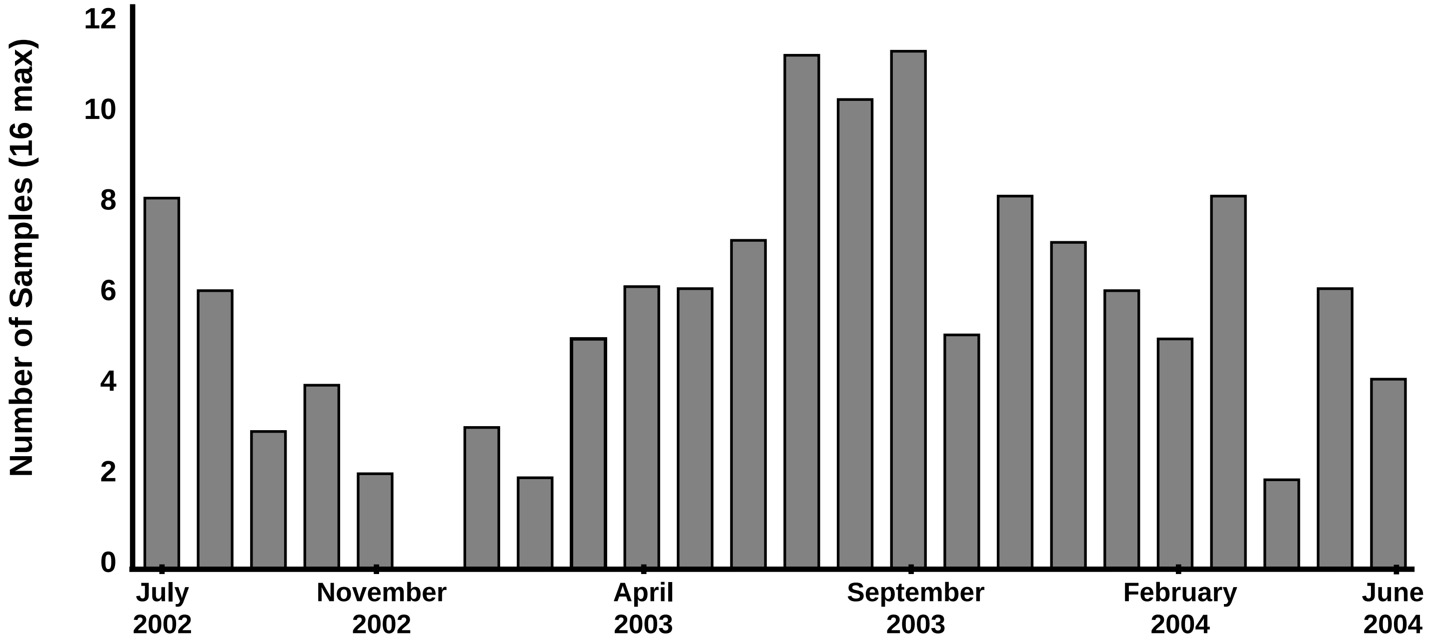


Figure 11. Number of samples per month classified as indicating stress on invertebrates in the Hudson River Park. The number of samples per month was 16. Months with 8 or more stressed samples had stressful conditions detected in more than half the samples for the month.

Discussion

A cultural asset at the heart of New York City, the Hudson River Park harbors a large and diverse aquatic fauna making it an environmental sanctuary of substantial ecological importance. Our field sampling easily captured fish and benthic invertebrates in high numbers and broad diversity. Other field researchers (e.g., Duffy-Anderson et al. 2003, Woodhead et al. 1999) studying aquatic life in New York City have reported similar conclusions: large and species-rich fish communities are present with ecological and societal value. Despite the abundance and diversity of aquatic life in the Park, we found both the fish and invertebrate communities are dominated by inappropriate organisms for shoreline waters in a mesohaline section of an Northeastern US estuary. The Park and nearby waters of the harbor contain essentially all fish that would normally compose the proper mesohaline shoreline community. However, the current Park community is overwhelmingly dominated by a few species that primarily occupy open areas of coastal and estuary waters. Benthic invertebrates display a similar pattern: a large array of taxa documented in the Park with the most common taxa not indicative of a quality estuarine environment. While the invertebrate fauna is not overwhelmed by a few taxa as seen with fish, the most common organisms are known for their tolerance of pollution and abilities to colonize and persist in stressed environments. Our conclusions are not new because other field research (Woodhead et al. 1999, Iocco et al. 2000, Adams et al. 2003) with larger spatial scope reported similar assessments for the lower Hudson River and upper Hew York harbor. Our overall depiction of the Park fauna is a hopeful conclusion. The proper shoreline faunal elements are present suggesting that changes in the physical and chemical environment of the Park could shift community composition to a more appropriate mix of organisms.

This study was designed to identify impacts of dredging at one inter-pier site in the Hudson River Park. Without pre-impact data, we relied on a comparison of the dredged site with a series of seven undredged sites over a period of time adequate to detect biotic recovery. Differences among sites and the diminishing of any differences over time were the two lines of evidence sought to assess dredging impact. The dredged site was found to be deeper and slightly more saline than the other site and it was similar in thermal and oxygen characteristics. It terms of biological properties, our results do not indicate that the fish or invertebrate communities (abundance and diversity) at the dredged site differ from other undredged sites in the Park. During the two year study period, fish and invertebrate communities varied in abundance and diversity like the other sites, and much of the time the dredged site was within the margin of error of biotic measurements at other sites. One exception was benthic invertebrate abundance and diversity that was clearly below the other sites for the first few months of the study. This could reflect an initial impact to the invertebrates at the dredged site; an expected finding for dredged sites.

Although little was found different between the dredged and undredged sites, we were able to detect sites differences for other attributes in the study. The sites varied in average salinity with bottom waters and down-river sites most saline. While sites were not different in mean dissolved oxygen, surface waters were higher than bottom waters on average. All sites were similar in terms of fish abundance and diversity, but with invertebrates there were some clear site differences aside from the dredged site. Site 52 near 12th Street had an unusually abundant and diverse invertebrate community, and site 95 at 55th Street had the clearly most depauperate invertebrate community. These site variations could be a response to substrate variations which has been found to be an important factor shaping invertebrate communities in the harbor system (Franz and Harris 1988, Steimle and Caracciolo-Ward 1989) and elsewhere (e.g., Weisberg et al. 1997).

In addition to some variations among sites, we were able to easily document variation through time. Salinity, temperature, and dissolved oxygen followed the expected seasonal patterns of change. High water temperatures and low dissolved oxygen levels (bottom water) near critical levels for aquatic life were notable summer conditions. Fish abundance and diversity varied greatly through time with peaks in roughly corresponding to spring and fall periods when many migrating fishes would pass through the Park area. Movements and variation in the local abundance of bay anchovy also strongly shaped total fish abundance through time since this species accounted for most of our catch. Invertebrate abundance and diversity varied considerably through the study period in a more uneven manner than seen with the fish community.

Significant site to site variation found for invertebrates would add to the spread in the seasonal pattern seen for the pooled collections. Two fairly clear drops in invertebrate abundance and diversity occurred in the late summer of 2002 and 2003. At these times, our bottom water dissolved oxygen values were near critical levels for long term aquatic life support. Invertebrate abundance and diversity were regularly highest in winter and spring when oxygen levels were consistently well above that needed for aquatic life and when some taxa reach the end of their growth stage.

Our analysis of fish community data from similar estuarine settings north and south of the harbor region provided a quantitative model for an expected or target fish fauna. The reference data are from estuaries with human dominated landscapes in recent times thus our target fish community should be a realistic goal for today. Unfortunately, the fish fauna we observed in the Park was very different from the target community. Obvious deviations from the target community were the strong dominance by a few open water planktivores (bay anchovy, blueback herring, Atlantic herring) and one piscivore (striped bass) with broad habitat requirements. The fishes we expect (windowpane, killifishes, silversides) to be dominant were present in the Park or nearby waters but at very low numbers. Most of these underrepresented fish primarily occupy shallow, shoreline waters with vegetation, cover, or coarse substrate. Therefore, the findings indicate that shallow and structured habitats common to estuary shorelines are deficient in the Park. This conclusion may have been anticipated because almost all of the shoreline is bulkheaded and 3 m or greater in depth at the water edge. The apparent importance of habitat in shaping the Park fish community is new, but habitat conditions have long been known to be the primary organizing factor for fish communities (e. g., Schoener 1974, Werner et al. 1977, Lobb and Orth 1991).

The earlier studies of the Manhattan shoreline fish community by Woodhead et al. (1992, 1999) reported a dominance by bay anchovy similar to findings reported here. However, when select Hudson River locations with gradually sloping shallow shoreline waters were sampled by Hurst et al. (2004) a clearly different community was found with silversides dominant. Their catch composition was more like our target community because common species like silversides are expected to be highly abundant. Pier piling fields could be the

Park's highly structured fish habitat, and these were habitats not sampled in this study. Able et al. (1995, 1998, 1999) reported these Park habitats harbored more fish than the inter-pier waters we sampled, and that the most common species were striped bass, black sea bass, and tomcod. However, the Able et al. (1995) study was not intended as a community assessment and it used traps which are a very selective sampling gear. Also the total catch (800 fish) and diversity (19 species) was a small fraction of our totals, and we believe our broad scale sampling better reflects the overall Park fauna. Finally, another New York harbor study of fish in pier and inter-pier habitats (Cantelmo and Wahtola 1992) reported contrasting patterns: more fish and more striped bass in open inter-pier waters. Consequently, we have differing study findings on fish use of structured pier and open inter-pier habitats likely because each environment forced the use of different sampling methods.

One concern about comparing a sampled fish community with a target community is the potential for sampling gear limitation to cause some of the deviations. We used trawl sampling which is an actively deployed gear capable of capturing a wide range of species and fish sizes. However, this gear could be expected to under-sample some fish such as those restricted to very shallow margins and surface waters. Some fish such as high marsh dwelling killifish would be difficult to capture in trawls. However, these fish are known to occur only in a few Hudson River marshes (Yozzo and Ottman 2003) and not the study waters. Despite some sampling limitations, trawls have been effective in capturing fishes we predict to be dominants in the target community. The fish we identified as the two most common fishes in the target community, windowpane and silversides, were captured in the study area. Martino and Able (2003) used a smaller trawl than ours with the same cod end mesh size to sample coastal waters in New Jersey. Windowpane was commonly caught in their sampling, and silversides were the second most commonly caught fish in bay waters. Woodhead et al. (2000) used trawling along the Brooklyn waterfront captured windowpane in higher numbers than in this study. Sampling bias likely caused some of our reported deviations between target and observed fish abundances in this study, but it appears unlikely that our use of trawls largely determined the composition of the captured fish fauna.

Benthic invertebrates in the Hudson River Park were sampled with a standard device (Ponar dredge) used in a large majority of benthic community assessment studies. The analysis method, benthic index of biotic integrity, is a common tool (Weisberg et al. 1997) that was tailored to the Hudson-Raritan Estuary ecosystem (Weisberg et al. 1998). Consequently, our finding that the invertebrate community in the Hudson River Park often displays characteristics of environmental stress appears sound. The level of stress we detected (35% of all samples) is similar to other studies using similar methods. The harbor survey of benthic invertebrates by Adams et al. (2003) in 1993-1994 and again in 1998 showed similar levels of stressed communities in the region of the Park: 53% and 31% respectively. Equally important was the broad spatial scope of frequent invertebrate community stress. Whiles fish may be primarily shaped by habitat conditions at a local scale, the invertebrates appear impacted by environmental conditions over large areas of the harbor system. Sediment analyses by Adams et al. (2003) show the Harbor is still extensively contaminated by cadmium, chromium, chlordane, mercury, and other chemicals. In addition, we found daytime dissolved oxygen concentrations in Park waters to decline to low levels (≤ 4 mg/l above substrate) in late summer when more than half of our invertebrate samples were classified as stressed. As with sediment contaminants, low oxygen concentrations are much more widespread than the Park waters (New York Department of Environmental Protection 2003) although water quality has improved greatly in the last two decades (Steinberg et al. 2004).

The most common invertebrate taxa recorded in this study add further evidence of a pollution tolerant fauna reflecting at least seasonally poor environmental conditions. Dwarf surfclams (*Mulinia lateralis*) are regarded as hardy organisms that are commonly colonists of disturbed areas. The frequently captured captellid thread worms (*Mediomastus* spp.) and the mud worm (*Streblospio benedicti*) are especially well known for tolerance to high levels of pollution. Tubificid worms (Oligochaeta) are characteristic inhabitants of organically enriched sediments with low oxygen. Thus the dominant invertebrates of the Park are pollution-indicative organisms. This is not unexpected or limited to Park waters. Iocco et al. (2000) surveyed the harbor for common invertebrate taxa and found across system communities were dominated by opportunistic or pollution-tolerant species with few differences in overall community quality. Although they highlighted the lower Hudson River and adjacent waters as one region especially marked by a pollution tolerant invertebrate fauna.

The nature of fish and invertebrate communities in the Hudson River Park make detection of dredging impacts difficult. The dominant fishes, which comprised a large majority of the community, are not sensitive to shoreline habitat conditions and their disruption. The common invertebrates are tolerant of environmental stress and appear to be influenced by large widespread factors such as sediment contaminants and seasonally poor quality of bottom waters. Dredging is known to impact aquatic life at the disturbed locations (Allen and Hardy 1980, Johnston 1981). However, effects such as reduced abundance and diversity of estuarine organisms are commonly localized and short term (Lewis et al. 2001) with recovery of pre-disturbance levels in 6 to 12 months (Conner and Simon 1979) and sometimes longer (Blanchard and Feder 2003). We observed some evidence for low abundance and diversity invertebrates at the dredged site in the first couple months of the study. Otherwise, we obtained no data indicating a lasting effect at the dredged site which distinguished this location from the other sites through the Park waterfront. Instead our results indicate why the anticipated impacts of dredging were not evident.

Recommendations

Potential environmental improvement actions that could be undertaken within the Hudson River Park could promote a more typical estuarine shoreline fish fauna. Strong evidence was obtained that development of new habitats could change the fish community toward that defined in our target community. The creation of shallow structured habitat in the Park could enhance the abundance of many species now found at very low numbers. Dedicating one or more inter-pier areas to shallow, vegetated fish habitat could result in sites supporting a variety of fish species described above as underrepresented. A potential enhancement action would require importing clean substrate that is sandy to reduce water depth (approximately 1 to 2 m through the tidal range) and planting the area with eelgrass (*Zostera marina*). Eelgrass is a common brackish water rooted aquatic plant with environmental tolerances that approximate conditions in the Hudson River Park (detailed by United Kingdom Marine Special Areas of Conservation 2001). Eelgrass beds support highly productive and diverse aquatic communities. This plant dominates the highly valued submerged aquatic vegetation beds in brackish waters of the Atlantic coast from Nova Scotia to South Carolina (Thayer et al. 1984). Techniques to restore eelgrass beds have been developed (Thayer et al. 1984, Granger et al. 2002) and applied in the United States and Europe. In combination with eelgrass beds, rock rip-rap could be placed along the water edge to further add complex surfaces for cover seeking fishes. A detailed analysis of site suitability and restoration planning would be needed to maximize the likelihood of successfully developing a self-sustaining shallow water submerged aquatic vegetation habitat.

While a recommendation for enhancing fish communities appears feasible for the Park, no similar action can be recommended for enhancing the invertebrate fauna. Invertebrates appear constrained by water and sediment quality problems at a scale of the upper harbor. Local actions in the Park seem unlikely to correct this, but improvements in water quality and declining contaminant levels are underway. Water quality improvement in the harbor is gradual but in time restoration of a more diverse invertebrate community may be feasible at the local scale of the Park.

References

Able, K.W., Studholme, A.L., and Menaderson, J.P. 1995. Habitat quality in the New York/New Jersery harbor estuary: An evaluation of pier effects on fishes. Final Report to the Hudson River Foundation. Rutgers University Marine Field Station, Tuckerton, NJ.

Able, K. W., J. P. Manderson, A. L. Studholme. 1998. The distribution of shallow water juvenile fishes in an urban estuary: The effects of man-made structures in the lower Hudson River. Estuaries 21:731-744

Able, K. W., J. P. Manderson, A. L. Studholme. 1999. Habitat quality for shallow water fishes in an urban estuary: The effects of man-made structures on growth. Marine Ecology Progress Series 187:227-235.

Adams, D. A., J. S. O'Connor, and S. B. Weisberg. 1998. Sediment quality of the NY/NJ Harbor system: an investigation under the regional environmental assessment program (R-EMAP). U.S. Environmental Protection Agency - Region 2, Edison, NJ. EPA/902/R-98/001.

Adams, D. A., and S. Benyi. 2003. Sediment quality of the NY/NJ Harbor system: a 5-year revisit. U.S. Environmental Protection Agency. EPA/902/ R-98/001.

Allen, K. O., and J. W. Hardy. 1980. Impacts of navigational dredging on fish and wildlife: a literature review. US Fish and Wildlife Service, FWS/ OBS-80/70, Washington, DC.

Bain, M. B., and M. S. Meixler. 2006a. Ecosystem management planning: setting a target community for river rehabilitation. Unpublished manuscript submitted to Environmental Management.

Bain, M. B., and M. S. Meixler. 2006b. Defining a target fish community for river restoration. Environmental Biology of Fishes. In press.

Bak, P. 1996. How nature works. Copernicus, New York, New York.

Beninger, P. G., and S. D. St. Jean. 1997. The role of mucus in particle processing by suspension feeding marine bivalves: unifying principles. Marine Biology 129:389-397.

Blanchard, A. L. and H. M. Feder. 2003. Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska. Mar Pollut Bull 46:1590-9.

Bostrom, C., and J. Matilla. 1999. The relative importance of food and shelter for seagrass associated invertebrates: a latitudinal comparison of habitat choice by isopod grazers. Oecologia 120:162-170.

Bricelj, V. M., S. P. MacQuarrie, and R. A. Schaffner. 2001. Differential effects of *Aureococcus anophagefferens* isolates ("brown tide") in unialgal and mixed suspension on bivalve feeding. Marine Biology 139:605-615.

Brown, L. 2004. The mapping of Eelgrass (*Zostera* spp) in Studland Bay. http://www.durlstonmarineproject.co.uk/research_eelgrass.asp

Cantelmo, F. R., and C. H. Wahtola, Jr. 1992. Aquatic habitat impacts of pile-supported and other structures in the lower Hudson River. Pages 59-75 in W. Wise, D. J. Suszkoski, and J. R. Waldman (eds.) Proceedings: Conference on the impacts of New York Harbor development on aquatic resources. Hudson River Foundation, New York, NY.

Chalermwat, K., T. R. Jacobson, and R. A. Lutz. 1991. Assimilation of bacteria by the dwarf surf clam *Mulina lateralis* (Bivalvia: Mactricidae). Marine Ecology Progress Series 71:27-35.

Chester, M.C. 1993. Comparative feeding biology of *Acteocina canaliculata* (Say, 1826) and *Haminoea solitaria* (Say, 1822) (Opisthobranchia: Cephalaspidea). American Malacological Bulletin 10:93-101.

Collette, B. B., and G. Klein MacPhee, editors. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Smithsonian Institution Press, Washington, DC.

Conner, W. G., and J. L. Simon. 1979. The effects of oyster shell dredging on an estuarine benthic community. Estuarine and Coastal Marine Science 9:749-758.

Connor, D. W., J. H. Allen, N. Golding, K. L. Howell, L. M. Lieberknecht, K. O. Northern and J. B. Reker. 2004. The marine habitat classification for Britain and Ireland, Version 04.05 JNCC, Peterborough. http://www.jncc.gov.uk/MarineHabitatClassification

Duffy-Anderson, J. T., J. P. Manderson, and K. W. Able. 2003. A characterization of juvenile fish assemblages around man-made structures in the New York-New Jersey Harbor estuary, U.S.A. Bulletin of Marine Science 72:877-889.

Dyrynda, P.E.J. 2004. Marine Biodiversity – an introduction. http://www.solaster-mb.org/mb/

Franz, D.R. and W.H. Harris. 1988. Seasonal and spatial variability in macrobenthos communities in Jamaica Bay, New York – an urban estuary. Estuaries 11:15-28.

Froese, R., and D. Pauly, Editors. 2005. FishBase. http:// www.fishbase.org/

Gibson, G. R., M. L. Bowman, J. Gerritsen, and B. D. Snyder. 2000. Estuarine and coastal marine waters: bioassessment and biocriteria technical guidance. U.S. Environmental Protection Agency, Washington, DC. EPA 822-B-00-024

Gilbert, W. H., and E. F. Suchow. 1977. Predation by winter flounder *Psuedopleuronectes americanus* on the siphons of the clam *Tellina agilis*. Nautilus 91:16-17.

Granger, S., M. Traber, S. W. Nixon, and R. Keyes. 2002. A practical guide for the use of seeds in eelgrass (*Zostera marina* L.) restoration. Part I. Collection, processing, and storage. M. Schwartz (ed.), Rhode Island Sea Grant, Narragansett, RI.

Gulf of Maine Biogeographic Information System. 2004. Bay of Fundy species information system. http://gmbis.marinebiodiversity.ca/BayOfFundy/search.html

Hardy Jr., J. D. 1978. Development of fishes of the Mid-Atlantic Bight: and atlas of egg, larval and juvenile stages Volume VI. U. S. Department of the Interior and the Center for Environmental and Estuarine Studies, University of Maryland, Solomons, Maryland.

Hughes, R. N. and D. Drewett. 1985. A comparison of the foraging behavior of dogwhelks, *Nucella lapillus* (L.), feeding on barnacles of mussels on the shore. Journal of Molluscan Studies 51:73-77.

Hurst, T. P. , K. A. McKown, and D. O. Conover. 2004. Interannual and long term variation in the near-shore fish community of the mesohaline Hudson River estuary. Estuaries 27:659-669.

Ingalls, A. E., R. C. Aller, C. Lee, and M. Y. Sun. 2000. The influence of deposit feeding on chlorophyll a degradation in coastal marine sediments. Journal of Marine Research 58:631-651.

Iocco, L. E., P. Wilber, R. J. Diaz, D. G. Clarke, and R. J. Will. 2000. Benthic habitats of the New York/New Jersey Harbor: 1995 survey of Jamaica, Upper, Newark, Bowery, and Flushing Bays. National Oceanic and Atmospheric Administration, Coastal Services Center, Charleston, SC.

Jenkins, R. E., and N. M. Burkhead. 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD.

Johnston, Jr., S. A. 1981. Estuarine dredge and fill activities: a review of impacts. Environmental Management 5:427-440.

Kaag, N. H. B. M., E. M. Foekema, M. C. T. Scholten, and N. M. Vanstraalen. 1997. Comparison of contaminant accumulation in three species of marine invertebrates with different feeding habits. Environmental Toxicology and Chemistry 16:837-842.

Lewis, M. A., D. E. Weber, R. S. Stanley and J. C. Moore. 2001. Dredging impact on an urbanized Florida bayou: effects on benthos and algal-periphyton. Environmental Pollution 115:161-171.

Lobb, M. D., III, and D. J. Orth. 1991. Habitat use by an assemblage of fish in a large warmwater stream. Transactions of the American Fisheries Society 120:65-78.

Lopez, G. R., and I. J. Cheng. 1983. Synoptic measurements of ingestion rate, ingestion selectivity,and absoprtion efficiency of natural foods in the deposit feeding mollusks, *Nucula annulata bivalvia* and *Hydrobia totteni gastropoda*. Marine Ecology Progress Series 11:55-62.

Mandelbrot, B. 1983. The fractal geometry of nature. Freeman, New York, New York.

Marine Biological Association. 2004. Marine Life Information Network for Britain and Ireland. http://www.marlin.ac.uk/

Marine Biological Laboratory. 2004. Marine organisms. Woods Hole, MA. http://www.mbl.edu/marine_org/

Martino, E. J., and K. W. Able. 2003. Fish assemblages across the marine to low salinity transition zone of a temperate estuary. Estuarine Coastal and Shelf Science 56:969-987.

Meixler, M., and A. Eleria. 2005. Defining a target fish community for the Charles River in Massachusetts. Charles River Watershed Association, Waltham, MA.

Morgan, S.G. 1992. Predation by planktonic and benthic invertebrates on larvae of estuarine crabs. Journal of Experimental Marine Biology and Ecology 163: 91-110.

Museum of Paleontology. 2004. University of California, Berkeley, CA. http://www.ucmp.berkeley.edu/

Museum Victoria. 2004. Marine Crustaceans of Southern Australia. Victoria, Australia. http://www.mov.vic.gov.au/crust/page1a.html

Nelson, D. M., and M. E. Monaco. 2000. National overview and evolution of NOAA's Estuarine Living Marine Resources (ELMR) Program. National Oceanic and Atmospheric Administration Technical Memo NOS NCCOS CCMA-144.

New York Department of Environmental Conservation. 1991. Stream Biomonitoring Unit, Macroinvertebrate Species List. New York Department of Environmental Conservation, Albany, NY.

New York City Department of Environmental Protection. 2003. 2002 New York Harbor water quality report. New York City Department of Environmental Protection, New York, NY.

Oakden, J. M. 1984. Feeding and substrate preference in five species of phoxocephalid amphipods from central California. Journal of Crustacean Biology 4:233-247.

Ping, L. Y. 2004. Raffles Museum of Biodiversity Research, The National University of Singapore. http://rmbr.nus.edu.sg/polychaete/

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid assessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. U. S. Environmental Protection Agency, Washington, D.C. EPA-444/4-89-001

Rosenberg, D. M., and V. H. Resh, Editors. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York, NY.

Ramel, G. 2004. EarthLife web. http://www.earthlife.net/inverts/

Rhodes, M.C and R.J. Thompson. 1993. Comparative physiology of suspension feeding in living brachiopods and bivalves: evolutionary implications. Paleobiology 19(3): 322-334.

Ricklefs, R.E., and G. L. Miller. 2000. Ecology. W.H. Freeman and Co., New York, New York.

Riisgard, H. U., and D. F. Seerup. 2003. Filtration rates in the soft clam *Mya arenaria*: effects of temperature and body size. Sarsia 88:415-428

Rouse, G. W., and F. Pleijel. 2001. Polychaetes. Oxford University Press, New York, NY.

Schoener, T. W. 1974. Resource partitioning in ecological communities. Science 185:27-39.

Science Daily. 2004. Glycera. http://www.sciencedaily.com/encyclopedia/glycera

Shimek, R. 2004. Odd critters. http://www.rshimek.com/

Silliman, B. R., C. A. Layman, and A. H. Altieri. 2003. Symbiosis between an Alpheid shrimp and a Xanthoid crab in salt marshes of mid Atlantic states, U.S.A. Journal of Crustacean Biology 23:876–879.

Smith, C. L. 1985. The inland fishes of New York State. New York Department of Environmental Conservation, Albany, NY.

Soil and Water Conservation Society of Metro Halifax. 2004. Freshwater benthic ecology and aquatic entomology homepage. Nova Scotia, Canada. http://lakes.chebucto.org/ZOOBENTH/BENTHOS/benthos.html

Solé, R., and B. Goodwin. 2000. Signs of life: how complexity pervades biology. Basic Books, New York, New York, USA.

Steimle, F.W., and J. Caracciolo-Ward. 1989. A reassessment of the status of the benthic macrofauna of the Raritan Estuary. Estuaries 12:145-156.

Steinberg, N., D. J. Suszkowski, L. Clark, and J. Way. 2004. Health of the harbor: The first comprehensive look at the state of the NY/NJ Harbor Estuary. Report to the NY/NJ Harbor Estuary Program, Hudson River Foundation, New York, NY.

Stone, S., T. Lowry, J. Field, C. Williams, D. Nelson, S. Jury, M. Monaco, and L. Andreasen. 1994. Distribution and abundance of fishes and invertebrates in Mid-Atlantic estuaries. National Oceanic and Atmospheric Administration Estuarine Living Marine Resources Report 12. National Oceanic and Atmospheric Administration/National Ocean Service, SEA Division, Silver Spring, MD.

Taylor, D. L., and M. A. Peck. 2004. Daily energy requirements and trophic positioning of the sand shrimp *Crangon septemspinosa*. Marine Biology 145:167-177.

Thayer, G. W., W. J. Kenworthy, and M. S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: a community profile. U. S. Fish and Wildlife Service FWS/OBS-84/02.

The International Commission for the Scientific Exploration of the Mediterranean Sea. 2004. CIESM Atlas of Exotic Species in the Mediterranean Sea. http://www.ciesm.org/atlas/Rhithropanopeusharrisii.html

Thomas, K. A. 1993. The functional morphology of the digestive system of *Lyonsia hyalina* Conrad, 1831 (Bivalvia: Anomalodesmata: Pandoroidea). Journal of Molluscan Studies 59:175-186.

Todd, J. A. 2004. Neogene biology of tropical America, bivalve life habits database. London, UK. http://porites.geology.uiowa.edu/database/bivalves/Bivalve_eco.html

United Kingdom Marine Special Areas of Conservation. 2001. *Zostera*. http://www.ukmarinesac.org.uk/zostera.htm

United Kingdon Marine Special Areas Conservation. 2004. Marine communities. http://www.ukmarinesac.org.uk/index.htm

The University of Michigan Museum of Zoology. 2004. Animal diversity web. http://animaldiversity.ummz.umich.edu/site/index.html

Valentine, J. W., K. Roy, and D. Jablonski. 2002. Carnivore/non-carnivore ratios in northeastern Pacific marine gastropods. Marine Ecology Progress Series 228:153-163.

Weisberg, S. B., J. A. Ranasinghe, D. M. Dauer, L. C. Schaffner, R. J. Diaz, and J. B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries 20:149-158.

Weisberg, S. B., J. A. Ranasinghe, J. S. O'Connor, and D. A. Adams. 1998. A benthic index of biotic integrity (B-IBI) for the New York/New Jersey Harbor. *In* Sediment quality of the NY/NJ Harbor system: An investigation under the Regional Environmental Monitoring and Assessment Program (REMAP). U.S. Environmental Protection Agency - Region 2, Edison, NJ. EPA/ 902/R-98/001.

Werner, E. E., D. J. Hall, D. R. Laughlin, D. J. Wagner, L. A. Wilsmann, and F. C. Funk. 1977. Habitat partitioning in a freshwater fish community. Journal of the Fisheries Research Board of Canada 34:360-370.

Whitman, K. L., J. J. McDermott, and M. S. Oehrleinc. 2001. Laboratory studies on suspension feeding in the hermit crab *Pagurus longicarpus* (decapoda: anomura: paguridae). Journal of Crustacean Biology 21:582–592.

Woodhead, P. M., T. Rotunno and S. Zappala. 1999. New York Harbor assessment project: biological assessment of fish habitat associated with shipping piers in New York Harbor. Marine Sciences Research Center, SUNY at Stony Brook, Stony Brook, NY.

Woodhead, P. M., T. Rotunno, and S. Zappala. 2000. Ecological surveys at the project test-site in New York Harbor. Marine Sciences Research Center, SUNY at Stony Brook, Stony Brook, NY.

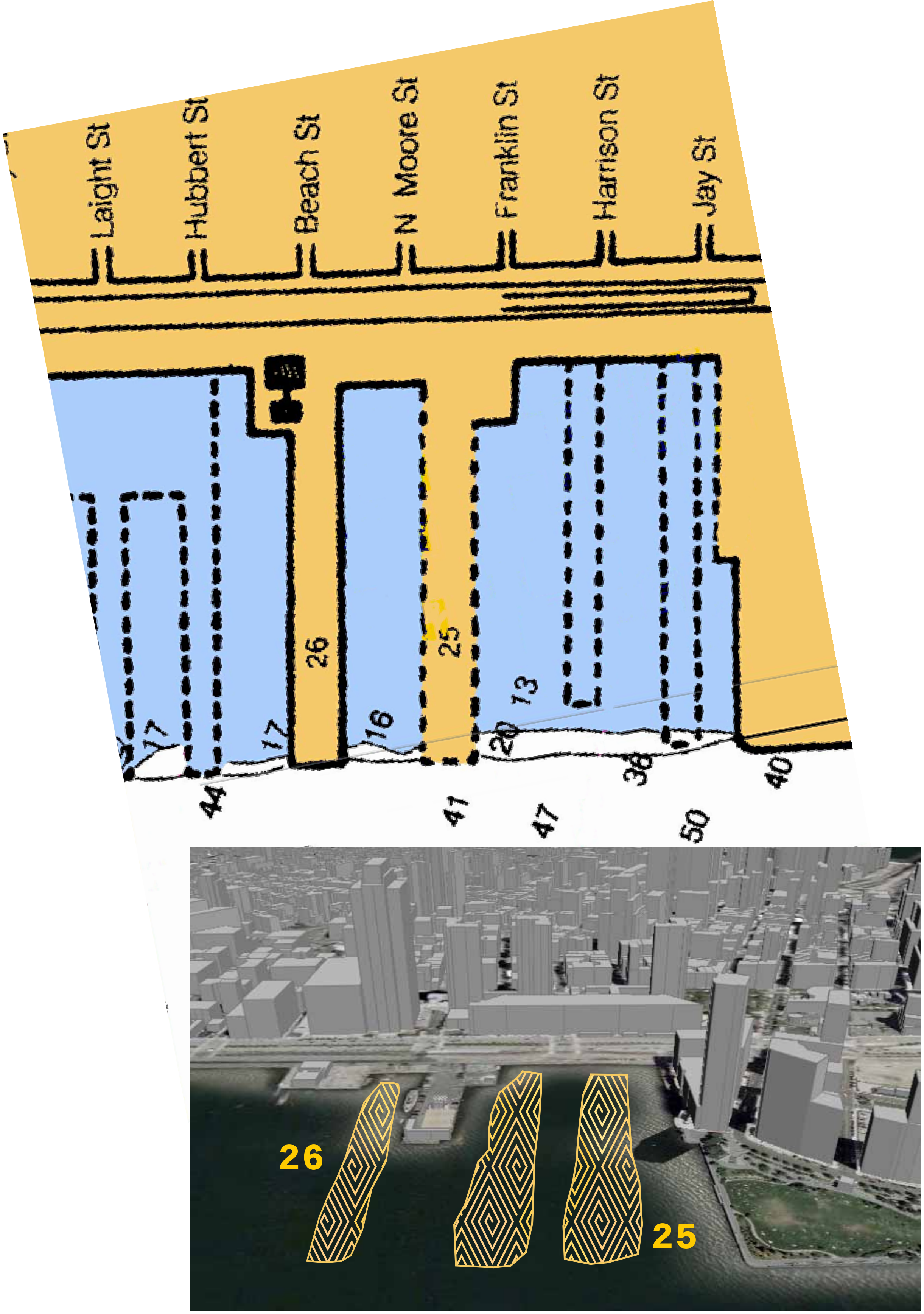
Woodhead, P. M. J., Rohlf, F. J., and O'Hare, M. A. 1992. The structure of the fish community and distribution of major species in the lower Hudson estuary and New York Harbor. Final report to Hudson River Foundation, Marine Sciences Research Center, SUNY at Stony Brook, Stony Brook, NY.

Young, C. M., and J. L. Cameron. 1989. Differential predation by barnacles upon larvae of two bryozoans: spatial effects at small scales. Journal of Experimental Marine Biology and Ecology 128:283-294.

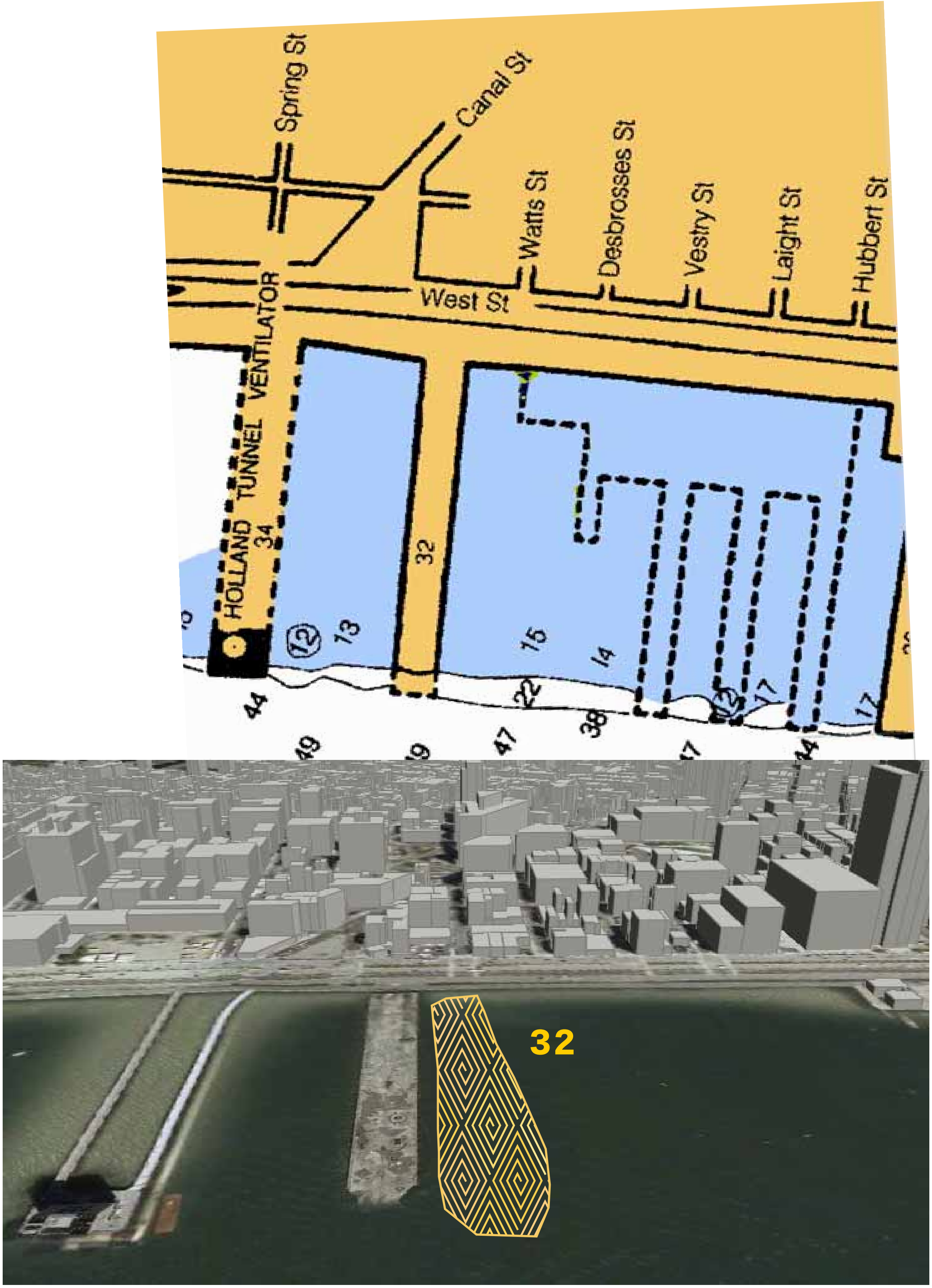
Yozzo, D. J., and F. Ottman. 2003. New Distribution records for the Spotfin Killifish, *Fundulus luciae* (Baird), in the lower Hudson River Estuary and adjacent waters. Northeastern Naturalist 10:399-408.

Appendix A

Images showing location of sampling by study site



Navigation map (depths in feet, dashed features submerged) and satellite image with sampling area shown by patterned overlay. Site numbers shown.



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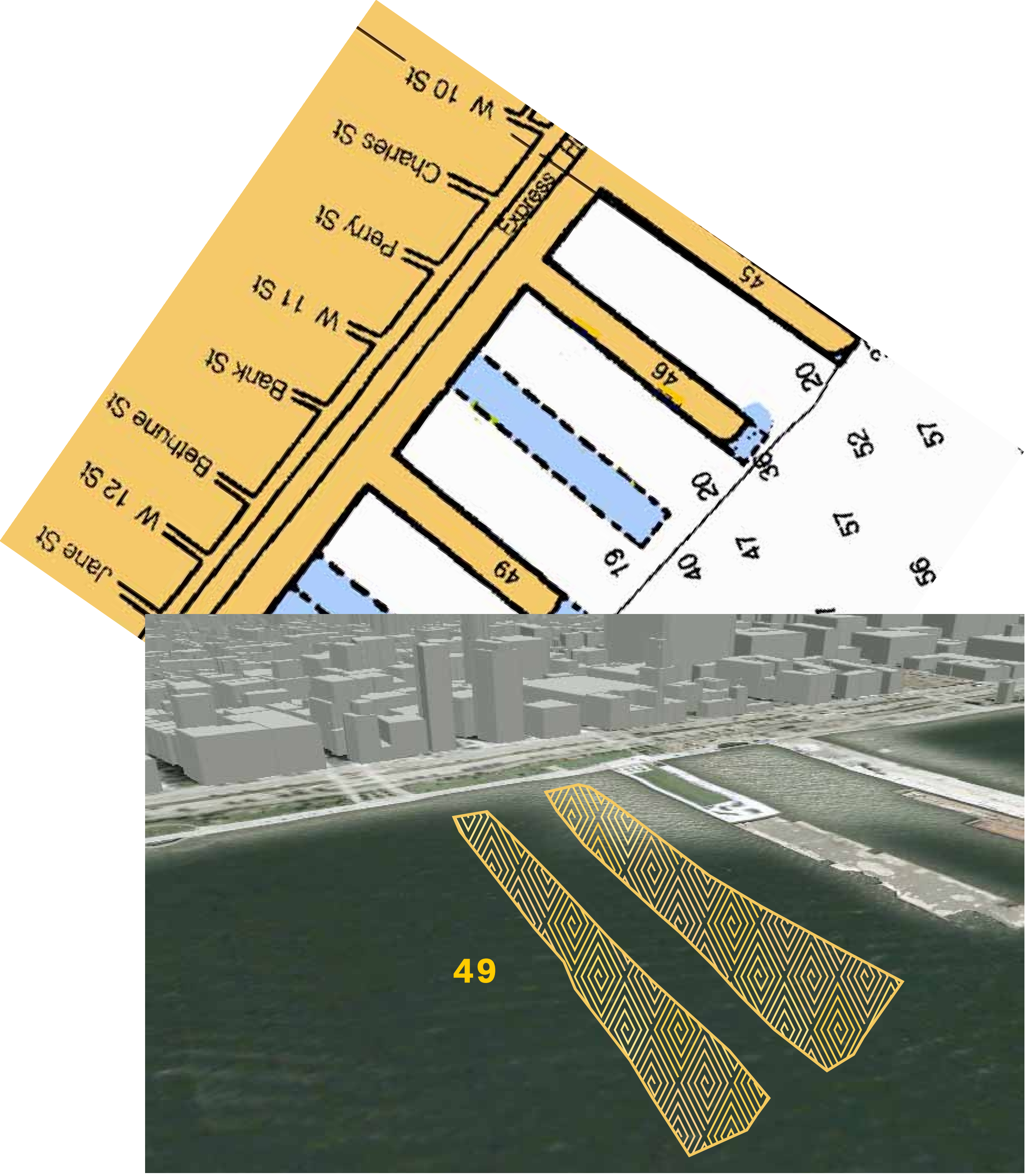

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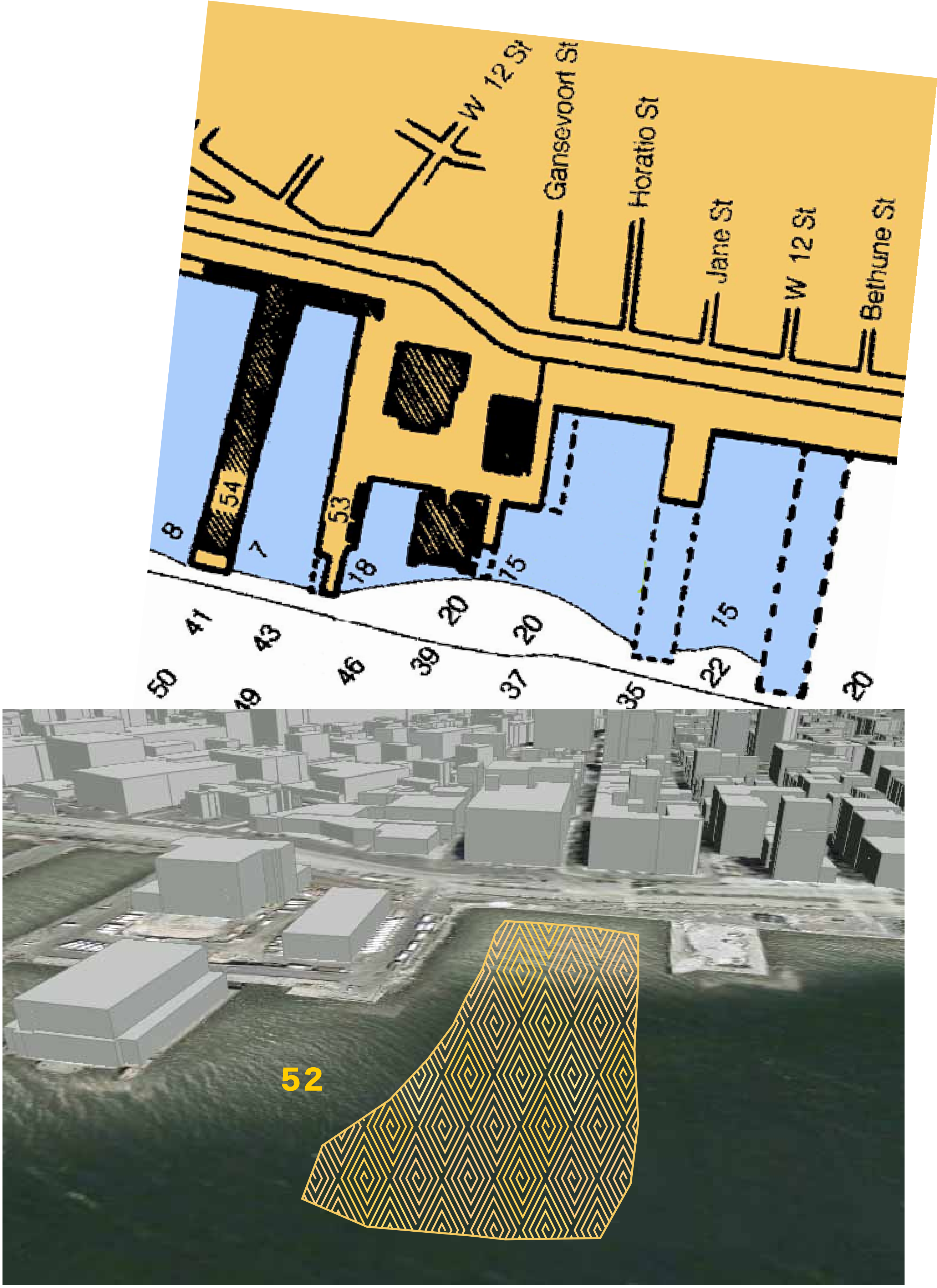

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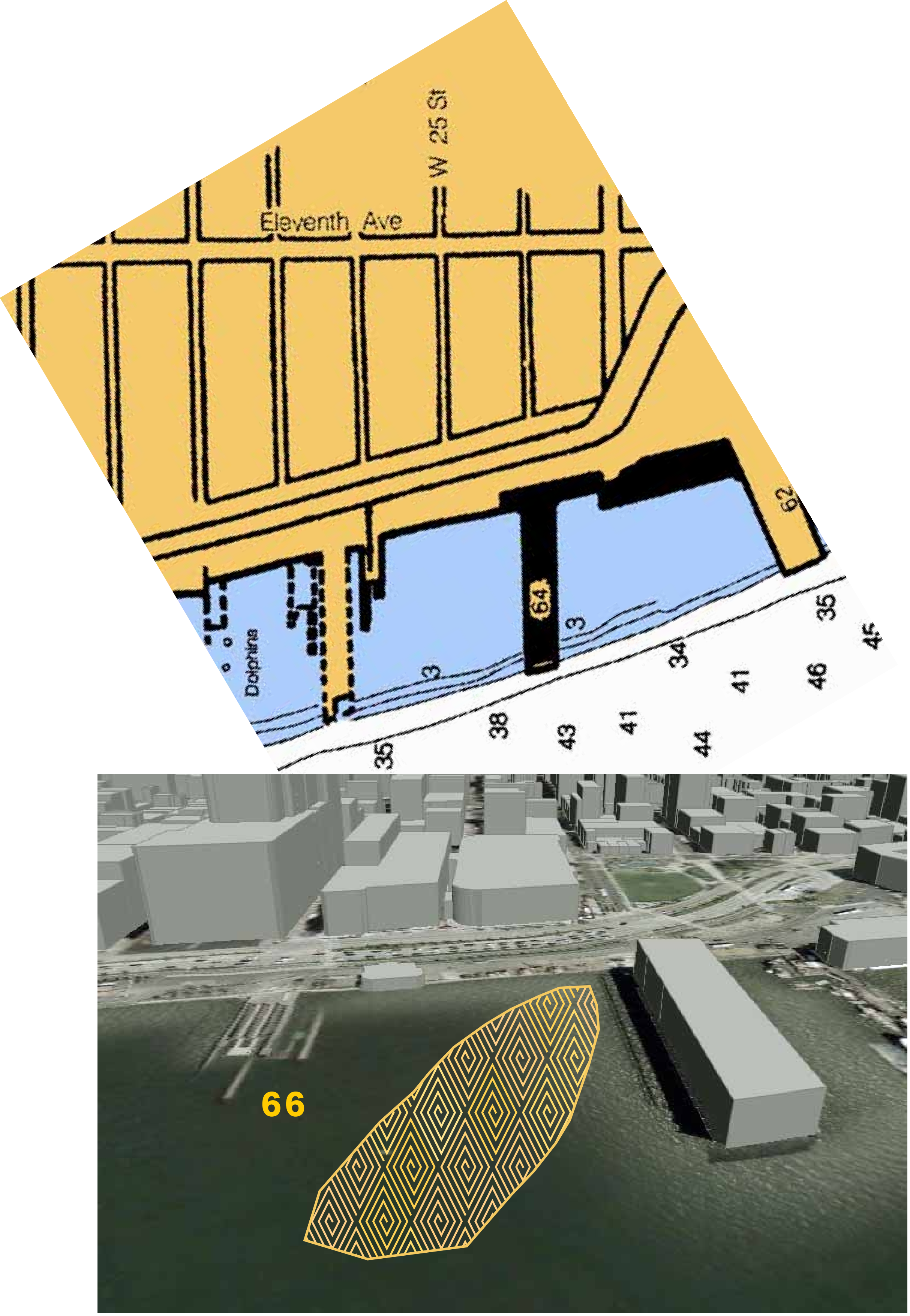

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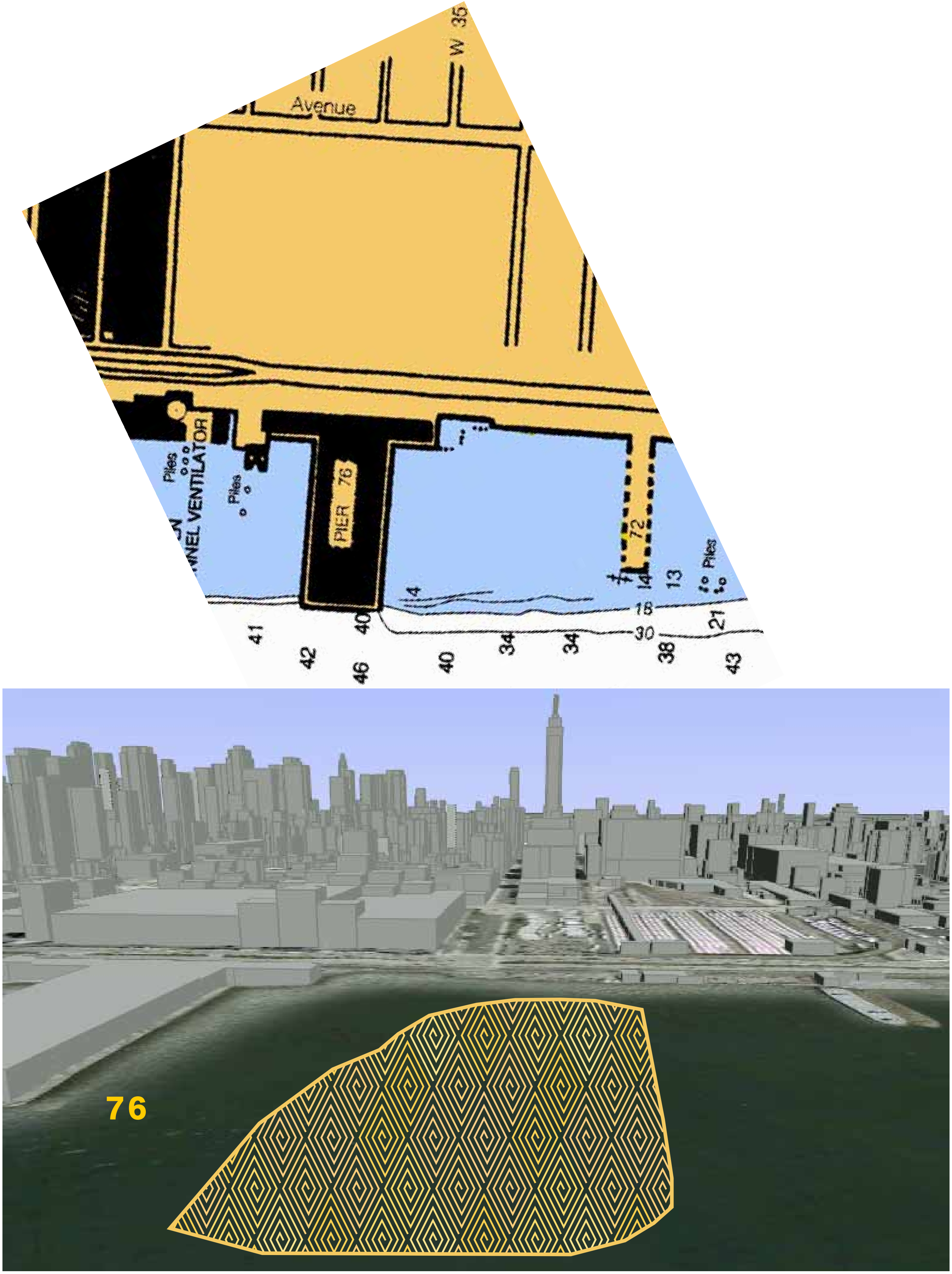
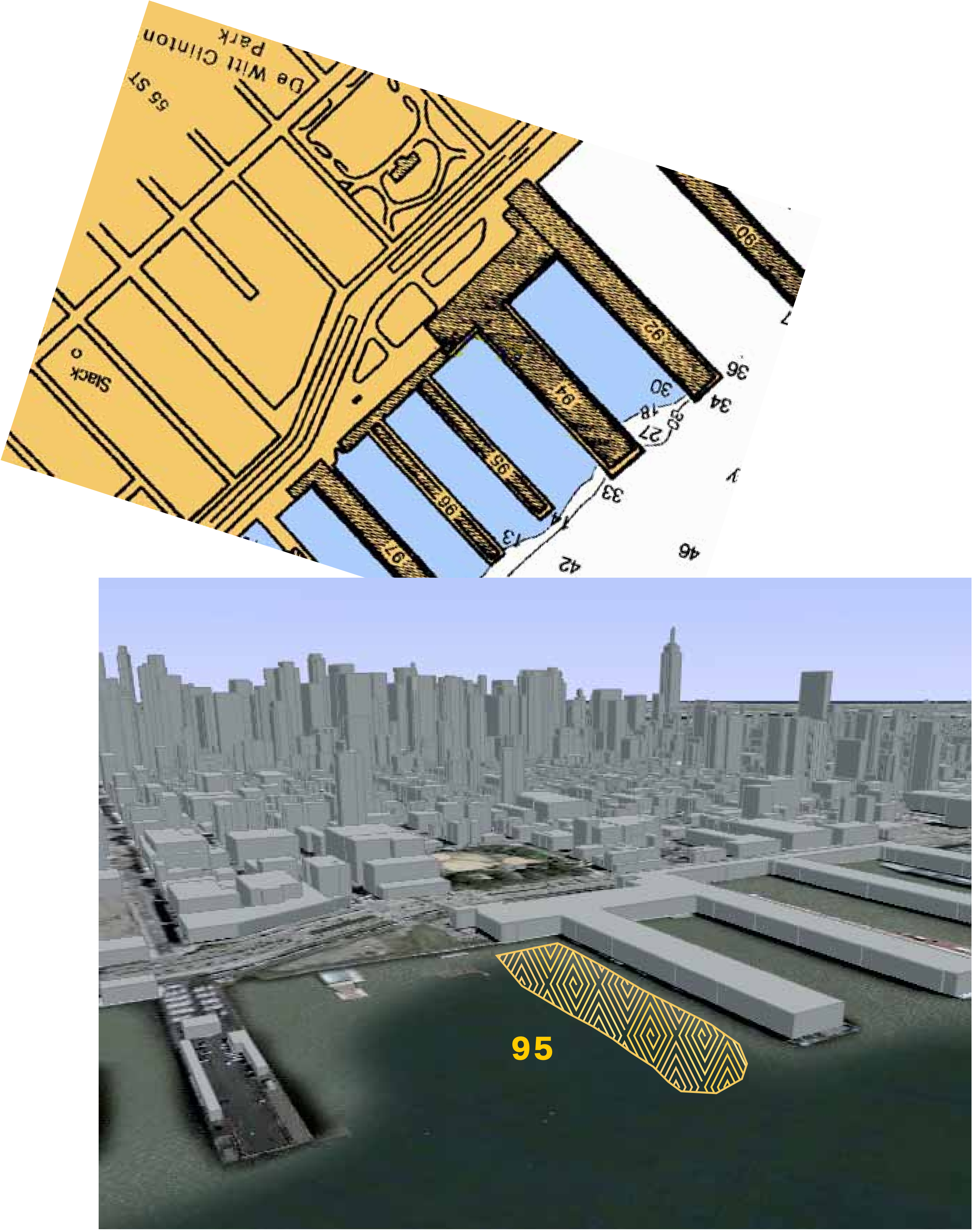


Navigation map (depths in feet, dashed features submerged) and satellite image with sampling area shown by patterned overlay. Site number shown.



Navigation map (depths in feet, dashed features submerged) and satellite image with sampling area shown by patterned overlay. Site number shown.

Appendix B

Biology of fish species classified as over or under-represented in the Hudson River Park

Windowpane, *Scophthalmus aquosus*

Physical Description
- Deep bodied and diamond shaped
- Eyes on left side of body
- Anterior dorsal fins longest near middle of fish
- Rounded tail
- Pectoral fins on both sides, left is slightly larger
- Greenish olive, reddish, grayish, slaty brown color on left side, whitish on blind side, slightly mottled or blotched, translucent

Size
- 230 to 250 mm total length

Habitat
- Adults live over sand, sandy silt, or sometimes mud
- Present up to depths of 73m, most abundant in less than 46 m
- Larvae most common in depths of 20 to 40 m
- Juveniles most common in depths of 6 to 14 m, but found in as little as 1.2 m
- 5.5 to 46.0 ppt salinity
- Sensitive to low dissolved oxygen

Food Habits
- Invertebrates, decapods, and small fishes

Reproductive Habits
- Spawning is temperature dependent, beginning in New York is summer and peaking in fall
- Occasionally split spawning season from April to July or May to June and September or September to October
- Spawning between 7 C and 20 C
- Mature at 3 to 4 years

Occurrence in the Park
- January 2003, May 2003, and December 2003, one fish each time

References

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume VI.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985

Atlantic silverside, *Menidia menidia*

Physical Description
- Slender, laterally compressed body, small head
- Translucent sea green top, almost white belly
- Silver stripe outlined in black

Size
- 50-88 mm total length as adults

Habitat
- Adults found in intertidal creeks, marshes, river mouths, beaches
- Not usually found in freshwater but prefers low salinity
- Congregate in schools over mud, sand, gravel, or peat
- At high tide can be found in sedge grass
- Juveniles more common over vegetated bottom

Food Habits
- Active feeding during daylight, continues at night
- Omnivorous visual feeder
- Eat copepods, barnacle nauplii, horshoecrab larvae, mysids, shrimps, amphipods, Cladocera, fish eggs, young squid, annelid worms, molluscan larvae, insects, algae, and diatoms.

Reproductive Habits
- Spawning dependent on temperature
- Schools move into estuaries; new and full moons at high tides
- Eggs laid in low water or on detrital mats

Occurrence in Park
- From 81 to 107 mm in length
- 4 sighted in November 2002, one in March 2003, and one in February 2004

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume VI.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

Killifishes. Fundulidae

Physical Description

- Stout body, flattened head
- Large, round scales
- Deep caudal peduncle
- Dorsal and anal fins same distance from snout

Size

- Mature in second year
- 40 to 70 mm total length

Habitat

- Found in shallow water
- Marshes, salt marshes, open beaches, coves, bays,
- Abundant in small, protected bodies of water
- Tolerant of low dissolved oxygen and high temperatures

Food Habits

- Wide range of food
- Small crustaceans, annelids, gastropods, mollusks, insects, fishes

Reproductive Habits

- Spawning in spring and summer
- Spawning takes place in shallow water near shore
- Elaborate courting rituals

Occurrence in the Park

- Not captured; present in harbor system

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume II.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

White Perch, *Morone americana*

Physical Description

- Short, deep body
- Olive, grayish green, or dark gray upper body, paler on sides
- Fins sometime have rose-colored bases

Size

- 203 to 254 mm

Habitat

- Found in shallow water, less than 4 meters
- Form schools
- Brackish water often with soft bottom
- Tolerant of broad range of salinity and temperature

Food Habits

- Feed on small fishes, crabs, shrimps, eggs of other fishes
- When young, they feed on small invertebrates—copepods

Reproduction Habits

- Spawning in May, June, and July
- Peak spawning in temperatures of 18 C to 20 C
- Males mature at 2-3, females at 3-4 years

Occurrence in the Park

- Most common in May and June
- Between 74 and 247 mm

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State*. Albany: New York State Department of Environmental Conservation, 1985.

Hogchoker, *Trinectes maculates*

Physical Description

- Small eyes on right side of body
- No pectoral fins, short and rounded tail
- Brownish color on eyed side, whitish on blind side

Size

- Not more than 20 cm
- Most often between 6 and 15 cm

Habitat

- Brackish water in bays and estuaries
- Sometimes in freshwater
- Larvae move into low salinity areas
- Over mud, silt, or sand
- Tolerant of wide range of salinity, temperature, and low oxygen

Food Habits

- Amphipods, clam siphons, nereid worms

Reproduction Habits

- Spawning from May to October in estuaries
- Spawning 1800 to 2000 hours, water 20 C, salinities 10-16 ppt

Occurrence in the Park

- Between 73 and 114 mm in length
- Captured in low numbers June to September

References

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume VI.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine.* Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

Winter Flounder, *Pseudopleuronectes americanus*

Physical Description:

- Right eyed
- Asymmetrical mouth
- Reddish brown body color
- Blunt snout, thick body

Size

- Under 40 cm

Habitat

- Mud or grassy bottoms
- In freshwater and seawater, but cannot survive below 15 ppt
- Sensitive to low dissolved oxygen
- Prefers water cooler than 23 C

Reproduction Habits

- Spawning on sandy bottoms
- Most successful with eggs laid on algal mats
- Mid-December to May
- Between 1 and 10 C

Occurrence in the Park

- Most common April to July, December and January

References

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume VI.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

Gobies, Family Gobiidae, Genera Gobiosoma

Physical Description:

- Small, deep body
- Pelvic fins connected to form a sucker
- No scales
- Two separate dorsal fins

Mean Body Size

- Maximum between 50 and 60 mm

Habitat

- Oyster bars, grass flats, weedy, protected areas
- Salinities between, .04 and 45 ppt
- Temperatures between 13 to 33.2 C
- Depths as shallow as 10 cm

Reproductive Habits

- Spawn in clam and oyster shells
- Spawn in estuaries, May to December

Occurrence in the Park

- 13 to 41 mm in length
- 1 fish collected in September 2002

References

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume V.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

Cunner, *Tautogolabrus adspersus*

Physical Description
- Long dorsal fin
- Somewhat pointed head
- Breeding females brown and males blue, non-breeding adults black

Mean Body Size
- Maximum size is 305 to 430 mm

Habitat
- Stays near shelter, either natural or manmade
- Often near wharves and pilings
- Rocky bottoms, eelgrass

Reproductive Habits
- Spawning inshore from June to August
- Group spawning in the water column with 75 to 125 fish

Occurrence in the Park
- Two specimens, 88 and 177 mm
- One in November 2002, one in March 2003

References

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume V.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

Oyster Toadfish, *Opsansus tau*

Physical Description

- Fleshy fins
- Flat head
- No scales
- Covered in slimy mucus

Mean Body Size

- Most shorter than 305 mm

Habitat

- Estuaries, shallow water
- Sandy or muddy substrates
- 0 to 34.2 ppt salinity
- May migrate to deeper waters during winter

Food Habits

- Carnivore
- Sea worms, amphipods, shrimps, crabs, mollusks, squid, fish fry including cunner, alewife, silversides, and winter flounder

Reproductive Habits

- Spawn in holes under rocks or shells, tin cans, eelgrass, or sunken logs
- April to July
- After hatching tadpoles stay attached to nest until yolk sac is absorbed

Occurrence in the Park

- Not captured; present in harbor system

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine.* Washington: Smithsonian Institution Press, 2002.

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume VI.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

Sheepshead Minnow, *Cyprinodon variegates*

Physical Description
- Short, compressed body
- Able to change color intensity with background
- Pattern of irregular bars

Size
- Up to 93 mm

Habitat
- Tolerant of very low oxygen levels and high salinities
- Shallow water, coves, bays, ponds, harbors, salt marshes

Reproductive Habits
- Spawn from May to September
- Spawn in shallow water, usually where there are rocks and logs
- In small bays, tide pools, gentle streams

Occurrence in the Park
- Not captured; present in harbor system

References

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume II.* Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

Atlantic Menhaden, *Brevoorta tyrannus*

Physical Description
- Large head with small eyes
- Blunt snout
- Dark blue, green or gray, with brassy luster

Size
- Up to 51 cm

Habitat
- Estuaries and bays
- Widely varying salinities
- Usually in water warmer than 10 C

Food Habits
- Filter feeder
- Main food is phytoplankters

Reproductive habits
- Spawning occurs during winter months
- Spawn on continental shelf
- Fish are mature between age 2 and 3

Occurrence in the Park
- Most common in August 2003 and November 2002
- 17 to 191 mm

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine.* Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

Northern Pipefish, *Syngnathus fuscus*

Physical Description
- Vary slender body with tube-like snout
- Polygonal cross-section
- Males have brood pouch

Size
- Most less than 20.8 cm, maximum size 30.5 cm

Habitat
- Prefer eelgrass or seaweed
- Found in shallow bays, salt marshes, harbors, creeks, river mouths
- Over mud, sand, and gravel
- Broad thermal tolerance

Food Habits
- Diurnal feeder
- Feed on tiny copepods, amphipods, fish eggs, and fish larvae

Reproductive habits
- Breeding from March to October
- Females deposit eggs into male's brood pouch
- When young leave pouch they never return

Occurrence in the park
- One or two fish captured throughout the year
- 49 to 225 mm

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State*. Albany: New York State Department of Environmental Conservation, 1985.

- Hardy Jr., Jerry D. *Development of Fishes of the Mid-Atlantic Bight: And Atlas of Egg, Larval and Juvenile Stages Volume II*. Solomons, Maryland: U.S Department of the Interior, Center for Environmental and Estuarine Studies, University of Maryland, 1978.

Yellow Perch, *Perca flavescens*

Physical Description
- Yellowish body color with medium size head
- Dark, even bands on sides

Size
- Males usually mature at 115 mm, females at 170 mm

Habitat
- Lakes and streams, and estuaries to 13 ppt salinity
- Near vegetation
- Adults prefer deeper water than juveniles

Food Habits
- Feed on crustaceans, insects, worms, mollusks, and fishes
- Feed by sight
- Feed during day, little activity at night

Reproductive Habits
- Spawning takes place in spring
- Spawn over sand, gravel, or vegetation in 5 to 10 feet of water
- Eggs attached by a gelatinous strand

Occurrence in the Park
- Not captured; present in harbor system

References

- Smith, C. Lavett. *The Inland Fishes of New York State.* Albany: New York State Department of Environmental Conservation, 1985.

- Jenkins, Robert E. and Noel M. Burkhead. *Freshwater Fishes of Virginia*. Bethesda: American Fisheries Society, 1993.

Bay Anchovy, *Anchoa mitchilli*

Physical Description
- Snout overhangs mouth with large eye
- Pale, almost transparent color

Size
- Usually 75 mm, maximum 110 mm

Habitat
- Very tolerant of different salinities, from freshwater to saltwater
- Clear to turbid and brackish water
- Common in shallow open water with muddy bottoms

Food Habits
- Primary food is zooplankton
- Some larger specimens eat larvae or crustaceans

Reproductive Habits
- Spawns in evening in water less than 20 m, salinity < 32 ppt

Occurrence in the Park
- 2 to 101 mm, with a few larger specimens
- Occurrences all year in large numbers

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State*. Albany: New York State Department of Environmental Conservation, 1985.

Atlantic Herring, *Clupea harengus*

Physical Description
- Small head
- Pointed snout
- Greenish blue and silver color

Size
- Up to 43 cm

Habitat
- Marine water, usually open sea
- Sometimes found in freshwater, bays or saline lakes

Food Habits
- Filter feeder
- Feed on zooplankton
- Can feed by biting

Reproductive Habits
- Widely varying spawning times depending on population
- Spring spawning usually occurs in inshore shallows
- Fall and summer spawning usually occurs in deeper water offshore

Occurrence in the Park
- Most common April to June
- 4 to 215 mm
- Most 38 to 66 mm

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Smith, C. Lavett. *The Inland Fishes of New York State*. Albany: New York State Department of Environmental Conservation, 1985.

Striped Bass, *Morone saxatilis*

Physical Description
- Stout body with bold stripes, olive green to steel blue
- Two dorsal fins of about equal length, one spiny, one soft rayed

Size
- Up to 50.9 kg
- Average length 690-856 mm TL

Habitat
- Usually found close to coast, eurythermal
- Found from saltwater to freshwater, also in brackish water
- Distribution often tracks prey species
- Often associated with strong currents

Food Habits
- Fish are main part of diet, species depends on what is available
- Sometimes bass eat invertebrates

Reproductive Habits
- Produce large numbers of eggs
- Return to rivers to spawn
- Males arrive first, then females; spring to summer
- Spawning in rivers takes place in estuaries and far into freshwater

Occurrence in the Park
- Present all year; more common from spring to fall
- 13 to 1090 mm, most below 100 mm

References

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

- Jenkins, Robert E. and Noel M. Burkhead. *Freshwater Fishes of Virginia*. Bethesda: American Fisheries Society, 1993.

Blueback Herring, *Alosa aestivalis*

Physical Description
- Deep body with large eye
- Head small and pointed

Size
- Up to 38 cm, most under 30 cm
- Females larger than males

Habitat
- Spend most of adult lives in sea
- Found over the continental shelf in water less than 13 C

Food Habits
- In saltwater, herring feed mainly on plankton and sometimes on shrimps or small fishes
- In freshwater, they eat copepods and cladocerans

Reproductive Habits
- Return to rivers to spawn
- Spawn in brackish or freshwater above the head of the tide
- Occurs in late spring to summer

Occurrence in the Park
- Many fish from November 2003 onward, except in February 2004
- 25-237 mm, most between 50 and 90 mm

References

- Jenkins, Robert E. and Noel M. Burkhead. *Freshwater Fishes of Virginia*. Bethesda: American Fisheries Society, 1993.

- Collette, Bruce B. and Grace Klein MacPhee, eds. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Washington: Smithsonian Institution Press, 2002.

Appendix C

Invertebrate taxa collected in low numbers

The following 124 taxa were recorded in low numbers in benthic samples: less than 1% of collection. The taxa are listed in rank order of organism counts from 348 down to 1.

Nereis zonata, *Odostomia* spp., *Periploma papyratium*, *Glycera dibranchiata*, *Ampelisca*, *Neanthes succinea*, *Glycera americana*, *Edotia triloba*, *Mya arenaria*, *Crangon septemspinosa*, Annelida, *Ampharete acutifrons*, *Haminoea solitaria*, *Nereis* spp., *Harpinia* sp., *Glycera* spp., *Eteone heteropoda*, *Oxyurostylis smithi*, *Maxillopoda*, *Neanthes virens*, *Nemertea*, *Capitella*, Polychaeta, *Bivalvia*, Ampharetidae, *Neomysis americana*, *Nephtys* sp., *Yoldia* spp., *Macoma balthica*, *Amphipoda*, *Modiolus modiolus*, *Polydora* sp., *Leitoscoloplos fragilis*, *Edotia montosa*, *Notomastus* spp., *Nemata*, *Dexamine thea*, *Rictaxis punctostriatus*, *Idotea metallica*, *Spiochaetopterus oculatus*, Syllidae, *Tharyx acutus*, *Callinectes sapidus*, *Mytilus edulis*, *Phyllodoce* sp., *Isaeidae*, *Lyonsia hyalina*, *Balanus improvisus*, *Diopatra cuprea*, *Phoxocephalidae*, *Cumacea*, *Edotia* sp., *Erichsonella attenuata*, *Leitoscoloplos acutus*, Naticidae, *Paranaitis speciosa*, *Phyllodoce arenae*, Cirratulidae, Glyceridae, *Idotea phosphorea*, *Molgula* sp., *Byblis gaimardi*, *Cylichna* sp., *Gammarus daiberi*, *Nassarius trivittatus*, *Nucella lapillus*, *Sabellaria vulgaris*, *Anaitides maculata*, *Atylus swammerdami*, *Cyathura polita*, *Leptocheirus plumulosus*, Mactridae, Mysidae, Spionidae, *Balanus* sp., *Euspira immaculata*, *Hirudinea* , *Malacostraca*, *Podarke obscura*, *Amphitrite ornata*, *Anurida maritima*, Aoridae, *Diastylis* sp., *Eteone longa*, Hesionidae, Isopoda, *Panopeus herbstii*, Phyllodocidae, *Tellina* sp., *Turbonilla* spp., *Yoldia limatula*, *Ampharete* sp., *Astarte undata*, Balanidae, *Chiridotea* sp., Decapoda, *Demonax microphthalmus*, *Diastylis sculpta*, *Epitonium* sp., *Eunice pennata*, *Euspira heros*, Gastropoda, *Glycera capitata*, Goniadidae, *Hydrozoa*, *Margarites helicinus*, *Marphysa* sp., *Nephtys picta*, *Neverita duplicata*, Opheliidae, *Ovalipes ocellatus*, *Pagurus longicarpus*, *Pagurus* sp., *Paracaprella tenuis*, *Parametopella cypris*, *Phoxichilidium femoratum*, *Politolana polita*, Porifera, Pycnogonida, Pyramidellidae, *Rhithropanopeus harrisii*, Sphaeromatidae, *Unciola irrorata*

Appendix D

Guide to Benthic Invertebrates of the Hudson River Park

Guide to Benthic Invertebrates of the Hudson River Park

Anne Gallagher Ernst
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Troy, New York

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2006

Special thanks to:

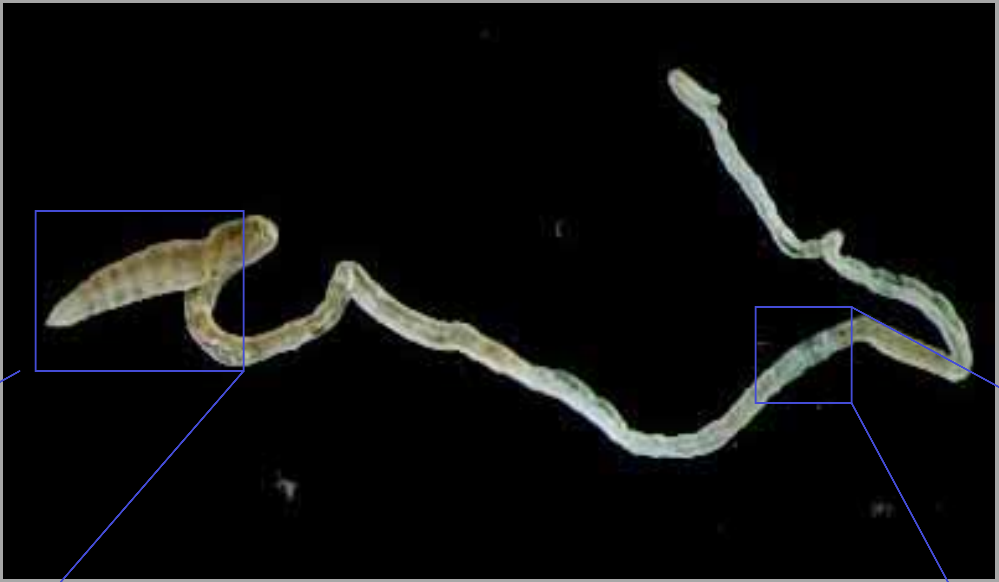
The Hudson River Park Trust

NYS Department of Environmental Conservation Stream
Biomonitoring Unit, especially Larry Abele

Dr. Robert Cerrato, SUNY Stony Brook

* Annelida *

Oligochaeta



Anterior region lacks parapodia.

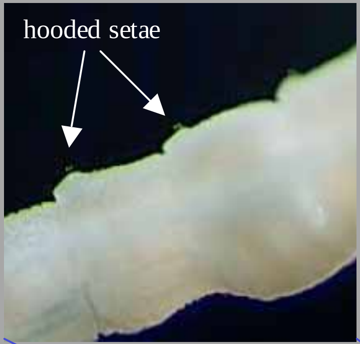
Oligochaeta are small segmented annelids, lacking anterior appendages and parapodia. Oligochaetes possess two groups of paired setae, one dorsal and one ventral. Family recognition requires assessment of ventral setae and its shape.

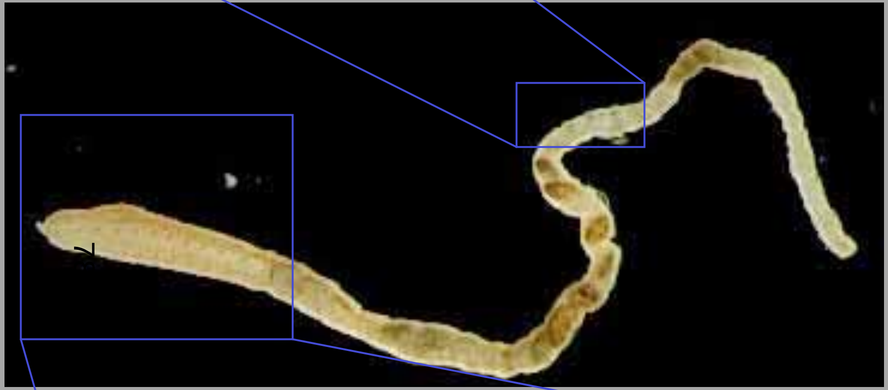
Abdominal segments lack hooded setae.

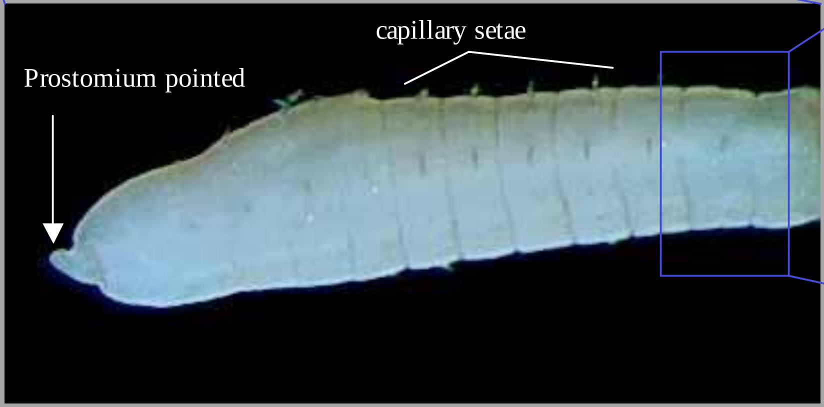
* Polychaete worms *

Capitellidae

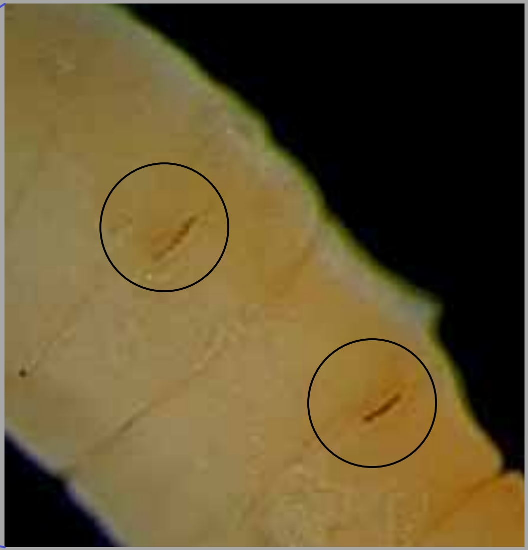
Capitellids, or threadworms, are the most rudimentary of polychaetes. Capitellids feed on organic matter in the sediments and are tolerant of disturbance and pollution. They are essentially featureless. Genera definition relies on counting the number of anterior segments possessing capillary setae. Abdominal segments have hooded setae enveloped by a clear membrane.







Head lacks appendages or adornments



Parapodia are highly reduced, appearing as mere ridges.

Sabellaria vulgaris

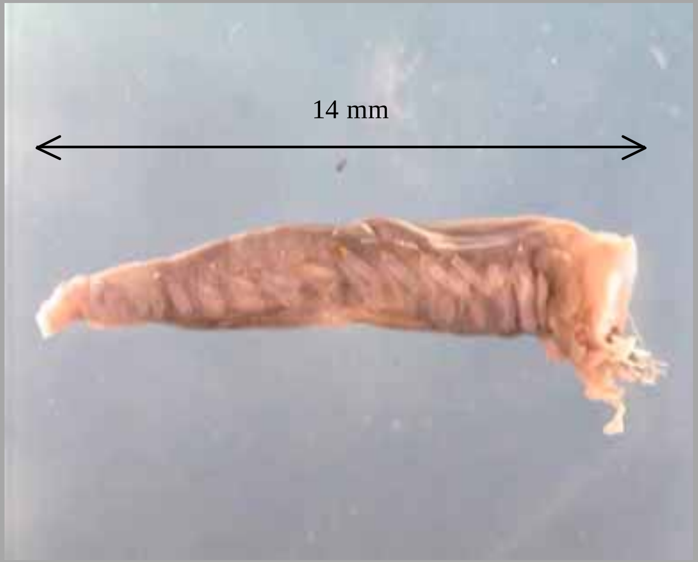
S. vulgaris, the cement-tube worm, builds sand tubes that can form reef-like structures when the worms are found in colonies. These colonies provide a food source, and possibly spawning and nursing habitats, for a large variety of fish, including winter flounder.

head of worm has operculum with a pad of golden tentacles, and an area of longer tentacles behind; body is stout, with 2 rows of setae; this specimen is missing its posterior

operculum has pad of golden tentacles arranged in 2 concentric semicircles

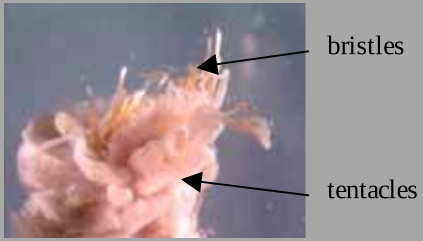
Pectinaria gouldii

P. gouldii, called cone worms or trumpet worms, live vertically, with their heads down and the pointed ends of their tubes up. They are common in the intertidal zone and offshore in muddy bottoms.



body is pink or beige, mottled with red or blue and with pale pinkish tentacles; worm can grow up to 5 cm long

head has two comb-like rows of golden bristles on head



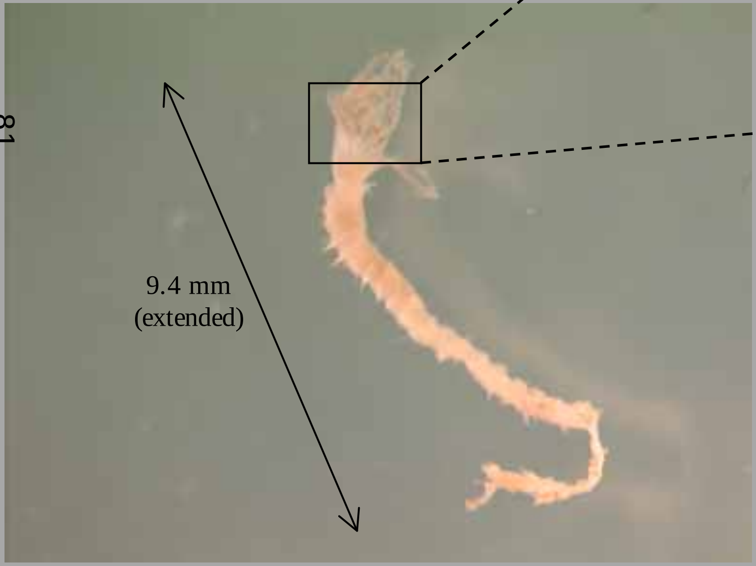
(ventro-lateral view)

(dorsal view)

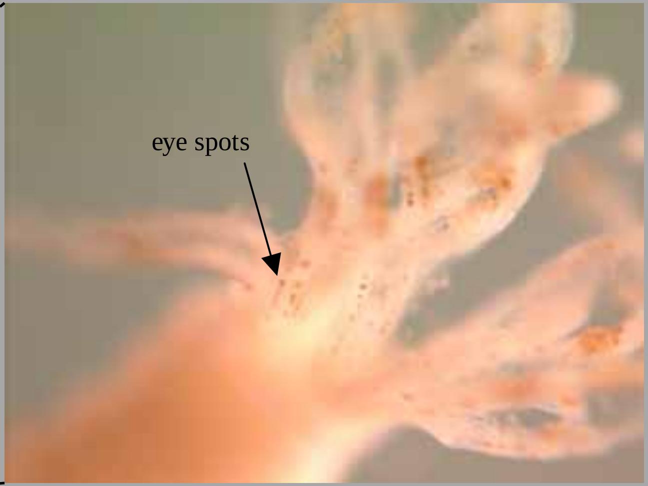
cone-shaped tubes are made from a single layer of sand grains

Sabella microphthalma

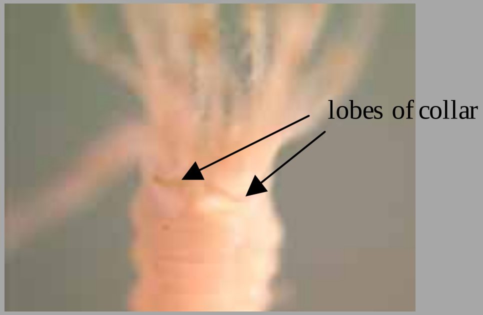
S. microphthalma and other sabellid worms are known as feather-duster worms because of their fan of tentacles. They live in flexible, leathery tubes attached to shells, and are thus considered epifauna.



worm has whitish body; more than 12 segments have setae; tentacles are arranged in 2 semicircular, fan-like lobes



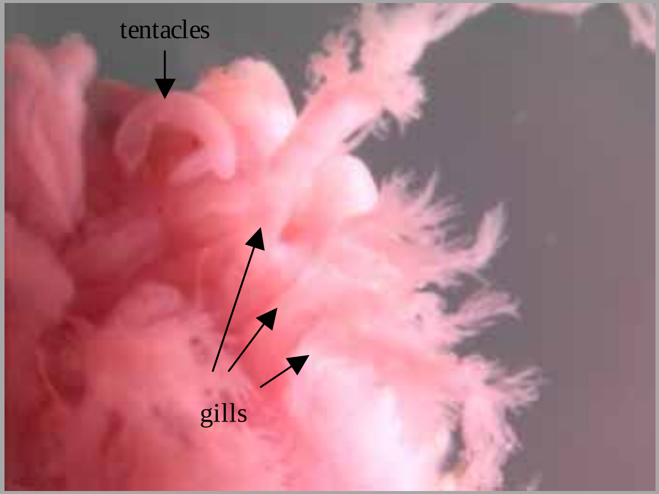
tentacles are joined only at the base; each tentacle has reddish-brown eye spots arranged in 2 irregular rows



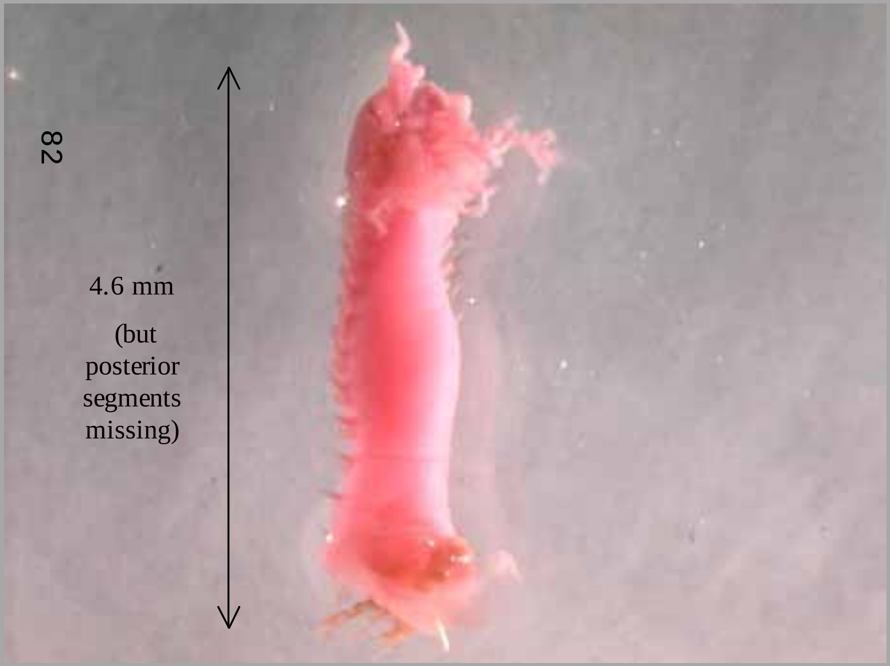
collar is divided into 2 lobes

Amphitrite ornata

A. ornata, the ornate worm, builds U-shaped tubes of black mud or sand near low water level and offshore. They are deposit-feeders, and disturb the sediment through both their feeding and their tube-building.



head has 3 pairs of bushy, branched gills; tentacles cannot be withdrawn into mouth

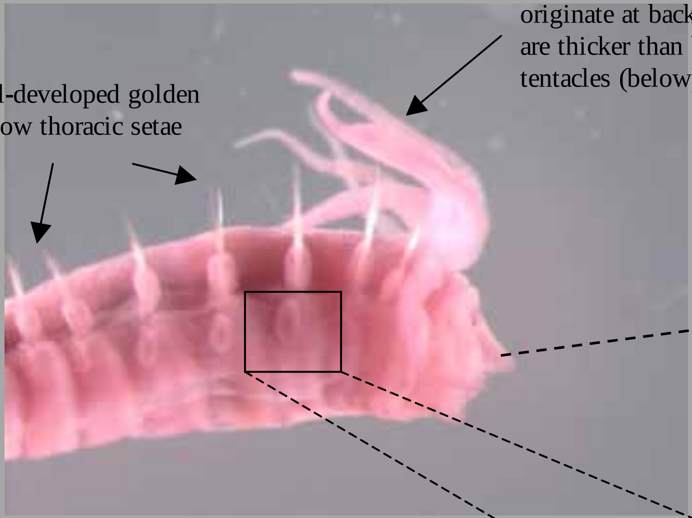


setae are found on 40-50 anterior segments and are absent from posterior segments (this specimen is missing much of its posterior segments, so this feature isn't apparent)

setae extend down sides of worm

Ampharete acutifrons

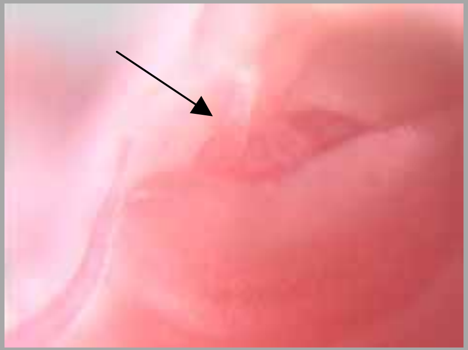
A. acutifrons, like all ampharetids, are tubicolous tentacle feeders. They are short-lived, mature in a few months, and serve as a main source of food for flounders in spring and summer. Recruitment of young takes place in the spring. Recruitment varies widely; a related species, *A. falcata*, has benthic larvae and thus reduced dispersive capacity.



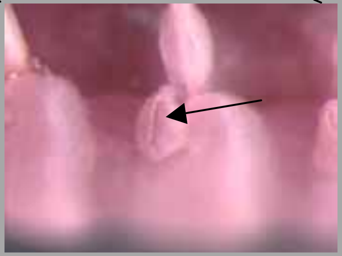
well-developed golden yellow thoracic setae

unbranched, tentacle-like gills originate at back of head and are thicker than branched tentacles (below)

males are greenish white, and females are rose colored (this specimen has been stained with rose bengal)

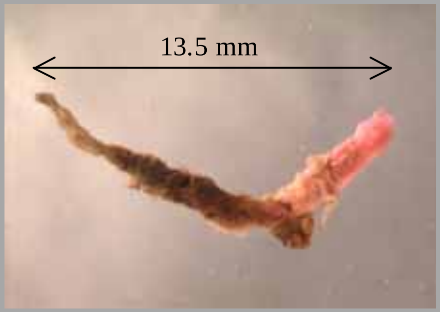


branched (pinnate) tentacles can be withdrawn into mouth



thoracic uncini have 8-10 teeth

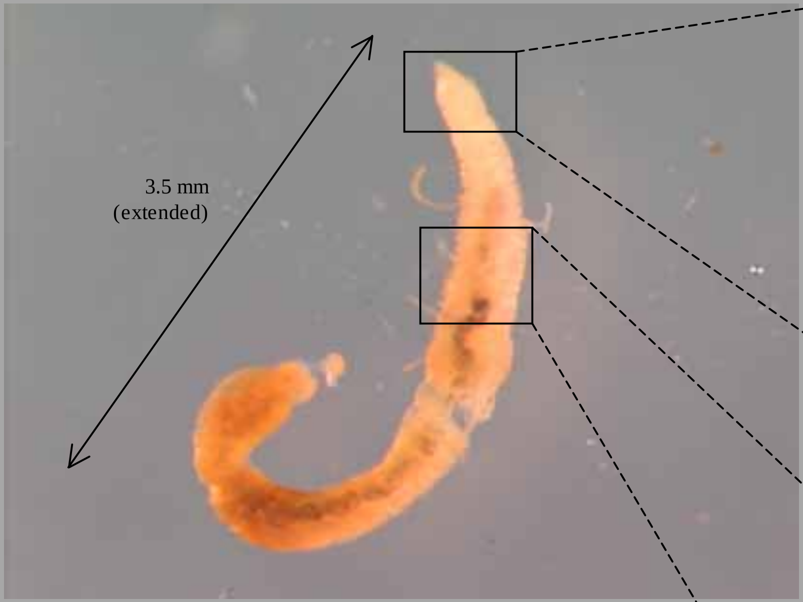
about 14 anterior segments have setae; 12 (or fewer) posterior segments have none; pygidium has 10-14 cirri (pygidium missing on this specimen)



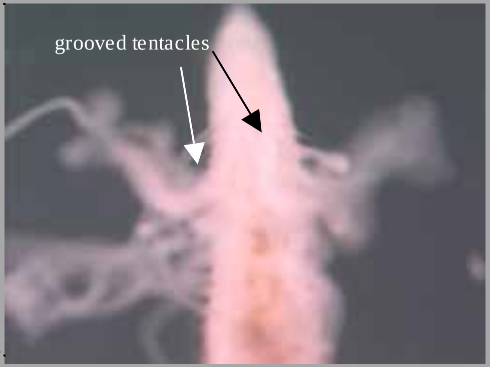
membranous tube is generally covered with sand and mud

Tharyx acutus

T. acutus and other cirratulid worms are mostly mud dwellers and tentacle feeders. They form impermanent tubes. *T. acutus* is the most common *Tharyx* species; it is found on dredge spoil dump sites and other polluted areas.



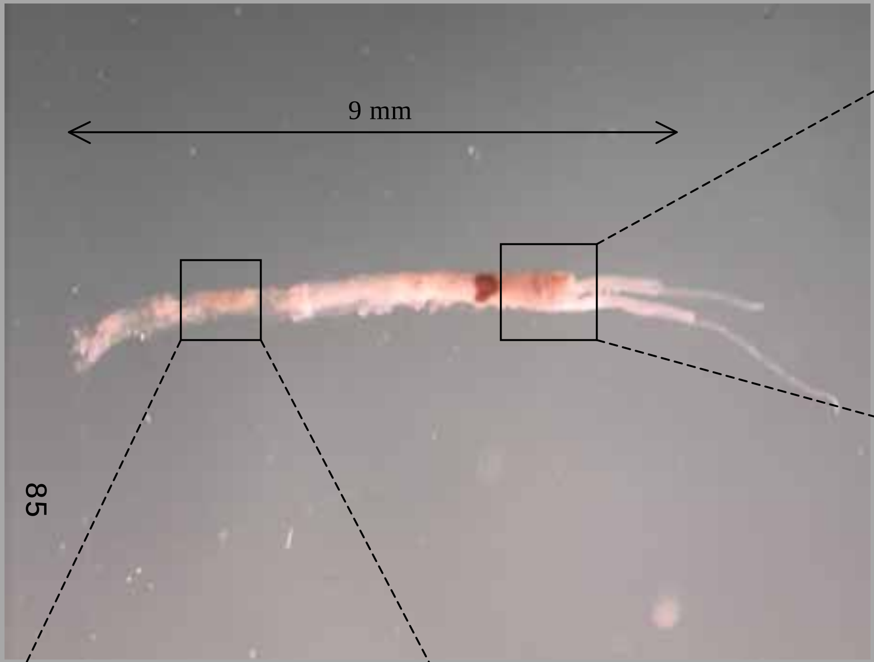
setae are tubes rather than crochets; body is pale-colored; grows up to 16 mm in length



first setiger has 2 grooved tentacles

short, thread-like gill filaments along entire length of body

Spiochaetopterus oculatus



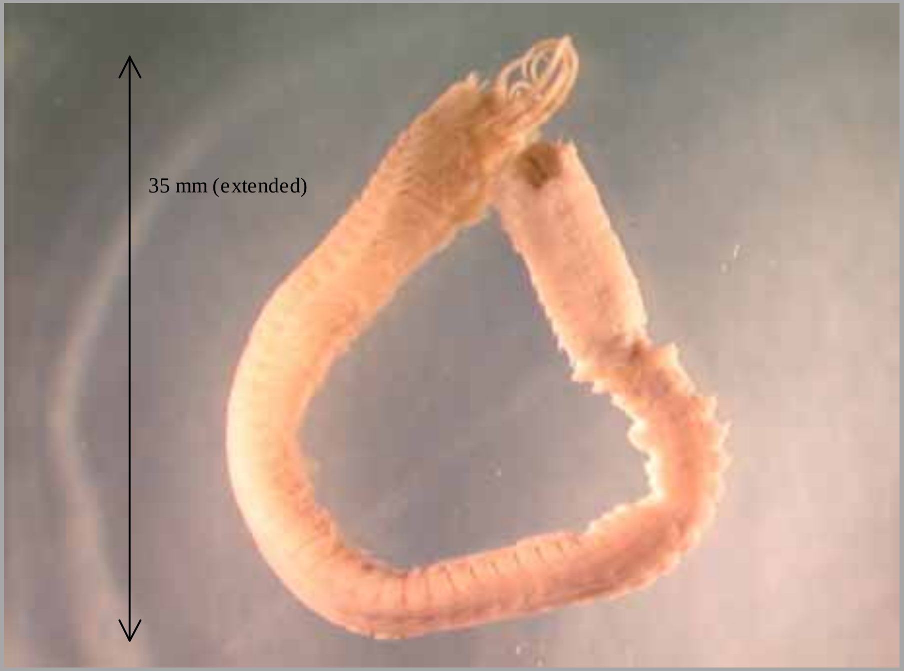
head is rounded, with 2 long tentacles (or specialized palps) extending forward

cylindrical worm tube is transparent and annulated

worm is yellowish to light brown and grows up to 6 cm; pygidium (most posterior segment) is lobed without cirri, though this specimen is missing the pygidium

S. oculatus, the glassy tube worm, is found in mudflats and in shallow water. It uses its 2 long tentacles to grasp prey. It changes sediment characteristics through bioturbation by constructing its tubes below the sediment surface.

Diopatra cuprea



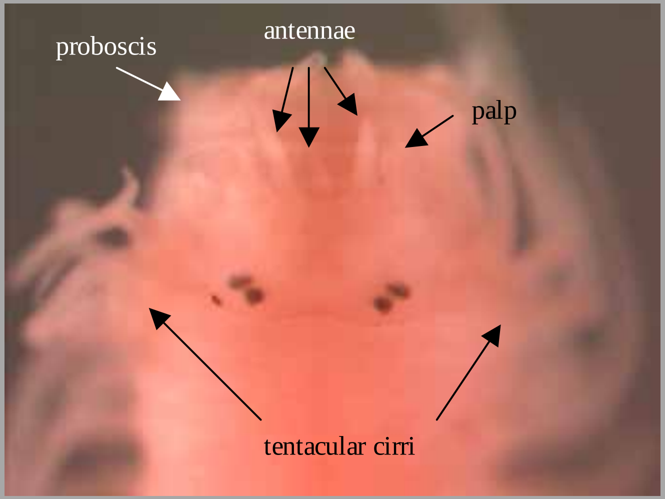
D. cuprea, or junk worms, live in long parchment-like tubes to which they attach bits of shells, pebbles, seaweed, and other “junk.” The tubes are mostly embedded but can extend several inches above the surface of the substrate. They are bright red when alive and can grow up to 30 cm. They are very common.

conspicuous feather-like gills anteriorly are strongly spiraled

5 tentacles, 2 globular palpi, 2 tentacular cirri; no eyes, but 2 sensory organs that may be mistaken for eyes (not pictured here); strong jaws

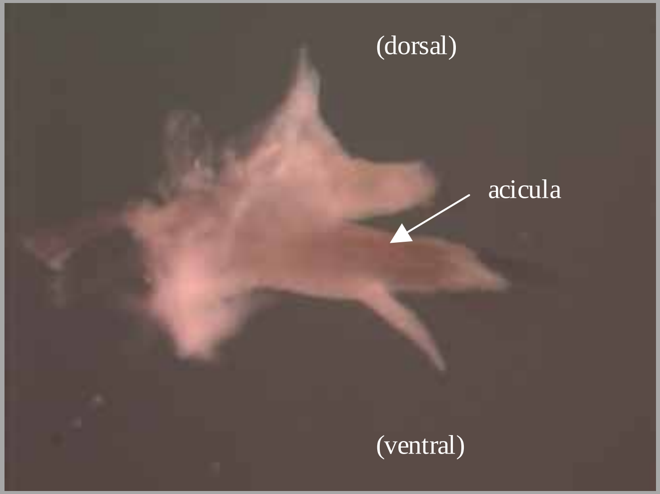
Podarke obscura

P. obscura, the swift-footed worm, is common in eelgrass and bottom debris from the interidal zone to deep water. It swarms to the surface at night in summer.



4 eyes; prostomium has 3 antennae (including a short, median antenna), 6 pairs of tentacular cirri, and 2 slender, jointed palps

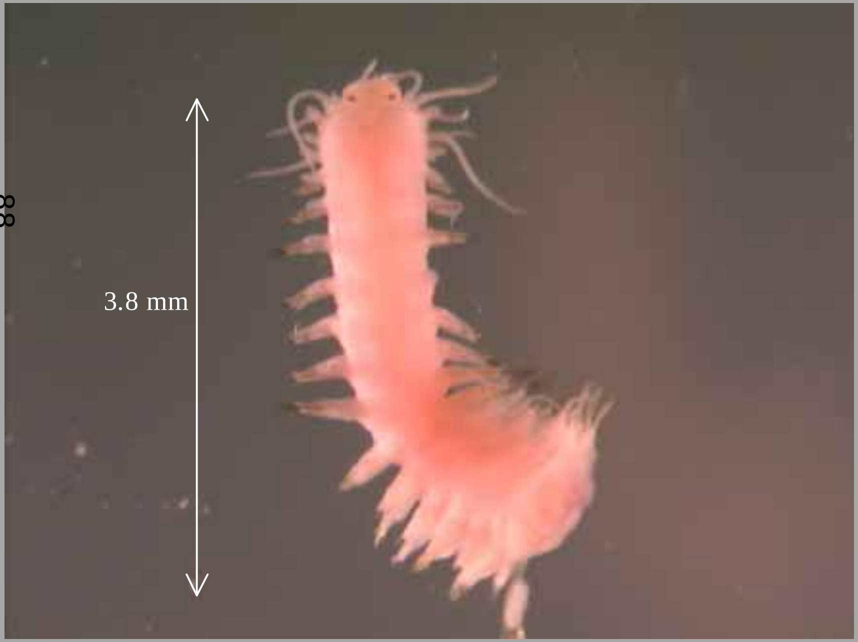
worm can have dark coloration with yellow cross bands; this specimen is missing posterior end (which can have defining characteristics)

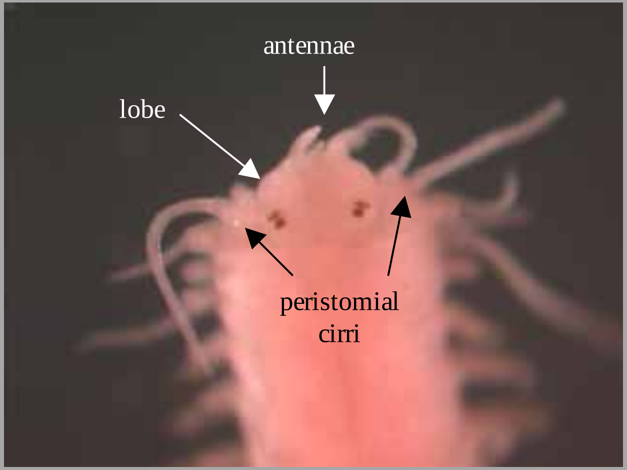


hesionid characteristic: parapodia are biramous, notopodia have internal acicula

Syllidae

Syllids are small, carnivorous worms, often found on sponges, hydroids, and ascidians. They include many genera with a range of life history strategies.





head has 3 antennae; 2 fleshy lobes that are not jointed; and 1-2 pairs of peristomial cirri

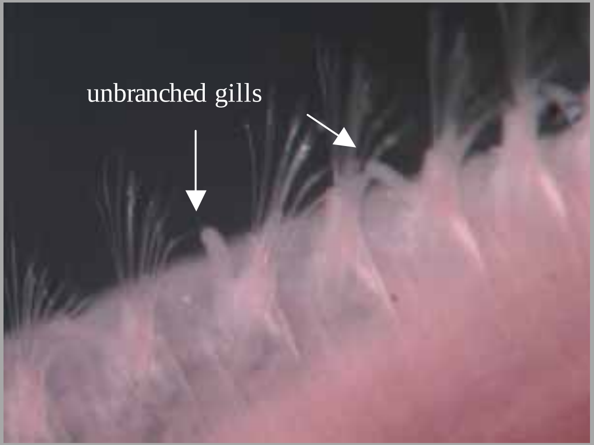
parapodia are uniramous

Glycera dibranchiata

G. dibranchiata are also called blood worms (patches of blood can be seen in live specimens along length of body) or beak throwers (they have an eversible proboscis). They can occur from near low-tide level to offshore, in sand or mud. They are detritivores.

body is pink or beige,; worm can grow up to 37 cm long and 1 cm thick

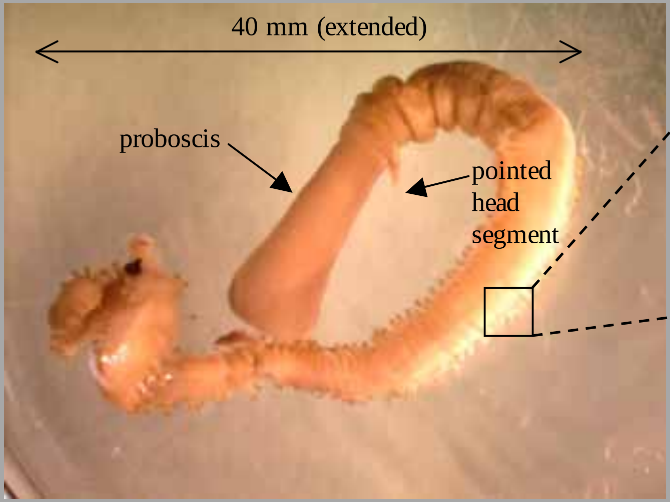
head segment is pointed and has 4 tiny antennae; proboscis in this specimen is not extended



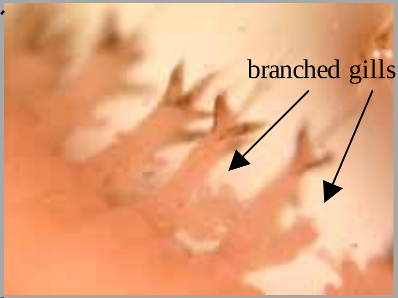
parapodia have lobes; gills are unbranched and cannot be retracted

Glycera americana

G. americana (and all members of the family Glyceridae, like *G. dibranchiata*), are called blood worms and beak throwers. They are found near low tide level in sand and mud and offshore. They are detritivores.



Worm with proboscis extended. The proboscis shoots out of the mouth when the worm is feeding or disturbed.

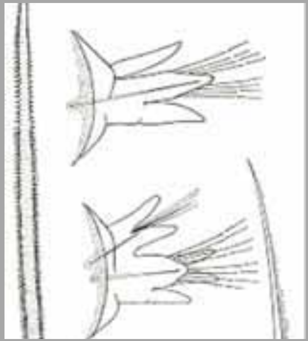


Each parapodium has branched gills that can be withdrawn.

(compare to *G. dibranchiata* with unbranched gills)

end of proboscis has four black jaws

G. americana (and all glycerids) have uniramous parapodia along the length of the body.

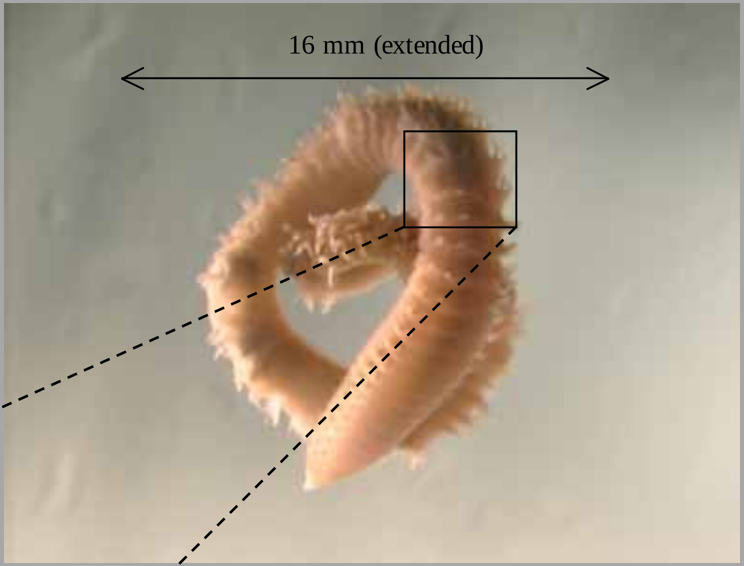


uniramous parapod

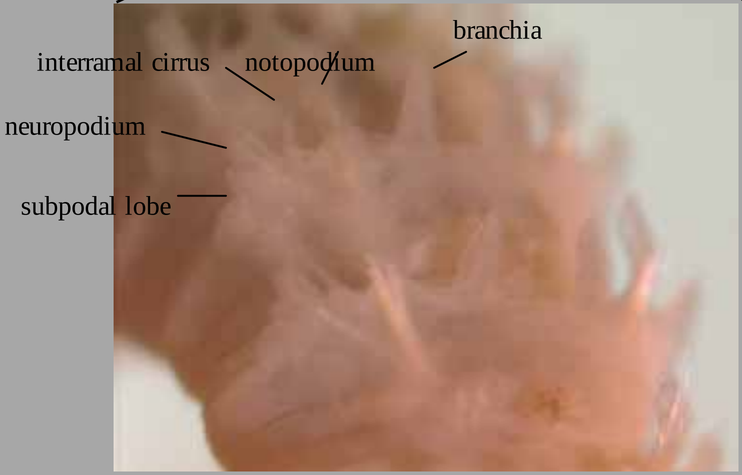
biramous parapod

Leitoscoloplos fragilis

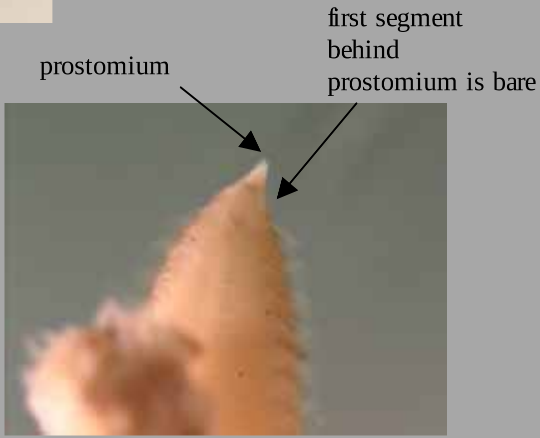
L. fragilis (and other members of the family Orbiniidae) are very common in mud and sand near the low tide level, and are found offshore as well. *L. fragilis* is the most common orbiniid worm.



These worms have a thicker mid-body and are narrower at the head and tail. The dorsal surface of the mid-body is covered with furry gills. The branchiae begin on setigers 20-32.



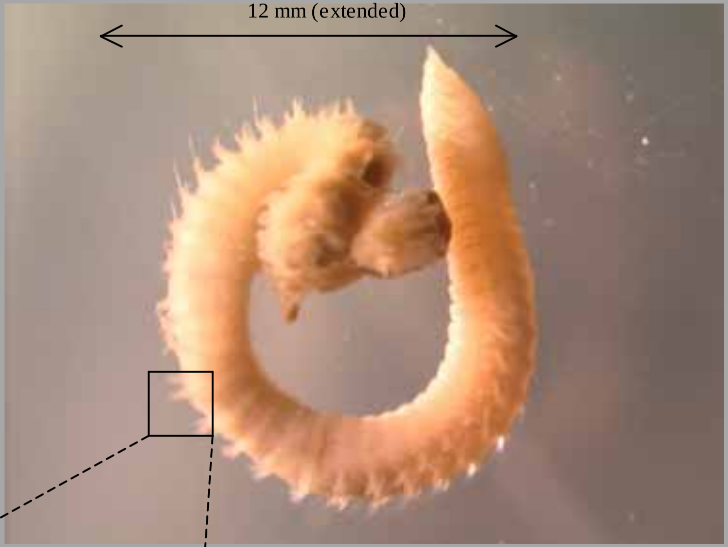
anterior abdominal segments have interramal cirri with a branched subpodal lobe below the neuropodium (compare to *S. armiger/acutus*)



Pointed head segment has no appendages, and the first segment behind the prostomium has no appendages or setae.

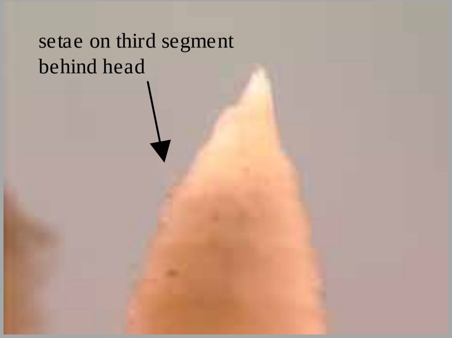
Leitoscoloplos armiger/acutus

Leitoscoloplos spp. are common in mud and sand near low tide, and found offshore as well. They tolerate a range of sediments, and so are widespread. They are mobile deposit-feeders, and serve as prey for flatfish as well as the polychaeta *Nephtys*. They play a large role in ecosystem functioning by their involvement in bioturbation in suboxic areas due to the practice of building tubes down to 15 cm below the sediment surface.

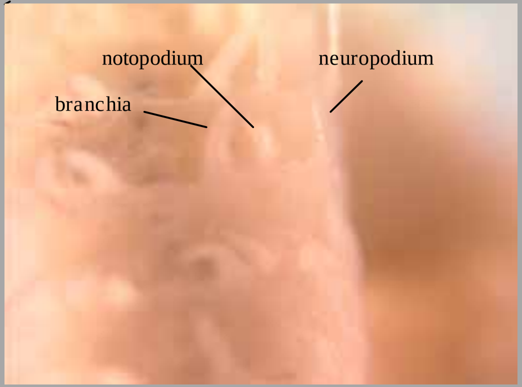


Thick mid-body, narrower at head and tail; dorsal surface of mid-body is covered with furry gills; branchiae begin on setigers 8-32; can grow to length of 40 mm (*L. acutus*) or 120 mm (*L. armiger*).

L. acutus and *L. armiger* differ in their transitional parapodia: *L. acutus* has no subpodal papillae and *L. armiger* have 1-2.

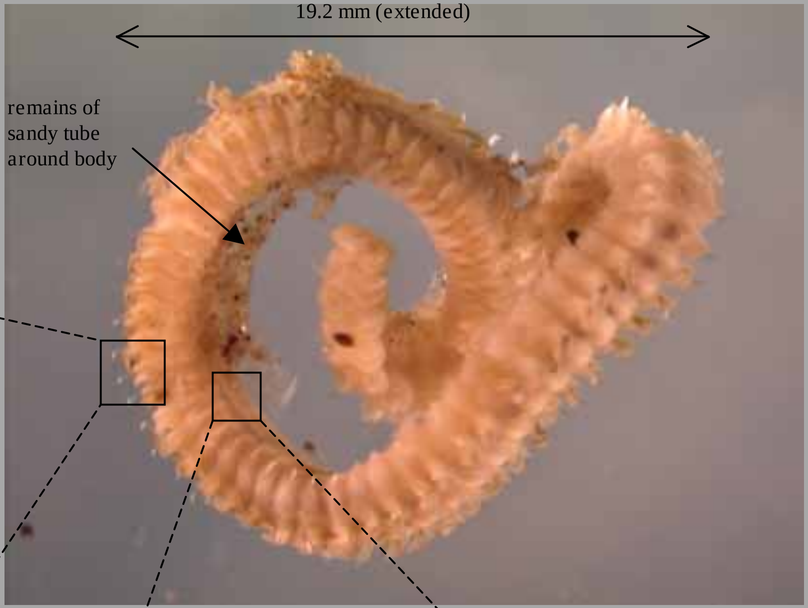


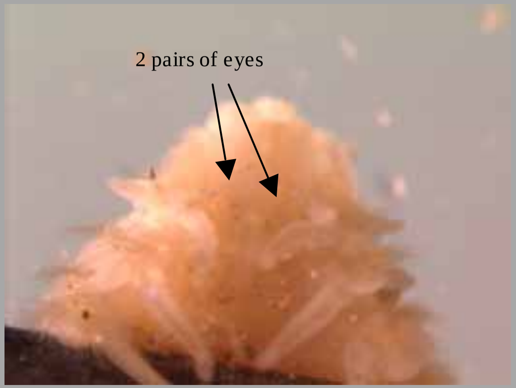
pointed head segment; first 2 segments behind head have no appendages or setae



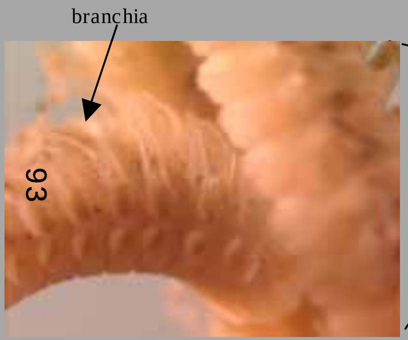
anterior abdominal segments have no interramal cirri (compare to *L. fragilis*)

Spio setosa

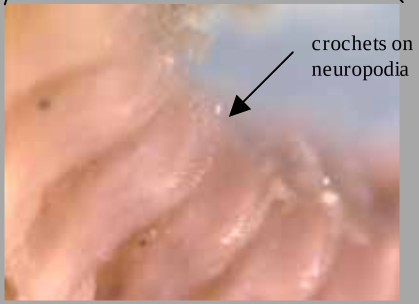




head has 2 pairs of eyes that are visible dorsally; branchiae are visible on the first setiger



branchiae begin on first segment and continue to the rear of the body

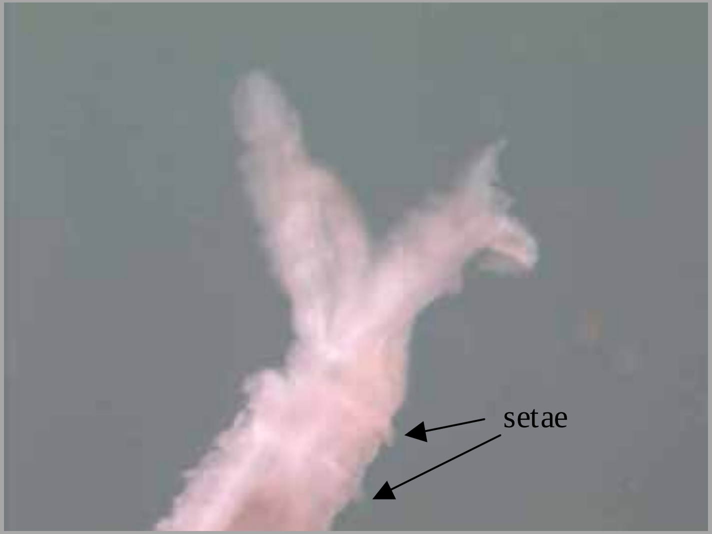


neuropodia have about 16 crochets

S. setosa is one of the most common spionid worms found in the Hudson. It lives in sandy, chimney-like tubes on protected beaches and sand flats.

Streblospio benedicti

segmented worm with 4 tentacles on head that are all longer than the head segment



setae are present on first two segments (and the rest of the segments as well)

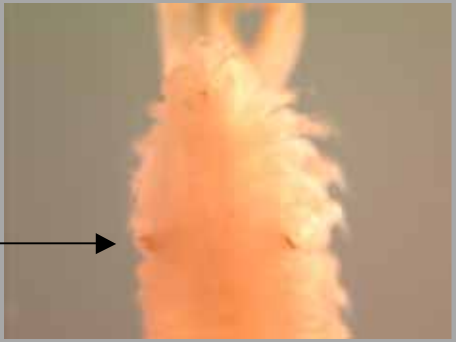
live specimens have 2 coiling tentacles, 2 gills banded with dark green stripes; however, color is often lost in preservation.

S. benedicti, a spionid polychaete, is indicative of polluted environments. It is an opportunistic, estuarine worm that tends to dominate the early successional stages of a benthic community. It has a tolerance for low dissolved oxygen levels.

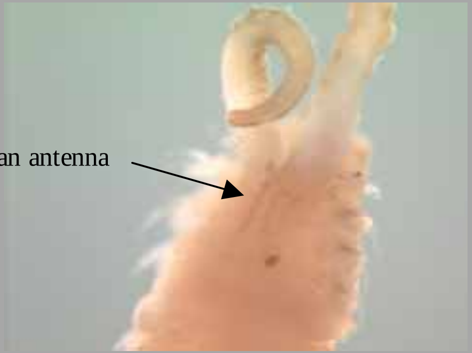
Polydora ligni

P. ligni, a spionid polychaete, is the most common free-living species of *Polydora* in the Hudson. It builds soft vertical tubes of mud attached to bottom mud and hard objects (e.g. shells) in shallow water. Large colonies can be found offshore on mudflats and oyster beds.

worm has a pair of tentacles; its body is not sharply divided into distinct regions



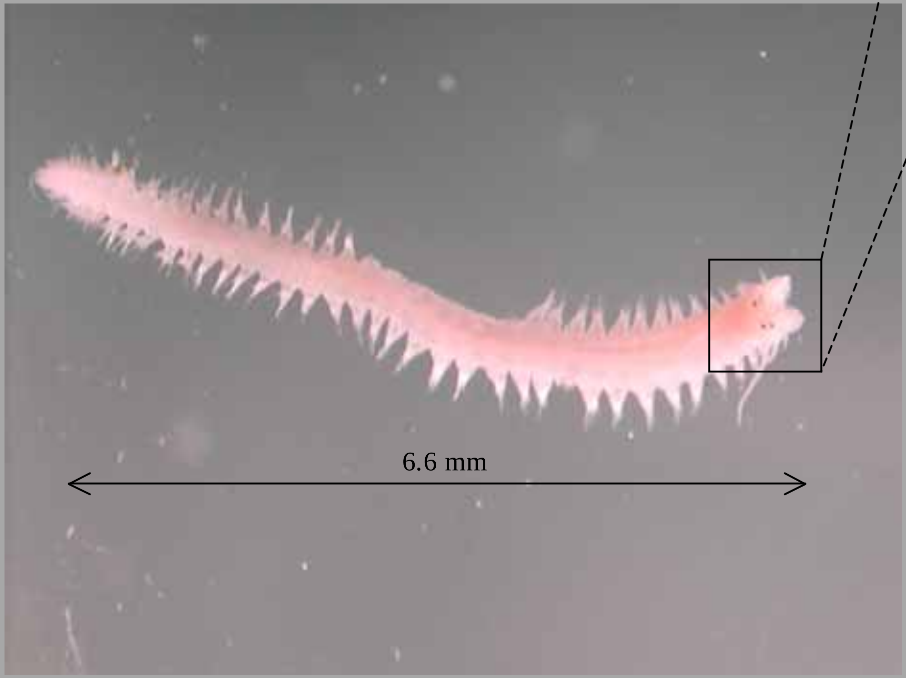
fifth setiger is unlike the other body segments

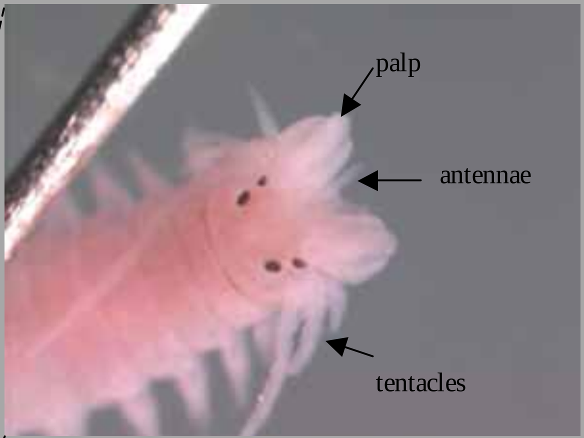


head has 2 long, coiling tentacles and a median antenna

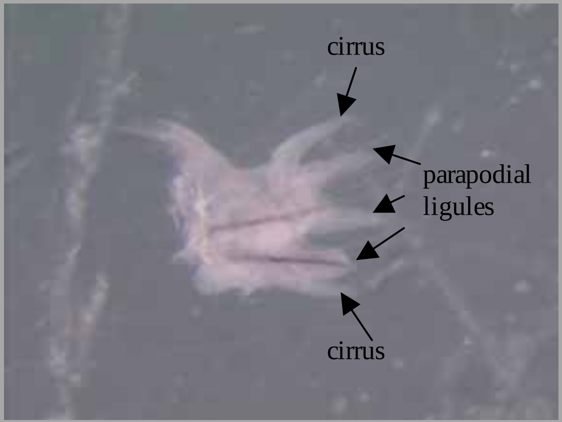
Nereis zonata

N. zonata, like all nereid worms (or clam worms), are predators. They generally hide in crevices and burrow in soft substrata, but they can actively swim.





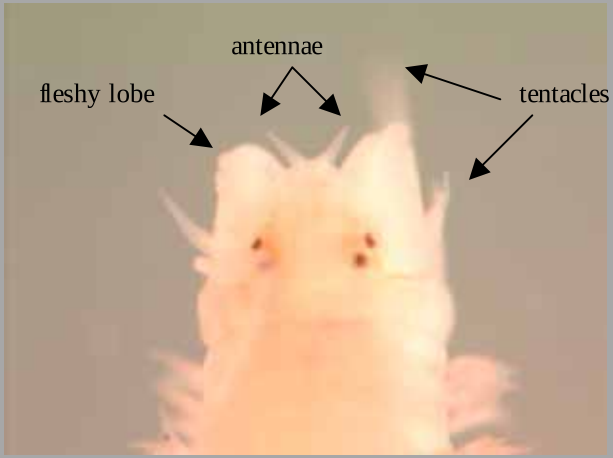
Nereis sp. have 4 pairs of tentacular cirri on their heads, 2 palps, and 2 antennae



parapodial ligules are triangular to conical (rather than evenly rounded); upper and lower lobes of parapodia are subequal; ventral cirri are single

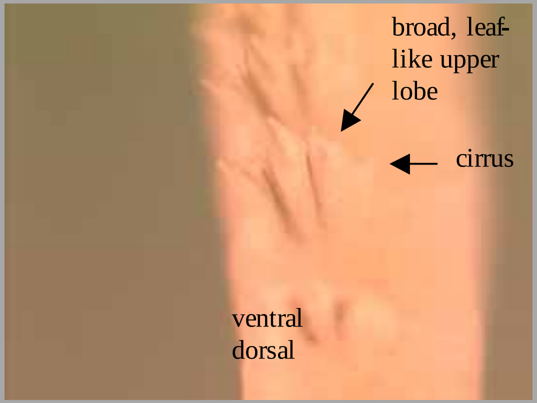
Nereis virens

N. virens, like all nereid worms (or clam worms), are predators. They generally hide in crevices and burrow in soft substrata, but can actively swim. They are common in mudflats and sandflats in the intertidal zone, and prefer higher salinity waters.



like all nereids, head has 4 eyes, 1 pair of antennae, 1 pair of fleshy lobes, and 4 pairs of tentacles

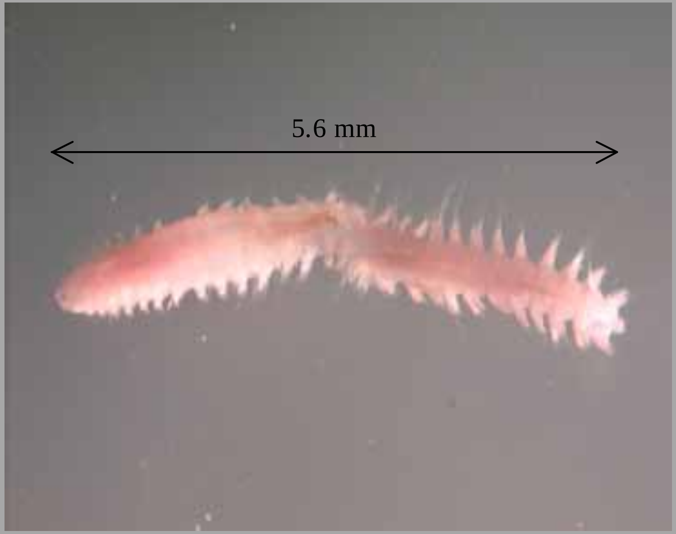
numerous paragnaths on prostomium

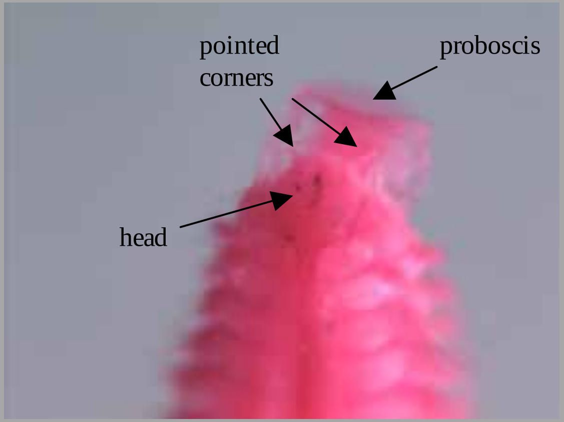


parapodia are biramous; upper lobes are leaf-like with a basal cirrus

Nephtys sp.

Nephtyid worms are commonly called painted worms. They are common shallow water and littoral burrowers and swimmers, and prey on other invertebrates. They have planktonic larvae, which can relocate to more favorable areas. *Nephtys* species serve as an important food source for fish.





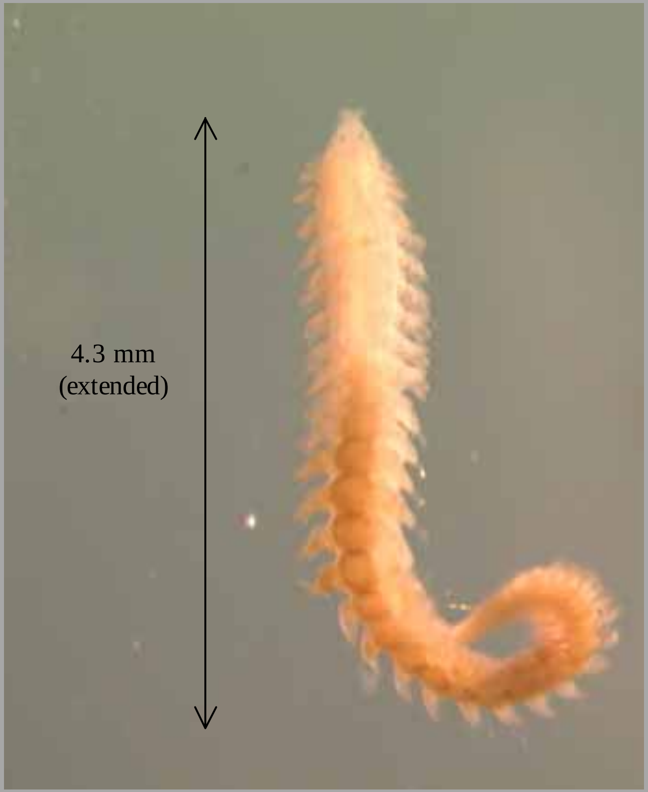
head is flattened in front with pointed corners; no obvious head appendages

setae runs in 2 distinct rows down each side of the worm (more apparent toward the anterior end)

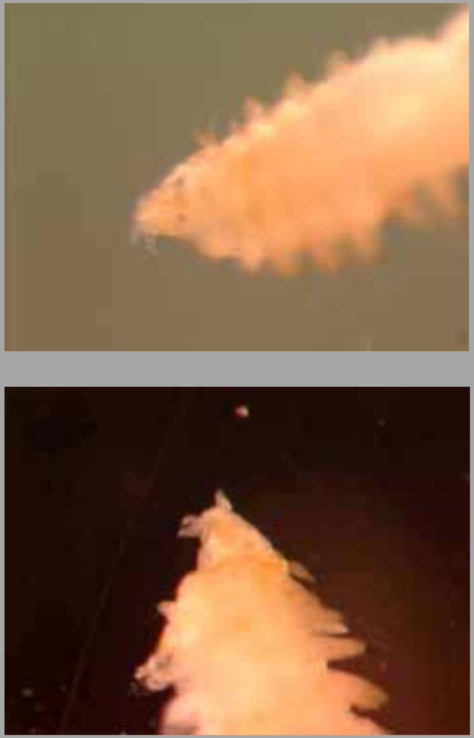
Eteone sp.

Eteone sp. and other phyllodocid worms are elongate, active worms. The occur off-shore and in the intertidal zone in mud and sand.

leaf-like parapodia

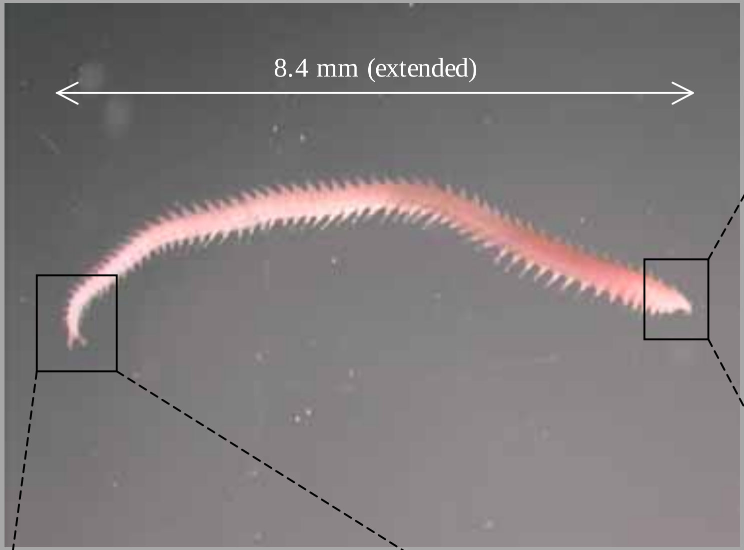


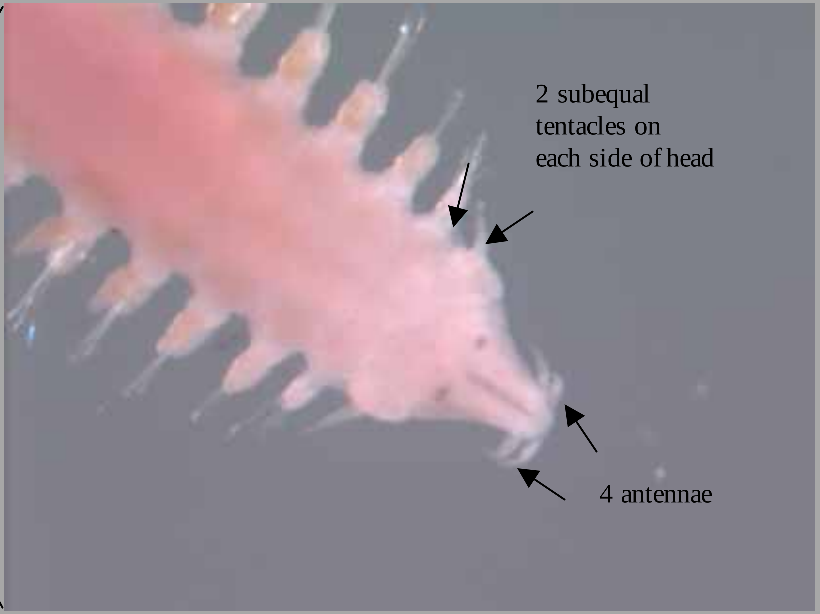
Note: *Eteone* sp. are differentiated by their anal cirri and by the lengths of their tentacular cirri. In these specimens, both sets of cirri are broken.



triangular head segment with 4 antennae at tip and 2 tentacles on either side of first body segment

Eteone heteropoda





Eteone characteristics include a triangular head, 4 antennae, and 2 tentacles on each side of head. On *E. heteropoda*, the dorsal and ventral tentacles are subequal.

anal cirri are tapering

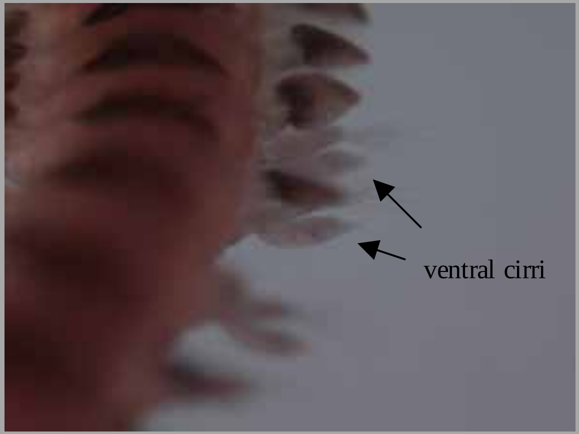
E. heteropoda and other phyllodocid worms are elongate, active worms found off-shore and in the intertidal zone in mud and sand. They are considered a pollution-indicative taxa at a range of salinities.

Phyllodoce arenae

P. maculata and other phyllodocid worms (or paddle worms) are elongate, active worms. They are found near low tide level and offshore.

P. arenae has dark, transverse bands along length of body

head has 4 antennae, 4 tentacles per side, and is heart-shaped with a posterior notch (*Phyllodoce* characteristics)

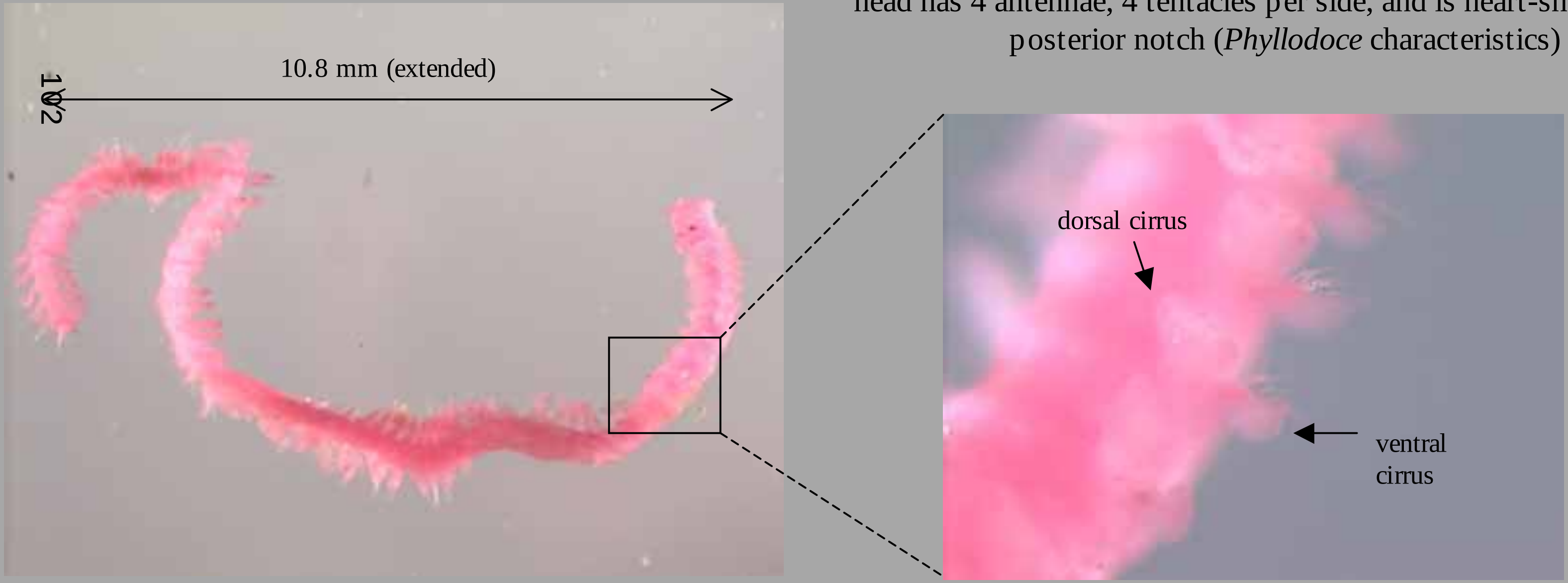


ventral cirri are tapered and pointed (compare to oval cirri of *P. maculata*)

Phyllodoce maculata

P. maculata and other phyllodocid worms (or paddle worms) are elongate, active worms. They are found near low tide level and offshore.

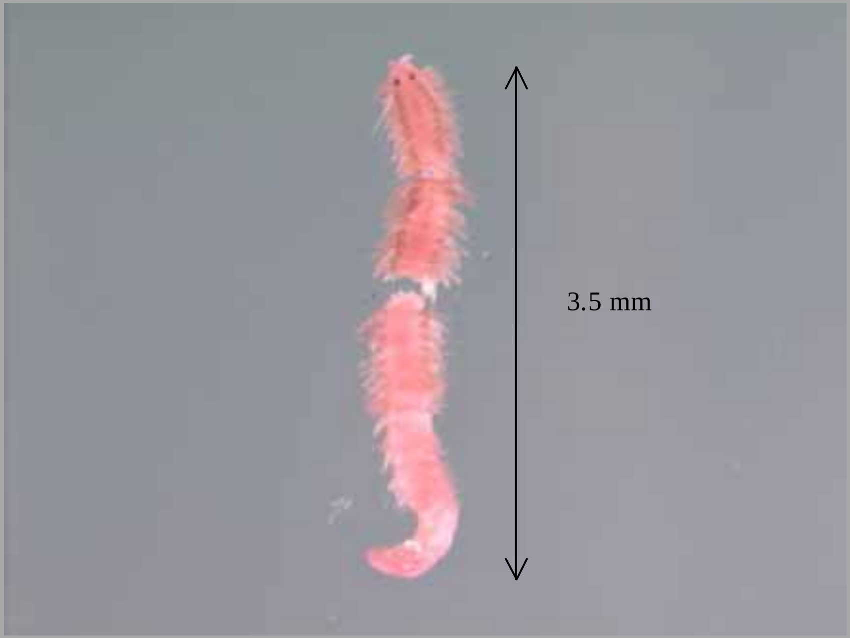
head has 4 antennae, 4 tentacles per side, and is heart-shaped with a posterior notch (*Phyllodoce* characteristics)



ventral cirri are oval (compare to other *Phyllodoce* sp. where ventral cirri are pointed or have pointed tip)

Paranaitis speciosa

head has 4 pairs of tentacular cirri and 4 frontal antennae; prostomium is subtriangular (rather than heart-shaped – compare to *Phyllodoce* spp).

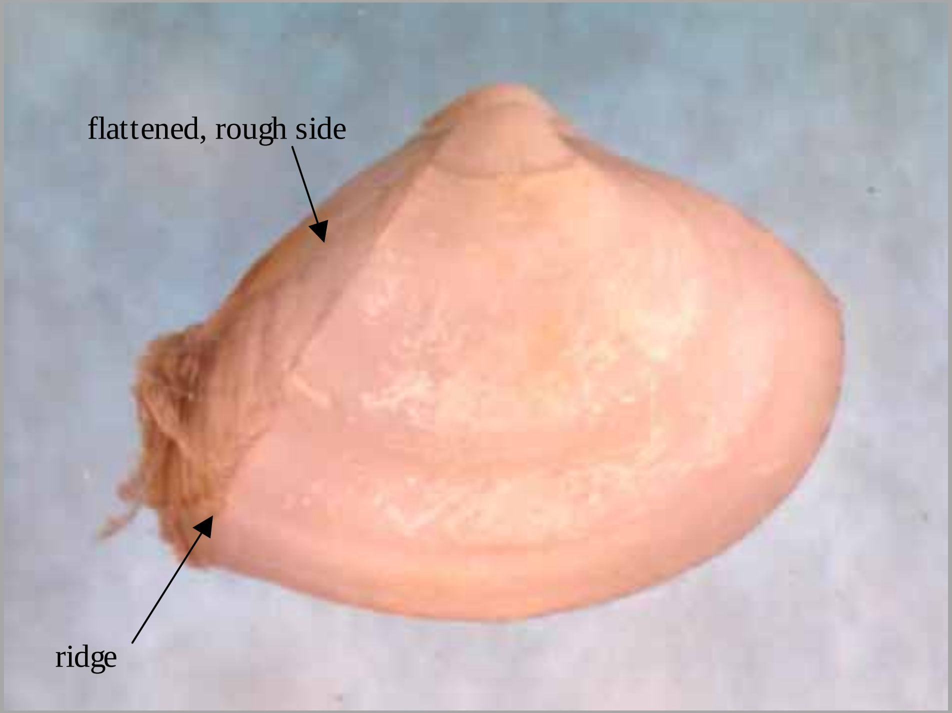


P. speciosa, a phyllodocid worm or paddle worm, is found in mussel beds and in shallow water on sand, clay, mud, and shells. It is an elongate, active worm.

dorsal cirri are tapered; parapodia are large and paddle-like

* Clams *

Mulinia lateralis



yellowish-white outer shell layer, shiny white underneath; low ridge extends from umbo to bottom shell; flattened end is somewhat darker and rougher than the rest of the shell

prominent spoon-shaped chondrophore

shiny white shell inside

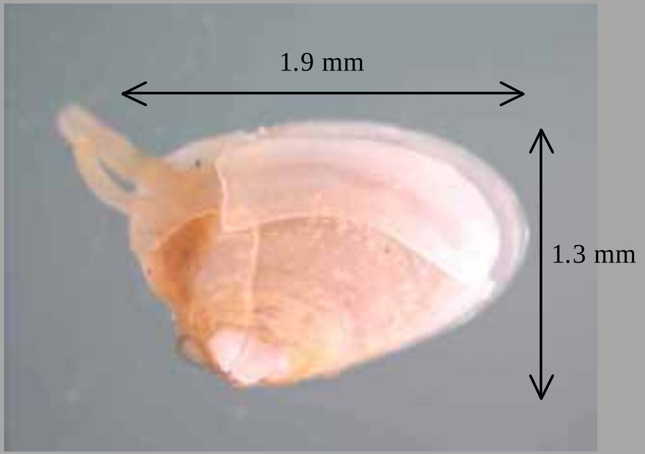
Macoma balthica

M. balthica live a few centimeters below the surface of sand, mud, and muddy sand. They are found from the upper regions of the intertidal into the sublittoral, particularly in estuaries and on tidal flats, but they are not a common species. They are active suspension feeders and surface deposit feeders. Adult flounders prey on them.

shell is mostly symmetrical, dull white with a yellowish periostracum that is generally worn away near the umbo

hinge of the shell has no chondrophore (hard to see on such a small specimen)

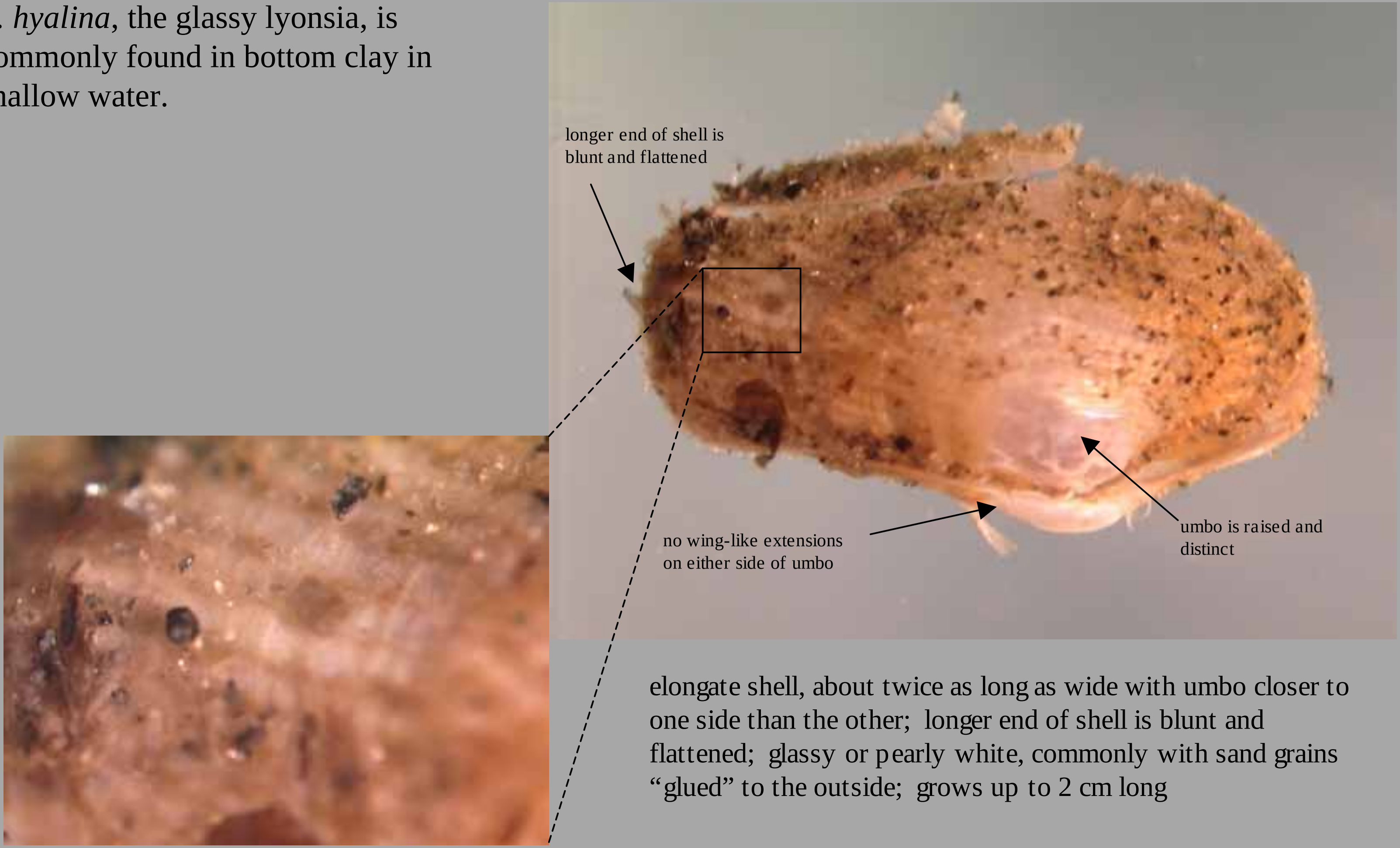
Tellina agilis



asymmetrical shell is white, yellowish, or pink, sometimes with pink blotches; umbo points up; prominent brown ligament behind umbones; shell length is less than 2 times its width; common in fine sand and mud in the intertidal zone and off-shore

Lyonsia hyalina

L. hyalina, the glassy lyonsia, is commonly found in bottom clay in shallow water.

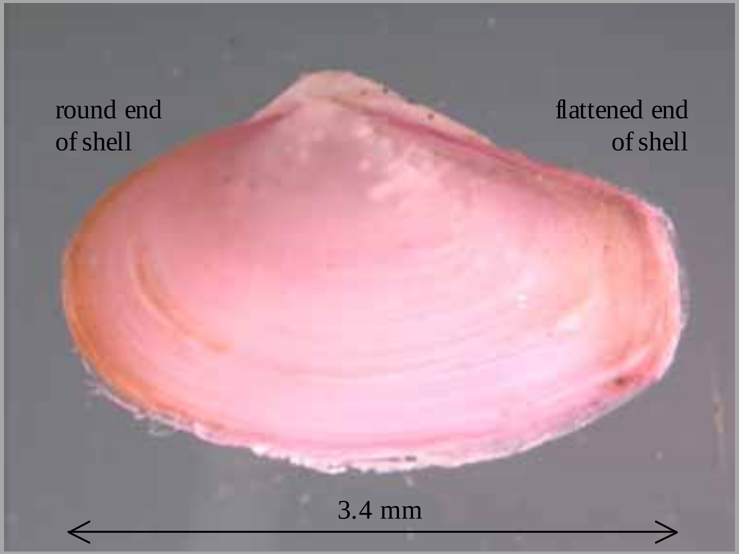


elongate shell, about twice as long as wide with umbo closer to one side than the other; longer end of shell is blunt and flattened; glassy or pearly white, commonly with sand grains "glued" to the outside; grows up to 2 cm long

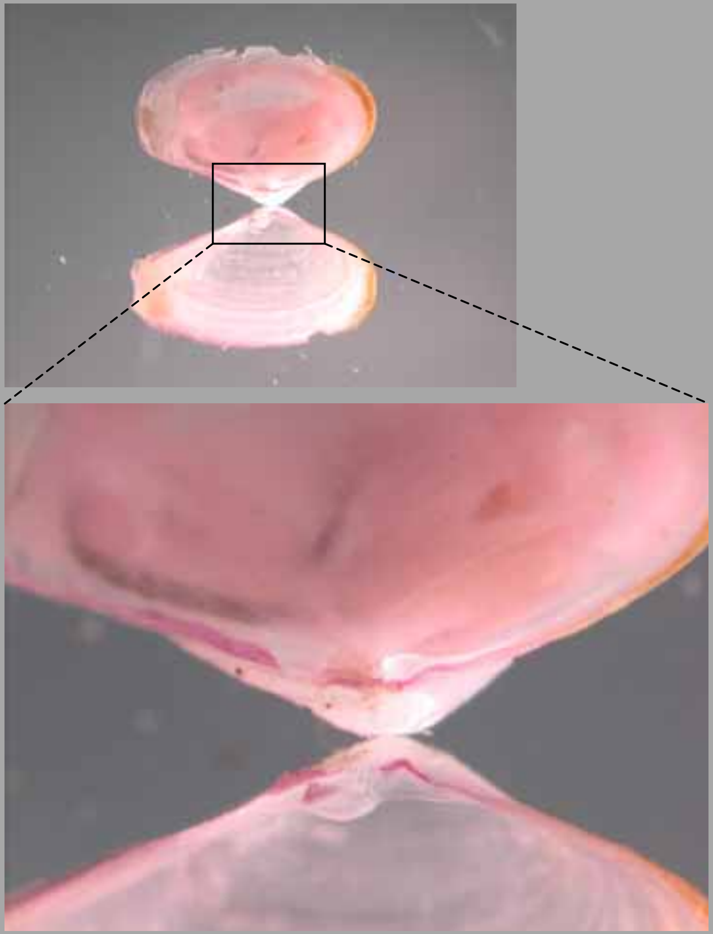
shell has very fine lines radiating out from umbo to edges

Periploma papyratium

P. papyratium is commonly called the paper spoon clam. It is not a common species.



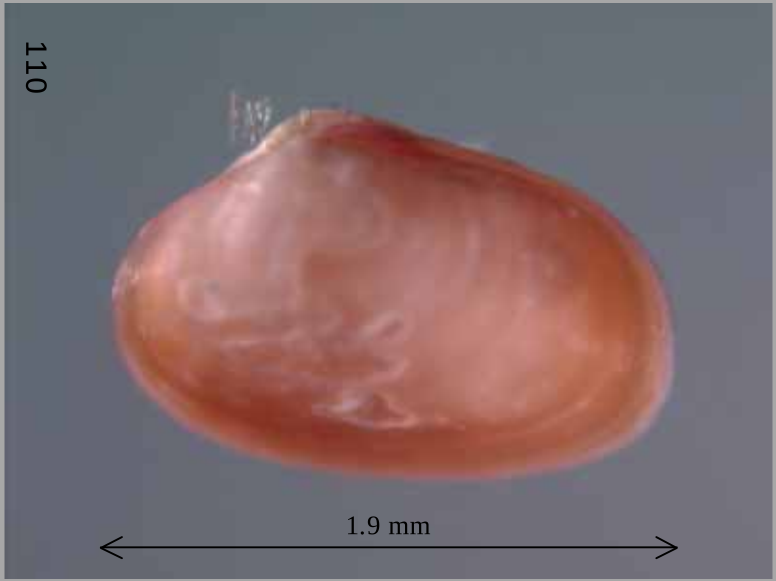
shell length less than twice the width; umbones point up; shell is asymmetrical – one end is flattened while the other is round; shell is smooth, white with yellow periostracum



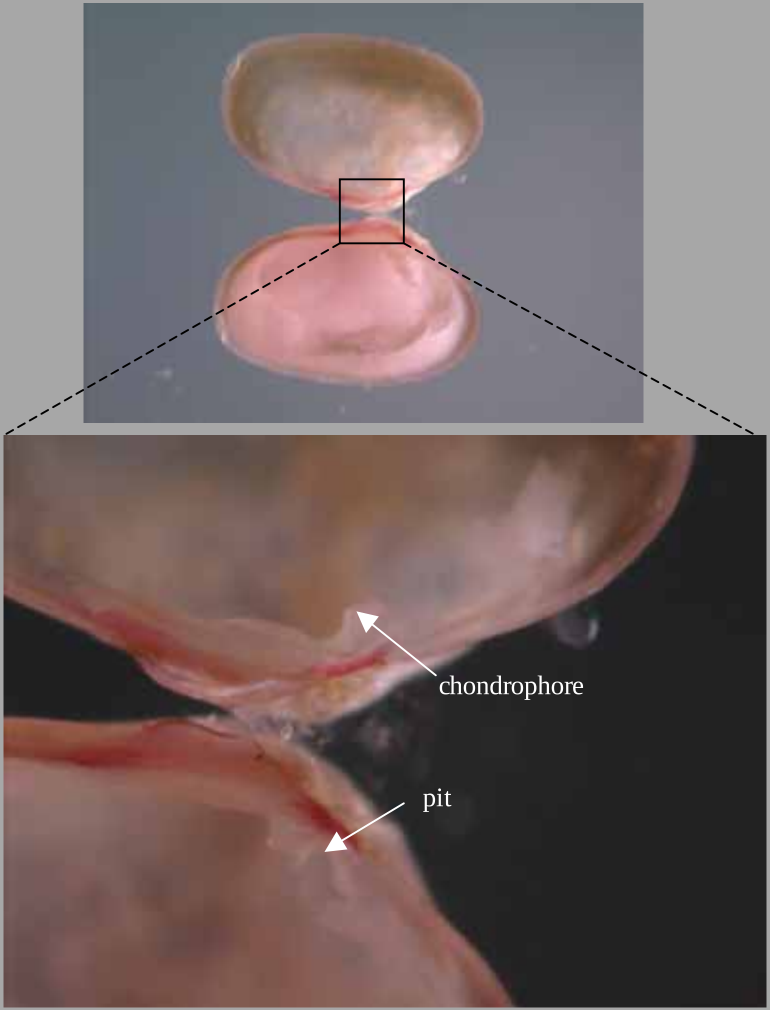
hinge has a well-developed chondrophore

Mya arenaria

M. arenaria, commonly called the softshell or long neck clam, lives in burrows up to 50 cm deep in sand, mud, and sandy gravels from the mid shore to the shallow sublittoral, and extends its long siphon to the water. It is often abundant on estuarine flats. It is long-lived, and has great adaptability to low salinity and to pollution.



chalky white shell with greyish periostracum; wider than long and fairly ovoid; in living specimens, ends of shell do not touch when clam is closed due to long siphon



hinge has a large, spoon-shaped chondrophore in one valve and a heart-shaped pit in the other; no teeth on shell hinge

Yoldia sp.

Yoldias are a group of mud-burrowing clams. They are a common Hudson species, and often eaten by flounder. They are deposit feeders.

shell is at least twice as long as it is wide; periostracum is smooth and shiny

shell has chondrophore and row of teeth on either side of umbo

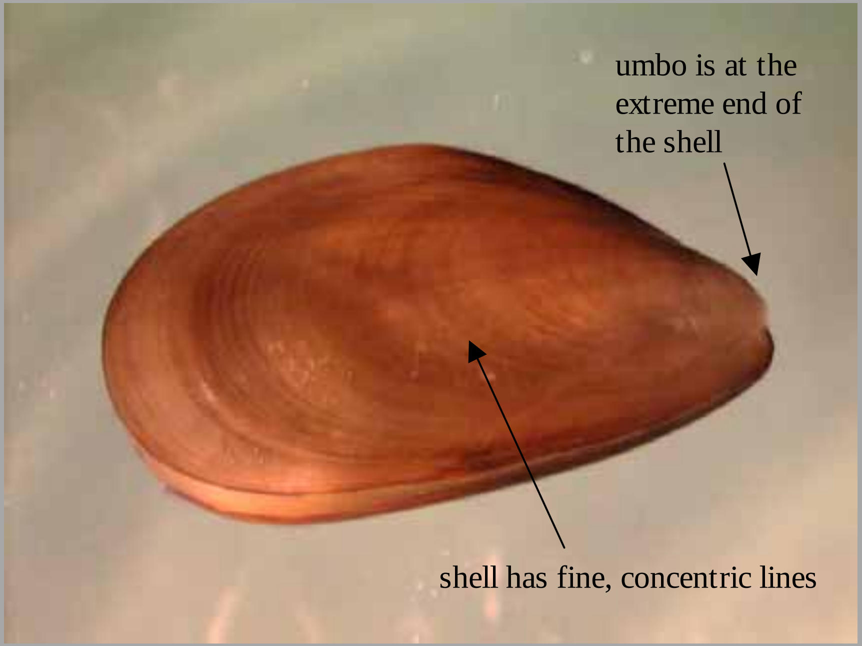
Astarte undata

A. undata, the wavy astarte, is common in bottom muds. It is also found in gravel bottoms of tidal rivers.

A. undata has a reddish-brown, often glossy covering; it has 10-20 deep, rounded ridges and grooves

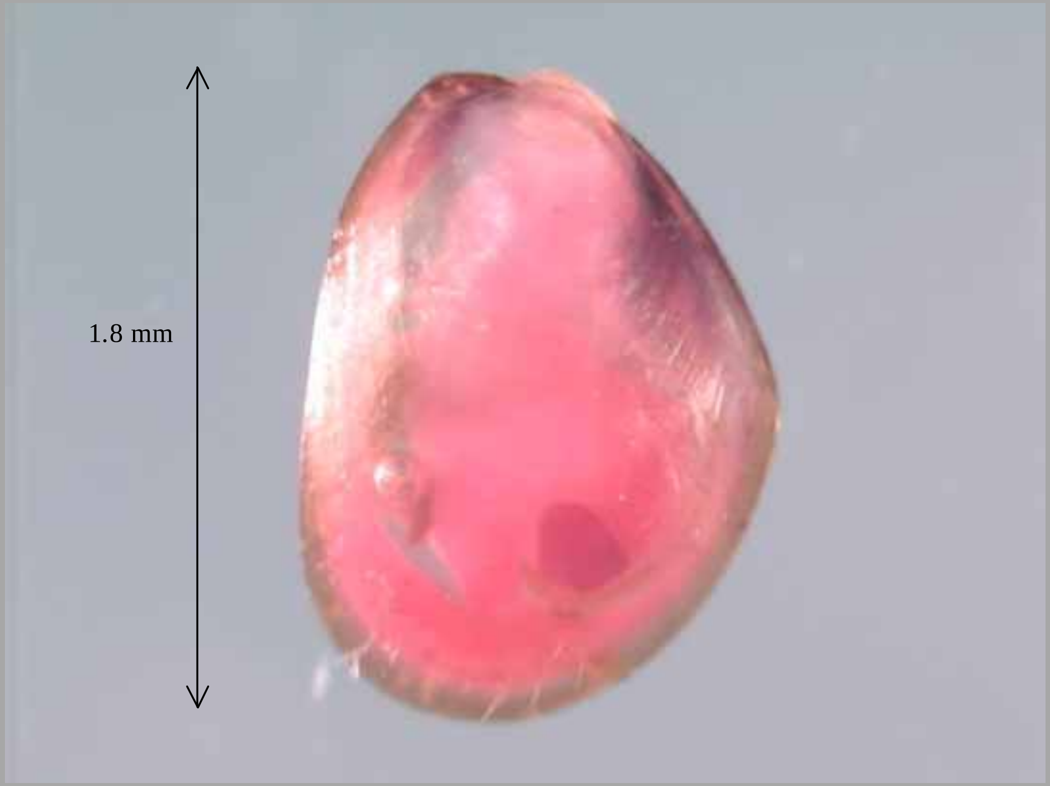
Mytilus edulis

M. edulis is known as the blue mussel. Its shell is dark bluish, and it is commonly found near low tide level and offshore, attached to rocks and shells. Its salinity tolerance ranges from marine to somewhat brackish estuarine waters.

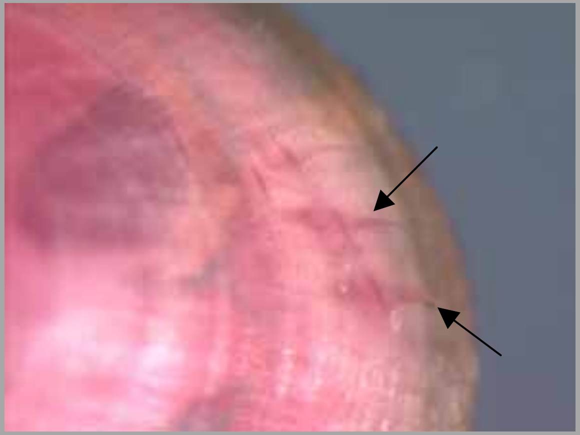


Blue mussel shell is strong and opaque. Shape of shell is only slightly curved.

Modiolus modiolus



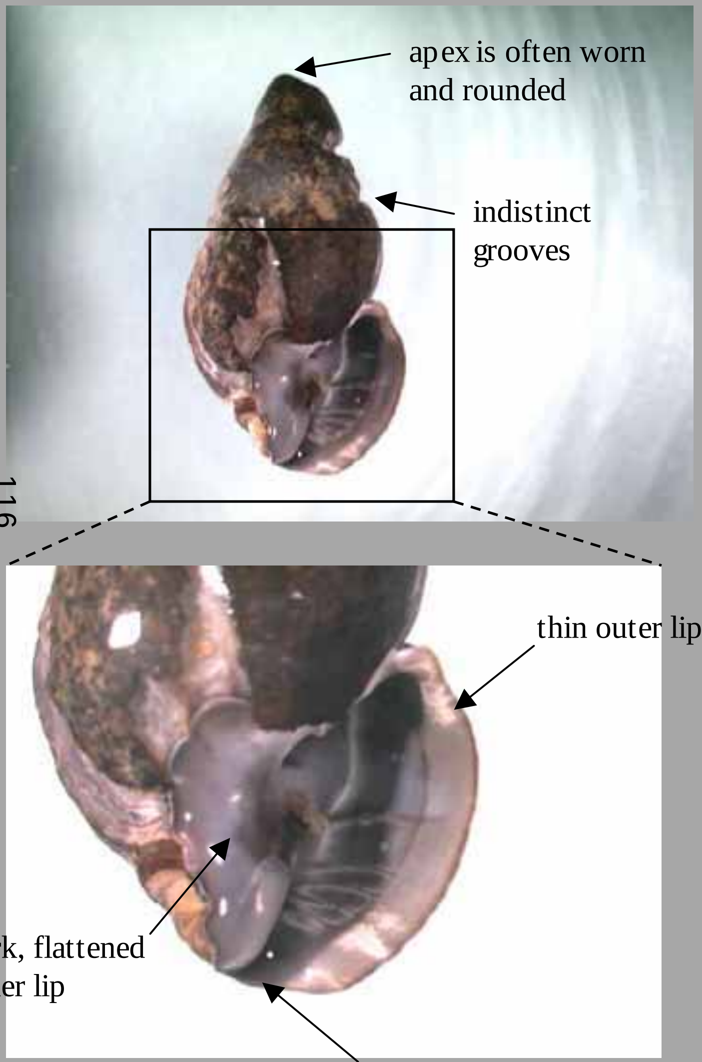
elongate, wedge-shaped shell; umbones are near anterior end of long axis but not at extreme end

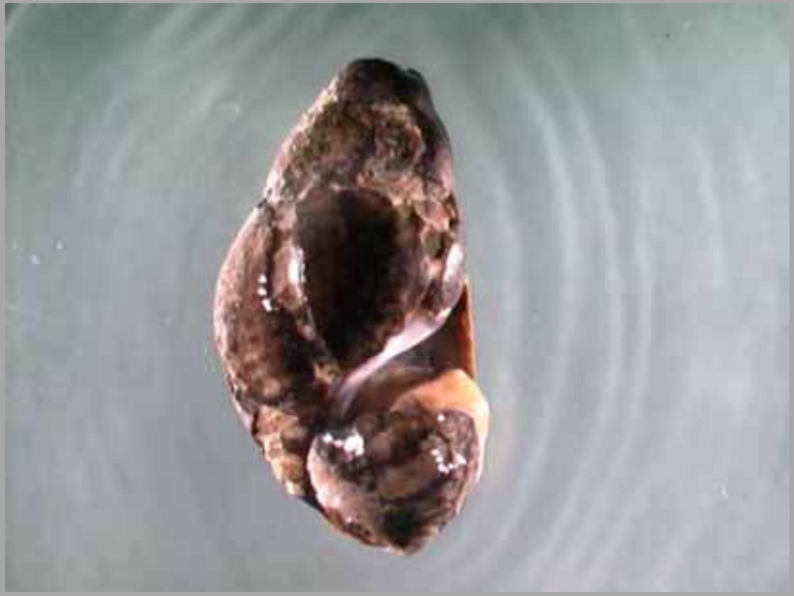


hair on periostracum

* Snails *

Ilyanassa obsoleta

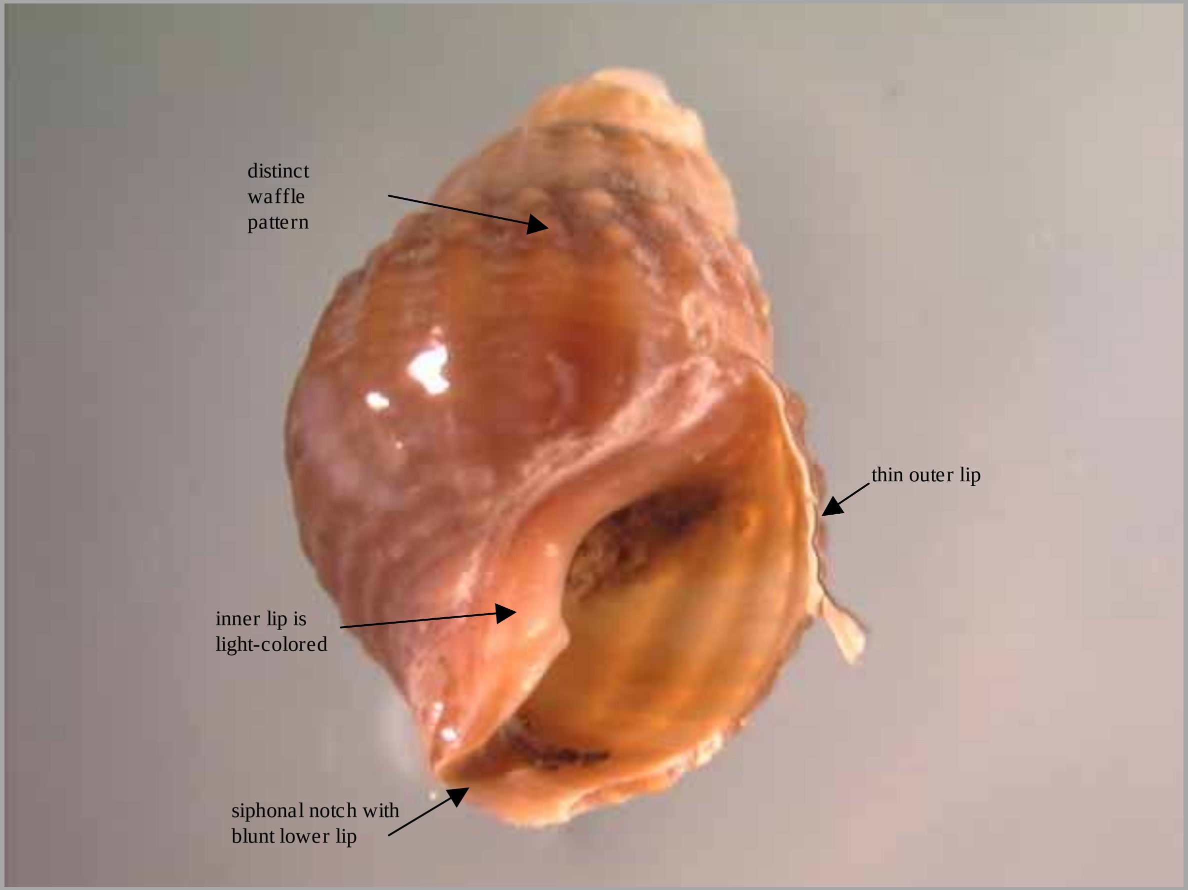




empty shell (left) vs. shell with snail (top); shell is grey-black or dark brown; can grow up to 25 mm; very common on mudflats

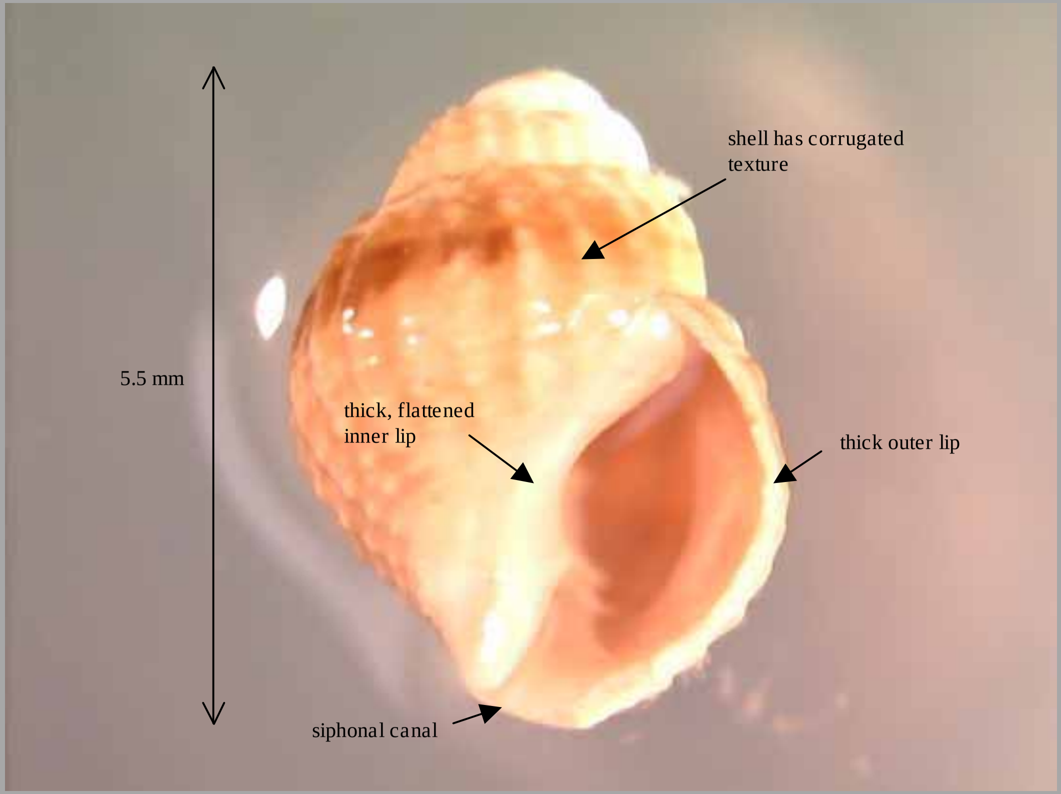
Ilynassa trivitatta

I. trivitatta, or the threeline mudsnail, is common offshore on sandy bottoms; not usually found on mudflats.



Nucella lapillus

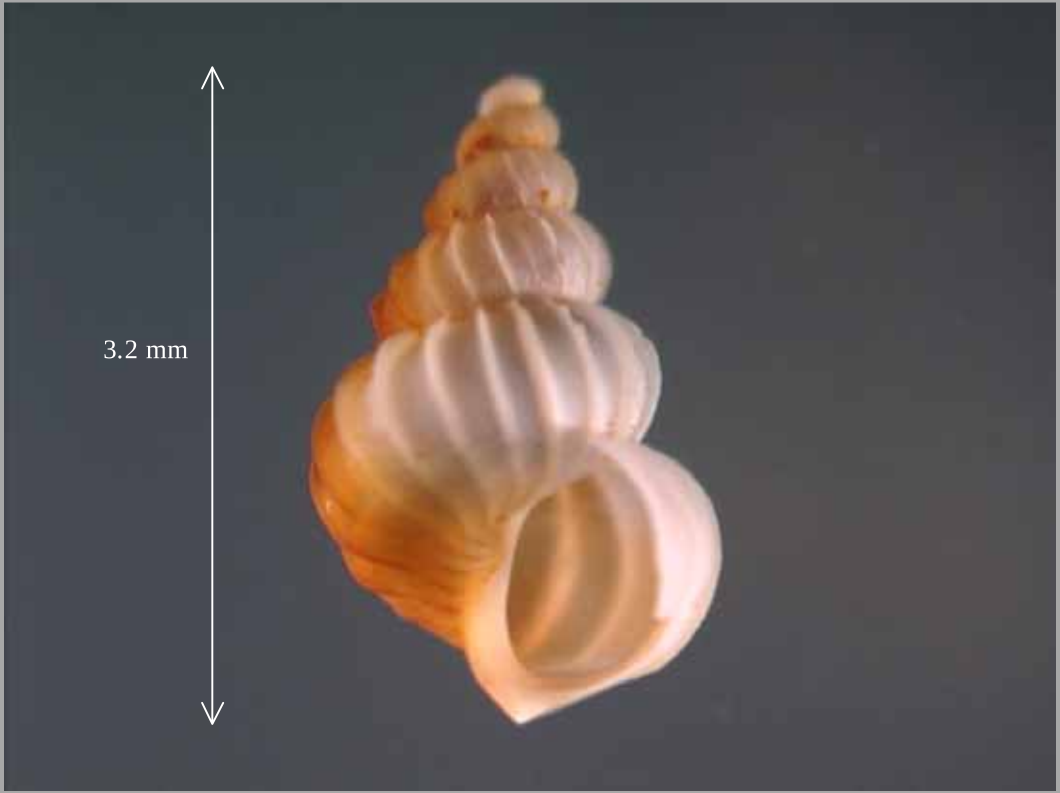
N. lapillus, the Atlantic dogwinkle, is a common drill snail in rocky intertidal areas.



stout, thick-walled shell; spiral ridges give shell a corrugated texture; siphonal canal and be short and blunt (as shown) or longer and more pointed (not shown); color is variable, including white, grey, purple, brown, and yellow; can grow up to 3.5 cm long

Epitonium sp.

Epitonium spp, or wentletraps, are snails not common on the northeast coast. They feed on the soft tissues of coelenterates, such as sea anemones and corals.

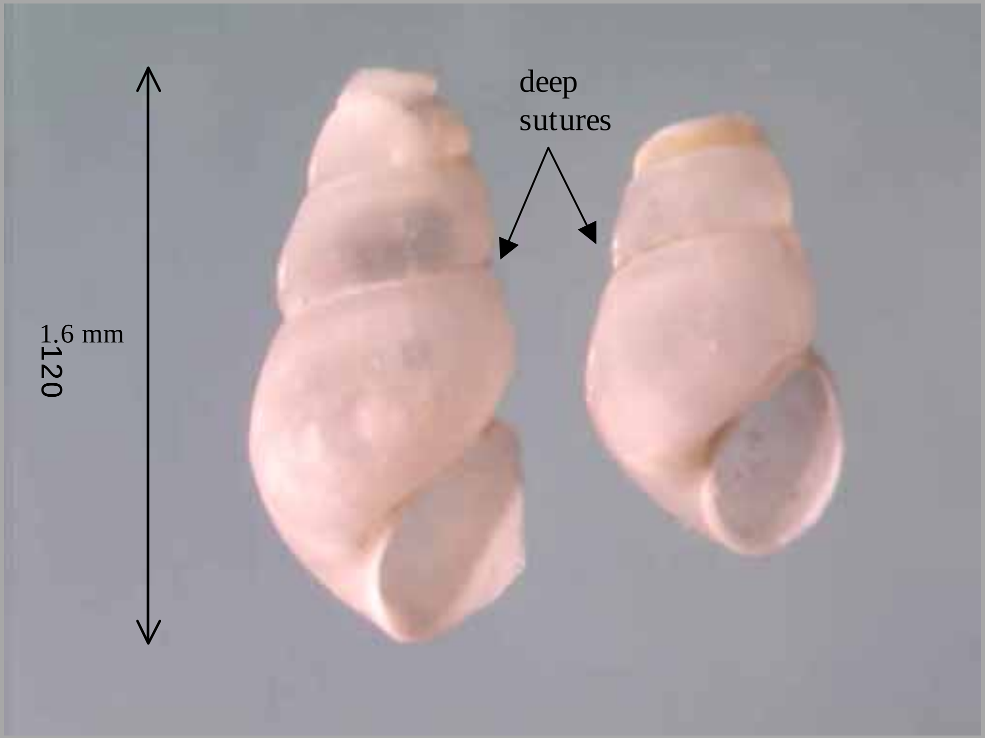


cone-shaped shell is sculptured with blade-like vertical ribs and has 8-12 whorls; most species have white shells, though some species have brown coloration

shell opening is less than 1/2 the length of the shell, and has no siphonal notch or folds (“teeth”)

Hydrobia totteni

= *H. minuta*



shell is shiny, translucent, and yellowish-brown; very tiny;
shell has distinct groves between whorls

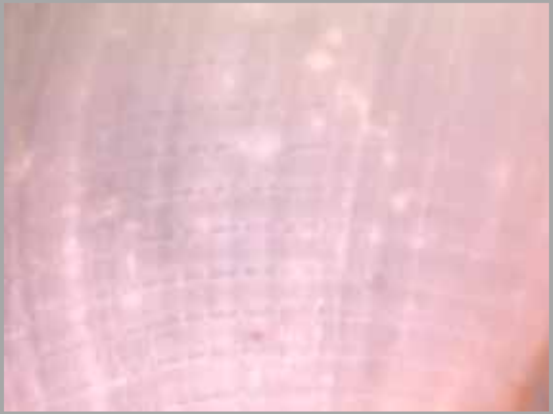
smooth shell with no sculpturing

Rictaxis punctostriatus

(Rictaxis p. = Acteon p.)

R. punctostriatus is called the pitted baby-bubble. It has a shiny white shell. This snail is not common.

Front and back views of empty shell. Opening is about 2/3 of the shell length. It does not have small teeth (i.e. folds) on the inner lip (columella) of the shell opening. Snail has an operculum, which can’t be seen in this empty shell.



shell has 10-15 spiral rows of dotted lines; dots are tiny pits on shell surface

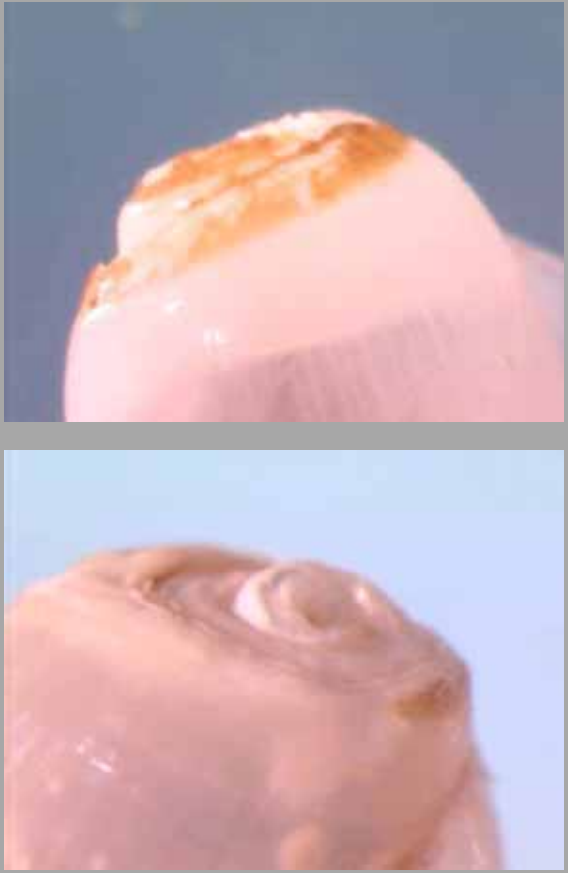
spire is apparent and elevated

Acteocina canaliculata

A. canaliculata (= *Retusa c.*)

A. canaliculata is called the channeled barrel-bubble.
It is common on sand and mudflats.

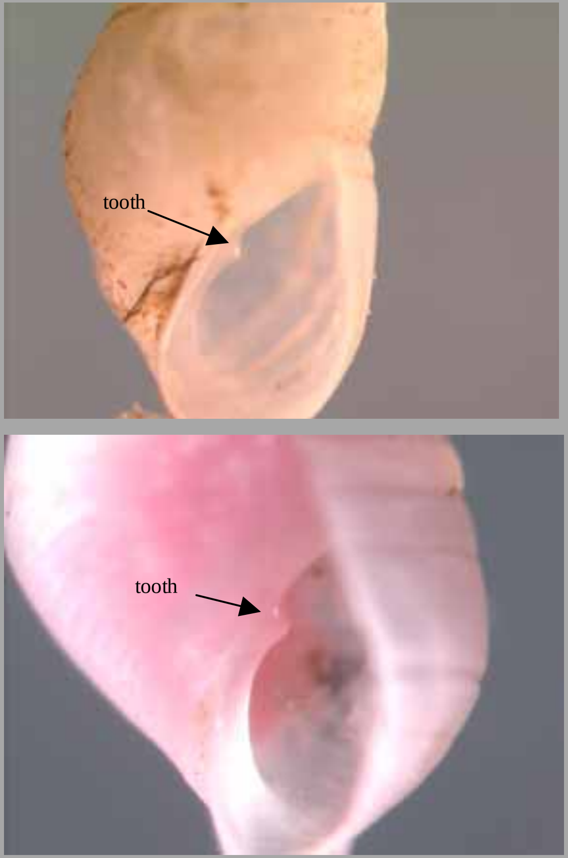
snail shell with (left) and without (right) the algal growth than tends to accumulate on the spire. The shell is shiny white and its opening is ¾ of the shell length. The inner lip (columella) has no folds or teeth.



spire is elevated, though in some individuals, this is not very prominent

Odostomia sp.

shell is cone-shaped, opening is oval and less than 1/2 the length of the shell; no siphonal notch; grows up to 6 mm long



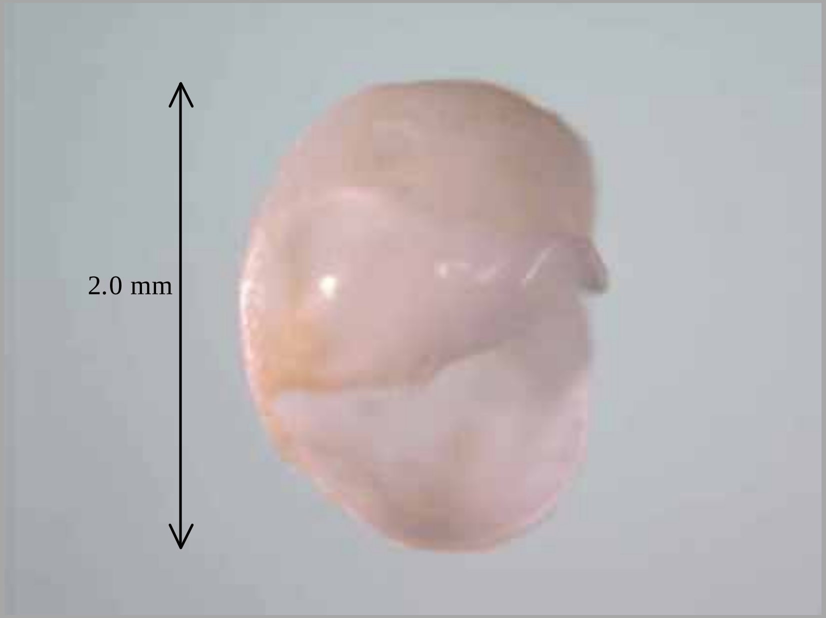
columella has 1 fold (or “tooth”) on the inner lip of the opening

Haminoea solitaria

H. solitaria, the solitary paper bubble, is the largest and most common bubble snail (order Cephalaspidea). They are small, hermaphroditic gastropods with a reduced, thin shell. Adults burrow into the mud, about half an inch below the surface.

shell is cylindrical but bubble-like; aperture is as long as the shell, with no spire; no siphonal notch or anterior canal

Euspira sp. (or *Tectonatica* sp.)



- globular shell with height less than 1.5 x width
- no siphonal notch
- D-shaped opening
- snails have an operculum (though all of these shells are empty)

Euspira heros

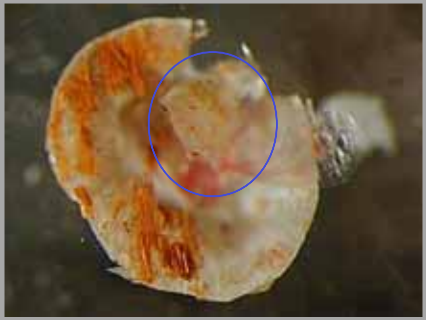
E. heros, the Northern moonsnail, is a common naticid snail on sandy bottoms in shallow water. Its foot is three times longer than its shell, allowing it to move easily through sand. It is a predator mostly on bivalves, but will also eat other moonsnails.

shell is round, with no siphonal notch; D-shaped opening; round umbillicus with no callus; inside of shell is not pearly

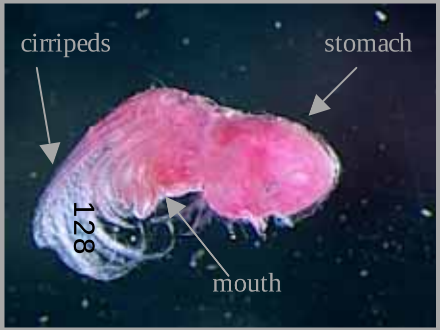
underside of shell

* Crustaceans *

Balanus improvisus



Ventral surface is calcareous.

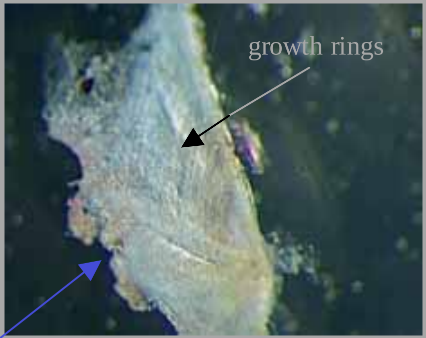


Barnacle anatomy

A close up of the cirripeds.

Barnacles are sessile crustaceans in the group Cirripedia. They filter feed using their modified thoracic legs, called
cirripeds. Barnacles are hermaphroditic and self-fertilize.

Balanus improvisus, the bay barnacle, is common in estuaries and has tolerances for low salinity.



Scutum shows faint growth rings,
but lacks vertical striations

Ovalipes ocellatus

O. ocellatus, or lady crabs, are common on sandy bottoms in shallow water. Their carapace is only slightly wider than long and has small rounded spots or reddish purple on a grey or beige background when alive.

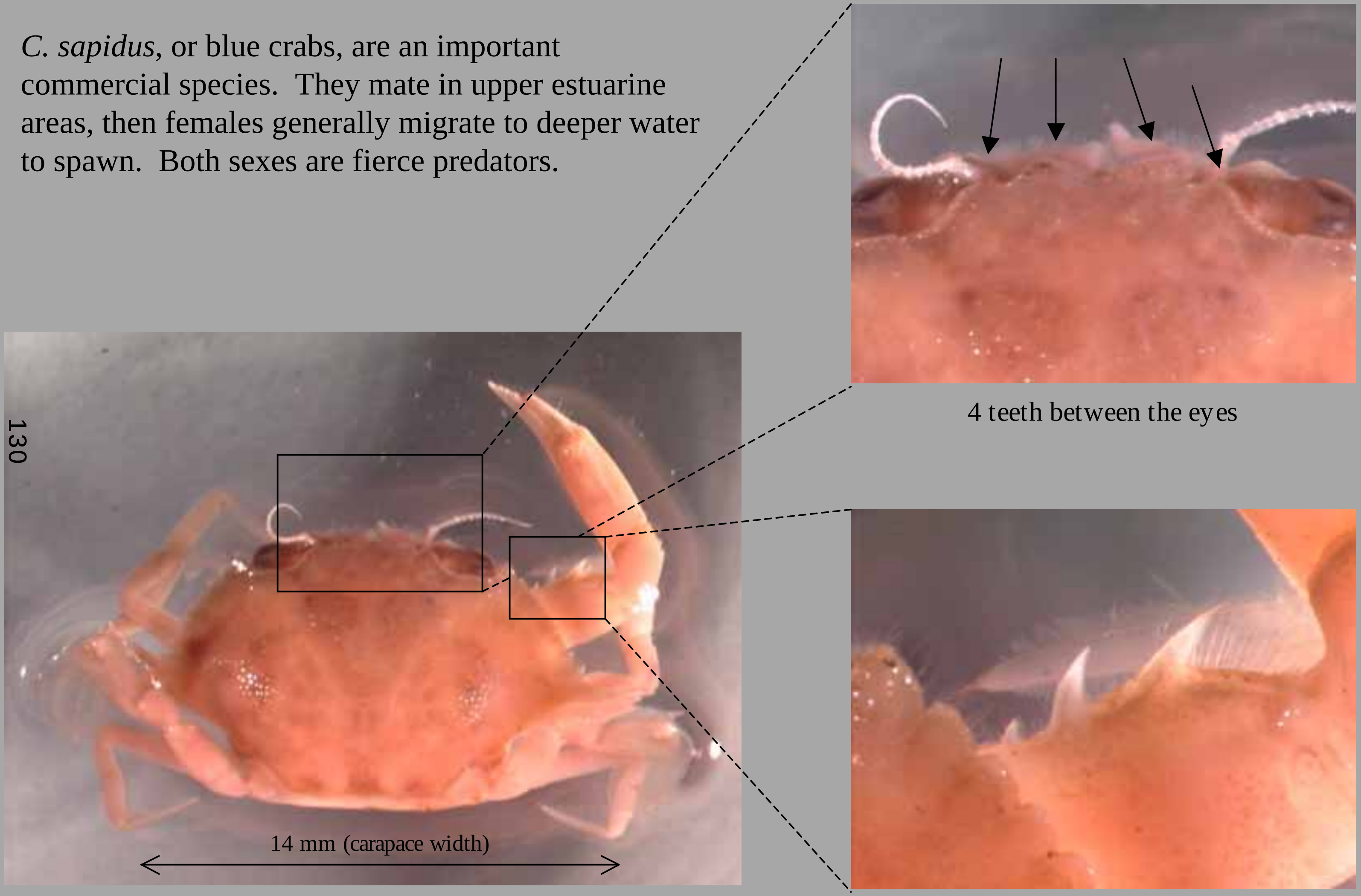
3-5 teeth on edge of shell to either side of eyes

last pair of legs are flattened and paddle-like with rounded tips for swimming

crab underside. This specimen happens to have legs and claws missing from one side of body, but generally they are symmetric.

Callinectes sapidus

C. sapidus, or blue crabs, are an important commercial species. They mate in upper estuarine areas, then females generally migrate to deeper water to spawn. Both sexes are fierce predators.



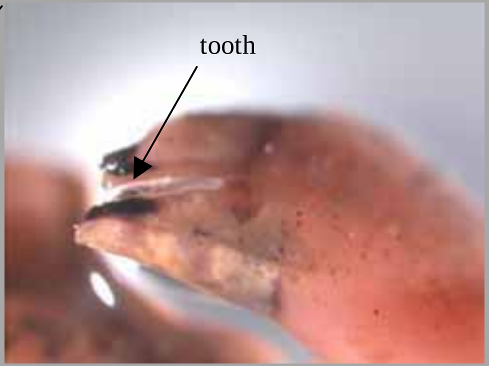
4 teeth between the eyes

3 spines on arms

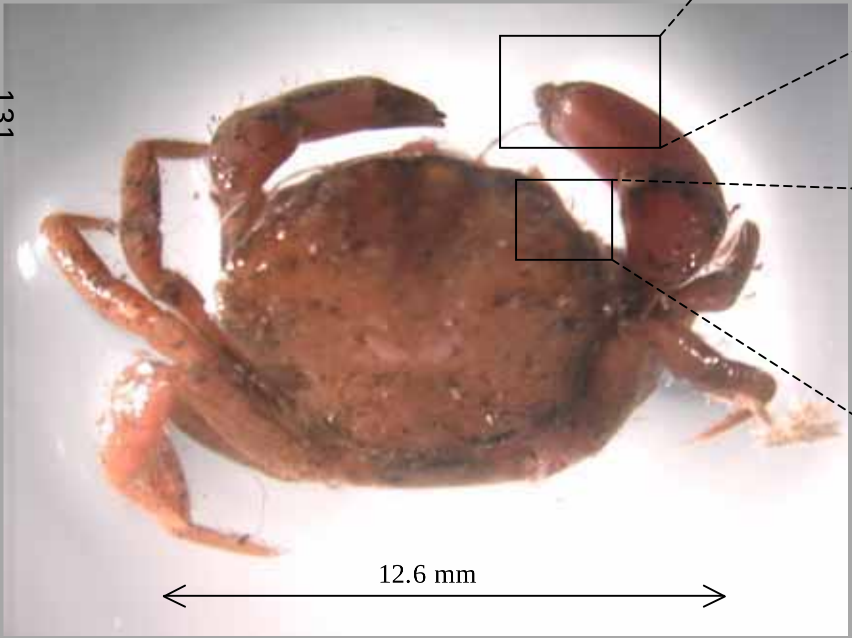
carapace is twice as wide as long, and outermost spine is longest; rear legs are flat and paddlelike; fingers of claws are bright blue in larger males

Panopeus herbstii

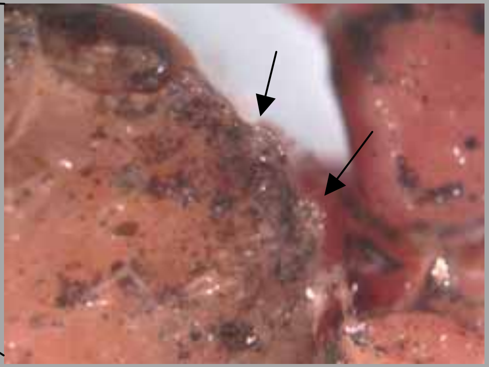
P. herbstii, the common mud crab or Atlantic mud crab, is a predator found in a range of habitats, including oyster beds, *Spartina* marshes, and muddy bottoms. It generally competes with other crabs for resources. All mud crabs are typically found in estuaries and waters with reduced salinity.



fingers of claws are dark, but marking does not extend far onto palm of claw; moveable finger of larger claw has a large, molar-like tooth



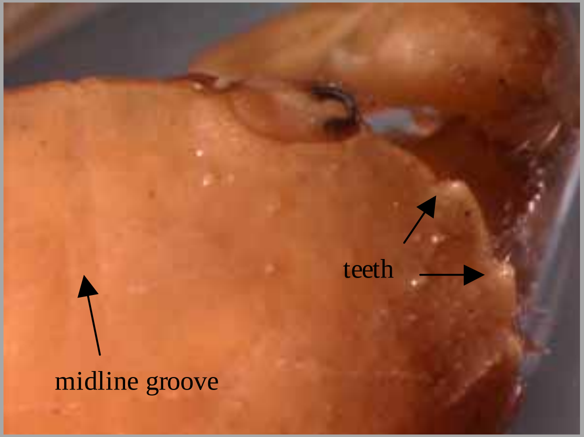
shell is muddy tan color; frontal area is flattened, has no teeth, and has a central notch; rarely gets wider than 5 cm



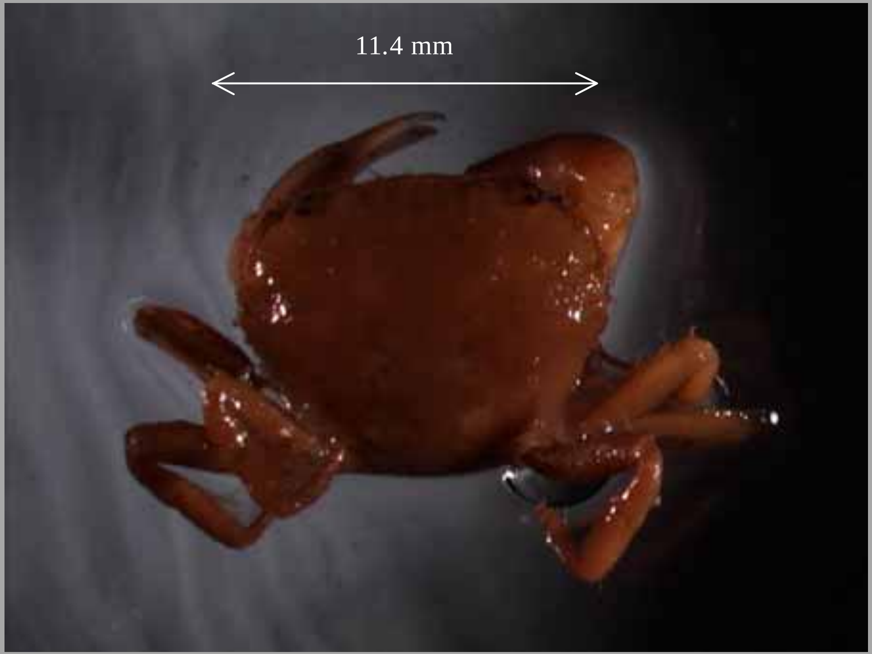
4-5 teeth to either side of eyes on front edge of shell

Rhithropanopeus harrisii

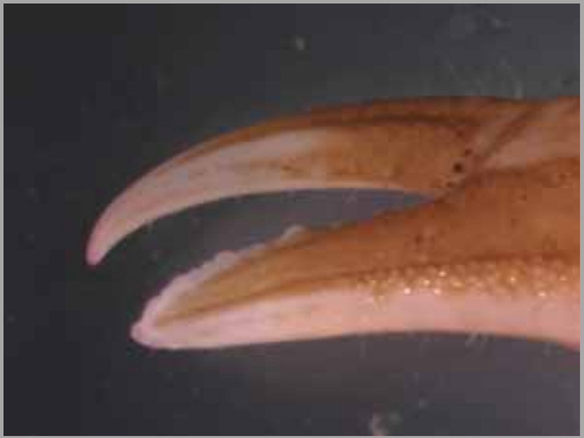
R. harrisii, the Harris mud crab, is a euryhaline species, found from brackish waters of estuaries to nearly freshwater. It prefers to live on sandy muds with some type of shelter, such as oyster beds. Due to its tolerance of a wide range of salinities, it poses an invasion threat in many areas.



front of crab between eyes and along midline of shell has a groove; 4 teeth on either side of eyes and no teeth between



shell is brownish above, paler on underside; rear legs are pointed (rather than flattened for swimming)



fingers of claws are pale/whitish

Pagurus longicarpus

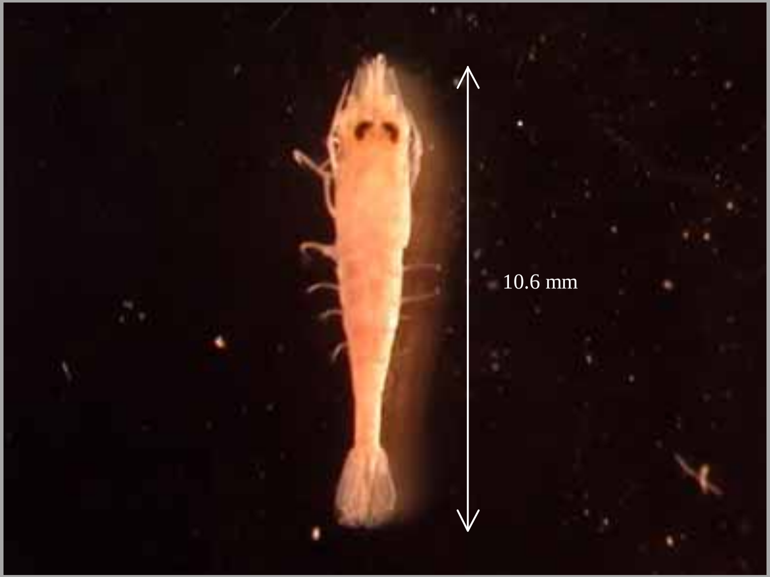
P. longicarpus, the longwrist hermit crab, is a common Hudson species. Like all hermit crabs, *P. longicarpus* lives in borrowed snail shells. It lives on muddy and sandy bottoms from just below the tide line to deep water. It is an omnivore, eating plant and animal detritus as well as live benthic organisms.

eyestalks are less than 3.5 times as long as wide

abdomen is soft and shell-less; right claw is larger than left

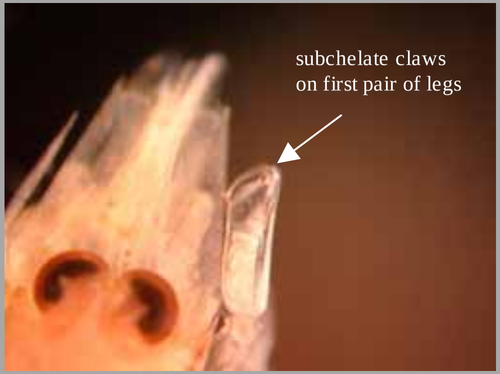
larger, right claw is slender, width less than half of length; claw weakly sculptured, no saw teeth on outer edge

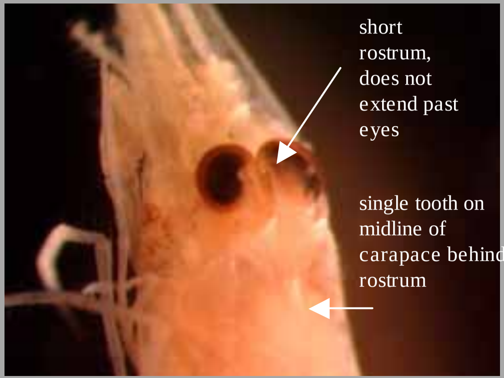
Crangon septemspinosa

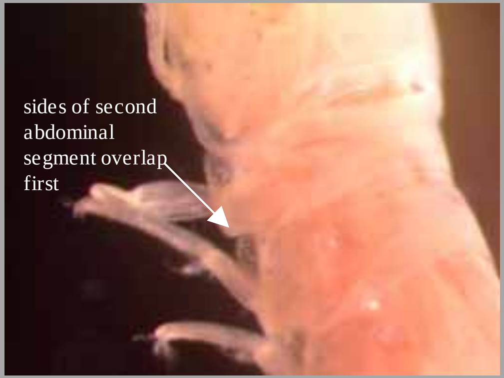


color ranges from brown to beige, often with speckles – can vary to match its substrate; up to 6 cm long

C. septemspinosa, commonly called the sevenspine bay shrimp or sand shrimp, is the most common shrimp in the northeast in shallow water and in estuaries.







Stomatopoda (mantis shrimp)

second pair of legs has large, powerful spiny claws (similar to claws of a praying mantis); eyes are large and on stalks

ridges and spines on telson can be defining characteristics of different species

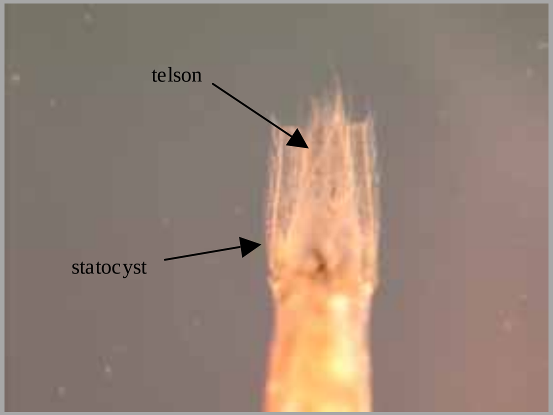
Adult mantis shrimp are benthic, and burrow into the sediment. Larvae are planktonic, and can be very common in the plankton. Both adult and larval mantis shrimp are predaceous.

Neomysis americana

N. americana, also called opossum shrimp or mysid shrimp, are very common in shallow, estuarine waters.

Like all mysid shrimp, *N. americana* has eyes on stalks, 5-8 pairs of biramous thoracic segments, tail with biramous uropods and a telson that form a fan, and uropods with a beadlike statocyst. It can grow up to 12 mm long.

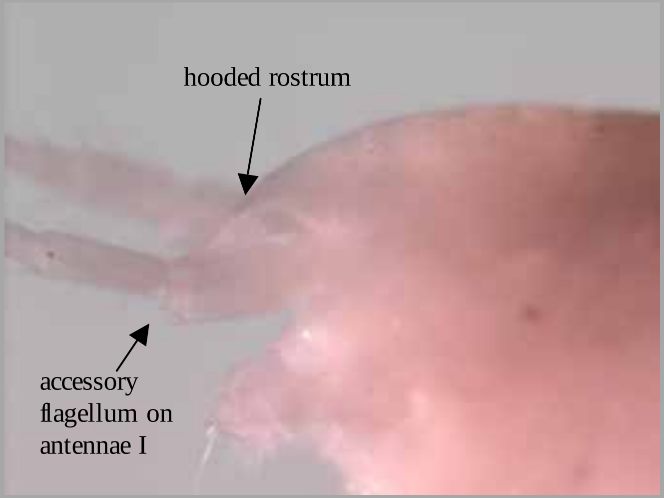
8 pairs of feathery, biramous legs



telson is pointed; beadlike statocyst on uropod

Harpinia sp.

Harpinia sp. (family Phoxocephalidae), or hood-headed amphipods, inhabit the surface of sandy and muddy sediments. They are generally found in the lower-intertidal zone of protected bays and estuaries. *Harpinia* are mobile diggers and feed on organic matter. They are generally scavengers, but can sometimes act as deposit feeders. The family is sensitive to oil spills.



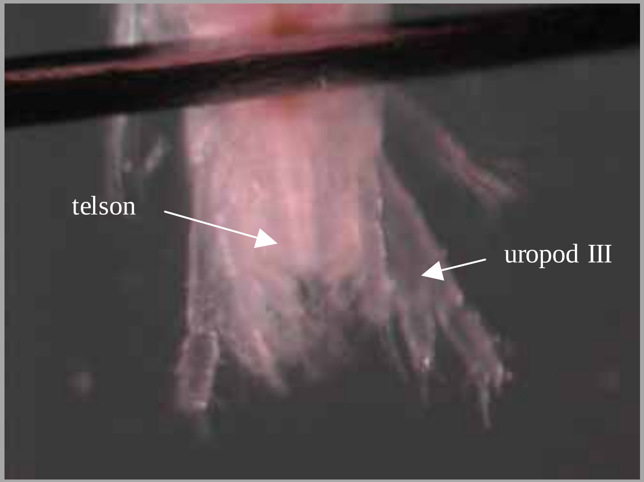
well-developed rostrum extended down beak-like between antennae, acting as hood; antenna I has an accessory flagellum; eyes are absent

legs are modified for fossorial existence; often armed with spines and setae for burrowing

Aortidae

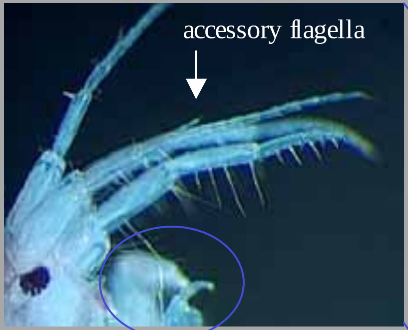
Aortids are an epifaunal species of amphipod. Some genera in this family are tube builders, while others are either free-living or live in the shelter of other tube builders.

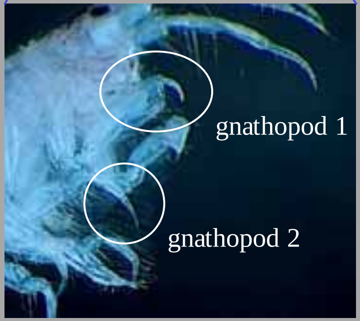
body is subcylindrical, less compressed than most amphipods; head is as long or longer than deep; gnathopod I more strongly developed than gnathopod II; antenna I has an accessory flagellum (missing on this specimen); midbody segments have legs



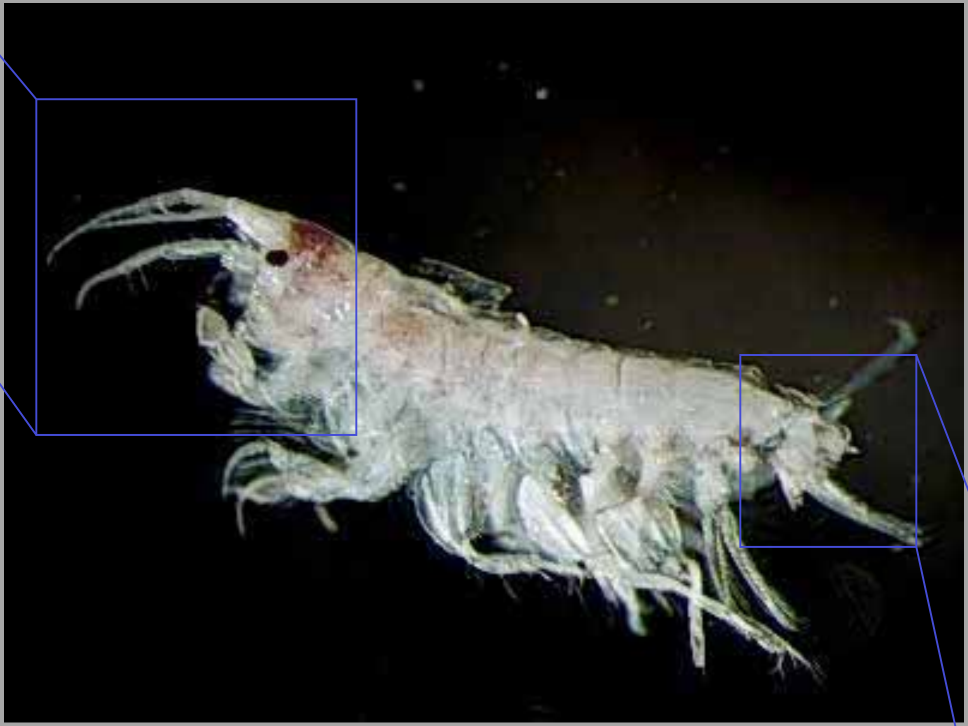
well-developed abdomen; telson is rounded (rather than split with a cleft); uropod III is biramous

Leptocheirus plumulosus



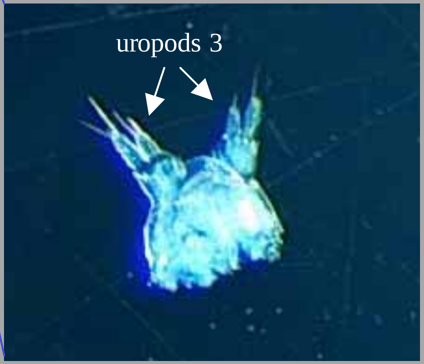


Gnathopods 1 larger than gnathopods 2.



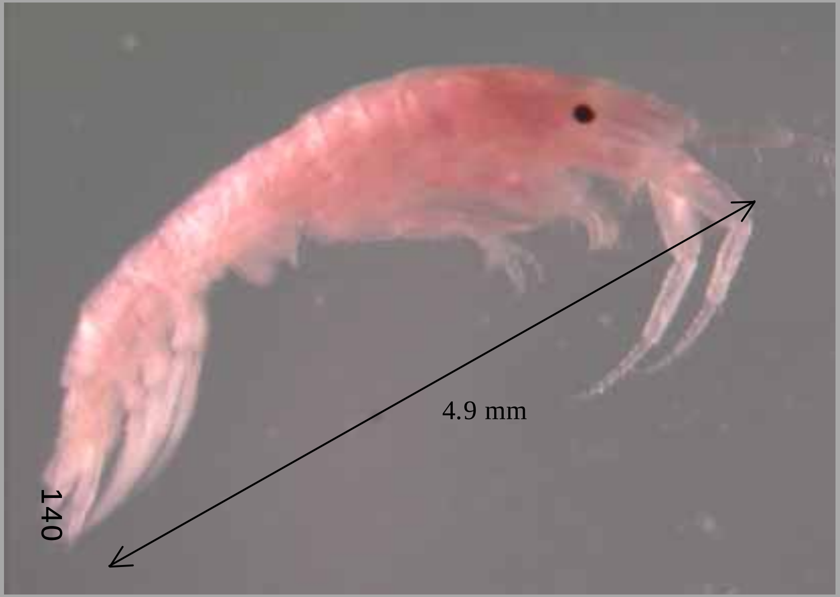
Leptocheirus plumulosus is a common burrowing Aorid amphipod found in estuarine areas. Like all Aoridae, L. plumulosus has an accessory flagella, biramous uropods 3, and an entire telson.

Telson is rounded and entire.

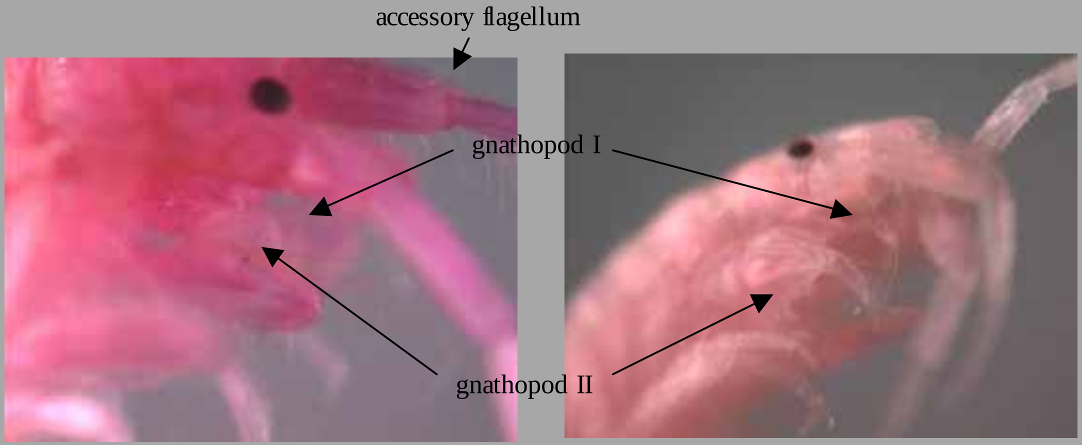


Uropods 3 are short and biramous.

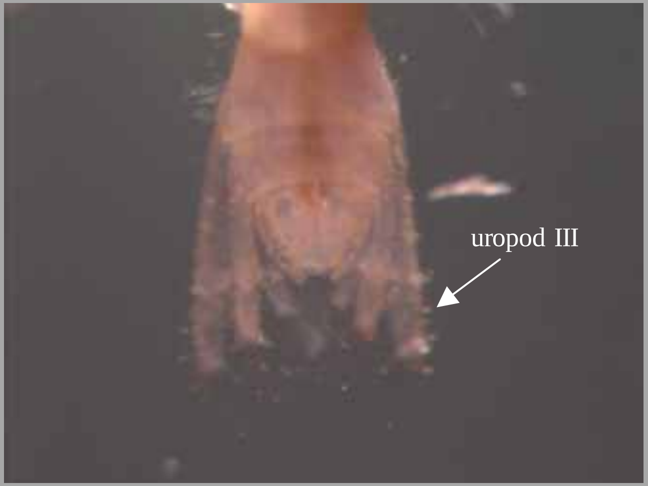
Photidae



Photid amphipods have diverse genera: many live in tubes, but some are free-living.



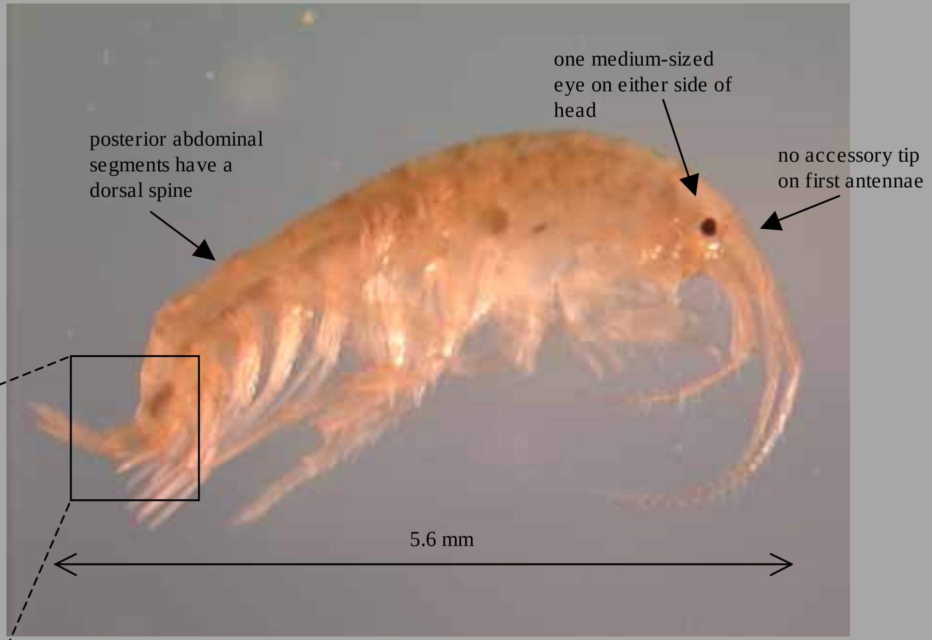
antennae I has an accessory flagellum; gnathopod II is more strongly developed than gnathopod I



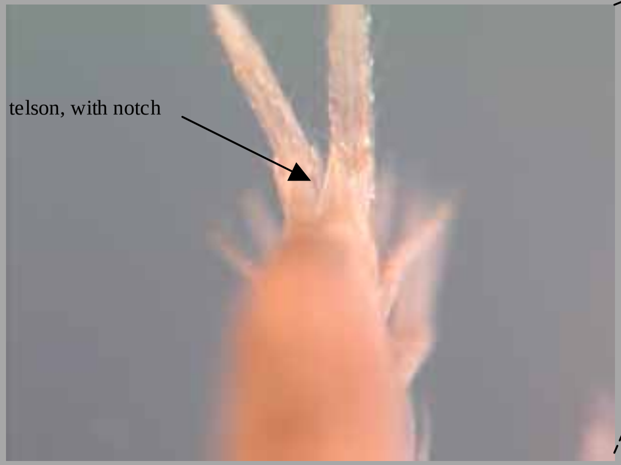
telson is small and rounded; uropod III does not have terminal hooks on it

Dexamine thea

D. thea nest among subtidal plants and stones.



rostrum is produced; first and second antennae are similar in length; pointed tips of the rear 3 pairs of legs point to the rear; color is pinkish, slighly translucent



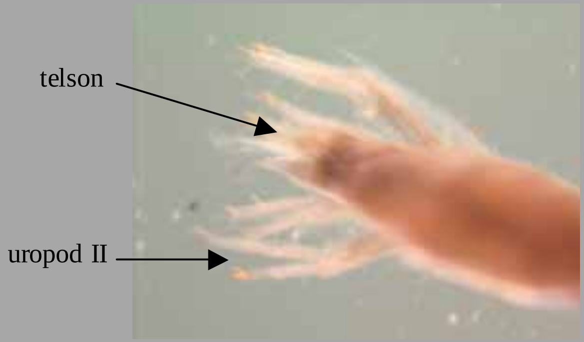
telson has a deep notch

Atylus swammerdami

A. swammerdami is the only atylid amphipod found in the Hudson. It has been found to exploit marine food resources following disturbance.

body is distinctly flattened from side to side with an arched back, and it has two eyes, one on either side of its head

antennae have no calceoli (=club-shaped sensory projections), and antenna I (top antenna) has no accessory flagellum; rostrum is not produced

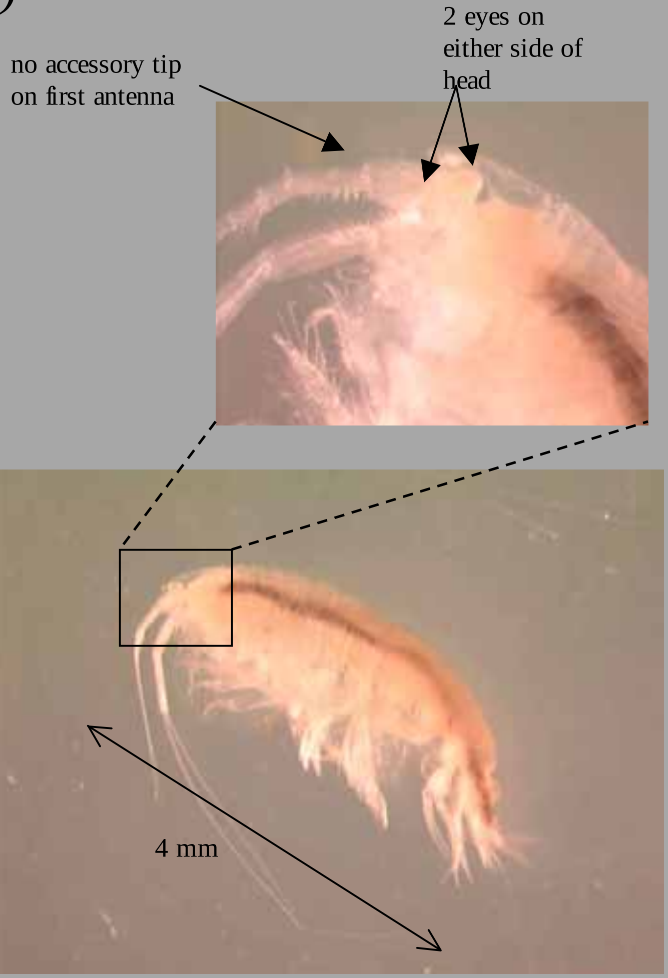


uropod II is biramous; telson is distinctly cleft

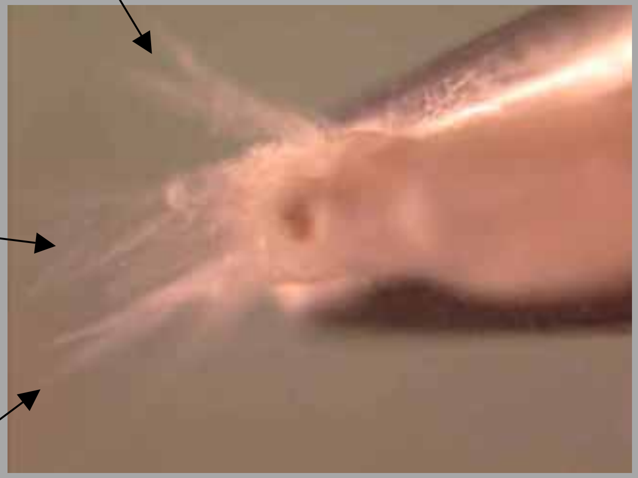
Ampelisca sp.

(A. vadorum or A. abdita)

Ampelisca sp. are in the family Ampeliscidae, known as four-eyed amphipods. They are very abundant offshore and in the lower intertidal zone on muddy and sandy bottoms, especially in eelgrass beds.



carapace (shell) is reduced; body is distinctly flattened from size to side with an arched back;



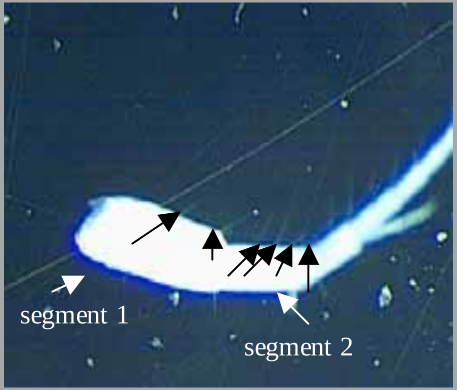
(telson is very faint, but split is clear by the darker overlap area)

telson is long and deeply split.

A. vadorum has outer margin of outer ramus of second uropod with 3-5 spines; *A. abdita* has 1 or 2 spines.

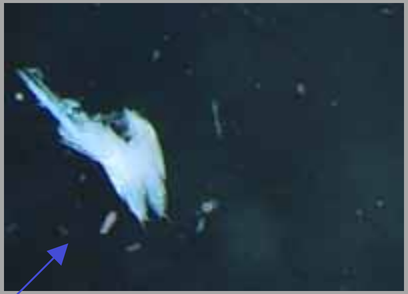
Gammarus daiberi

Antennae are nearly equal in length, and possess accessory flagella.



1st segment of antennae 1 has 2 setae groups , and 2nd segment 4 setae groups on ventral side.

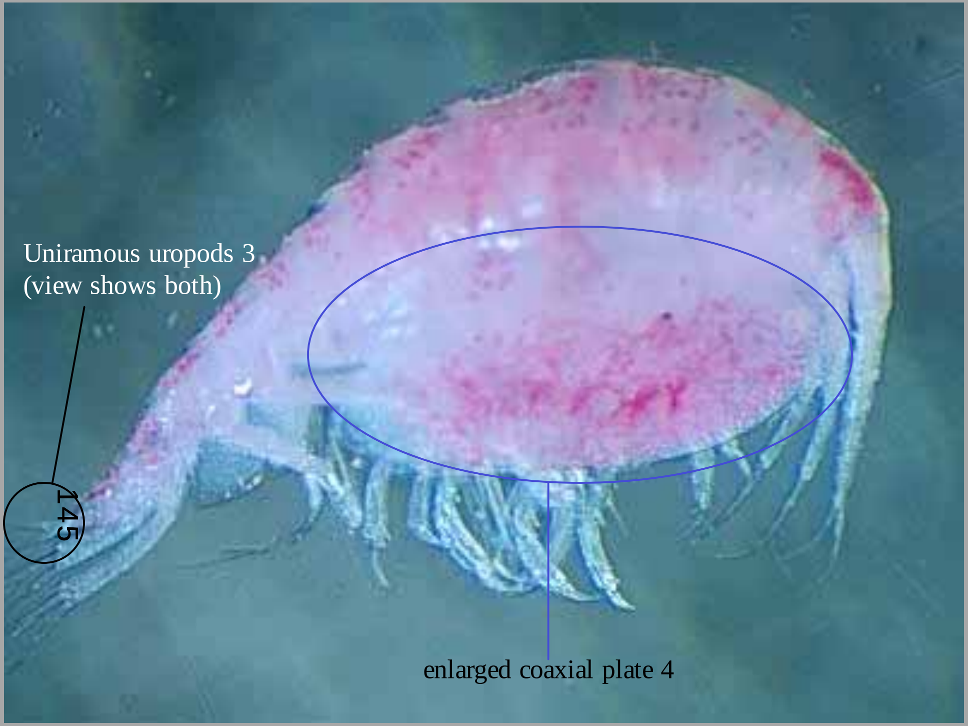
Gammarus daiberi is a common Gammaridean amphipod found in in upper to mid-estuarine environments.



Telson is deeply cleft.

Inner ramus of 3rd uropod is shorter than outer ramus but greater than ½ the length.

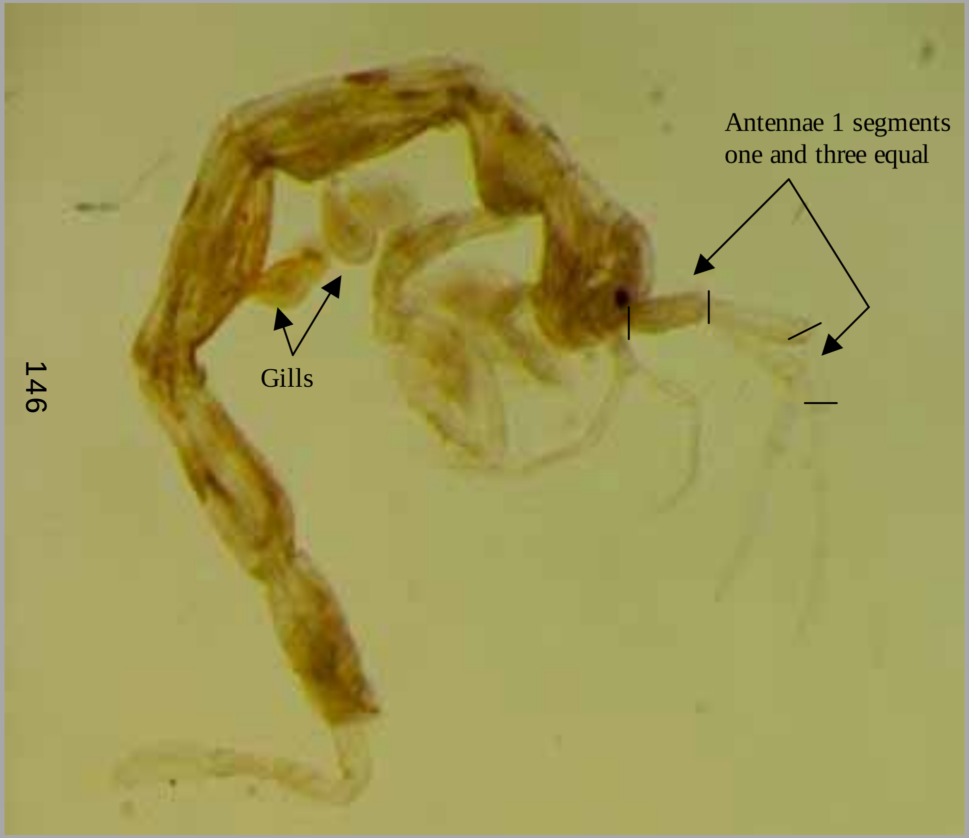
Parametopella cypris



Parametopella cypris is a Gammaridean amphipod within the family Stenothoidae.

Parametopella cypris lacks accessory flagella, the telson is entire, and uropods 3 are uniramous.

Paracaprella tenuis

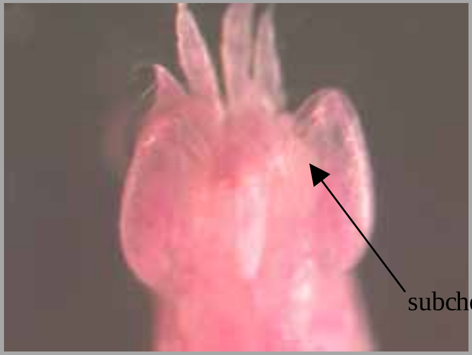


Caprellid amphipods, commonly called skeleton shrimp, often attach to ectoprocts or hydroids with their rear legs. They undulate in the current and grab passing food with their gnathopods.

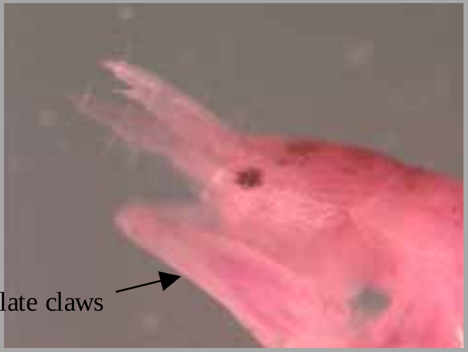
Paracaprella tenuis lacks a defined head suture and head, body, and leg spines. Antennae 1 segments one and three are nearly equal in length, and the anterior length of the head is intermediate in length of the first gill-bearing segment (segment 3).

This specimen is missing most of his terminal legs.

Cyathura polita

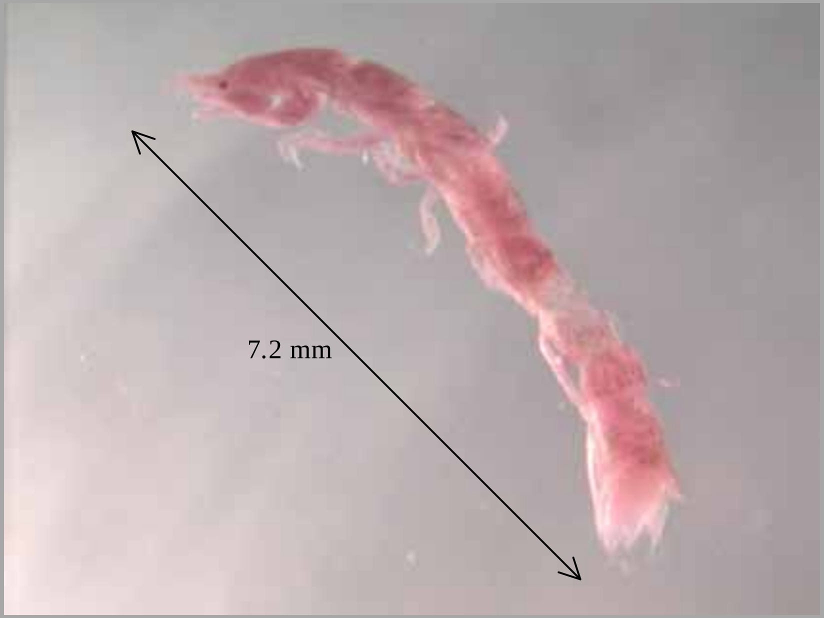


ventral view of head and claws



lateral view of head and claws

first pereopod is prehensile, with subchelate claws (anthurid characteristic); both pairs of antennae are short

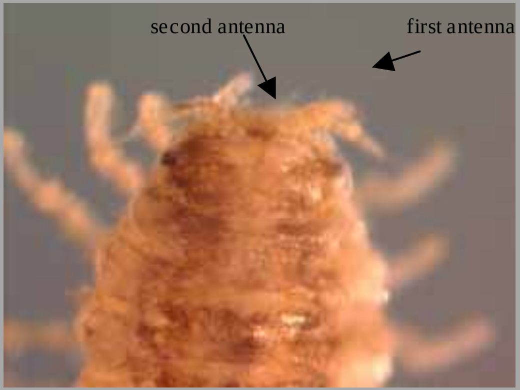


body is slender and tubular; six pairs of walking legs are similar in size and shape; telson and uropods form a fan, with telson broadly rounded (rather than pointed terminally); abdominal segments are fused together

C. polita is a common anthurid isopod found on shelly and muddy bottoms both in the intertidal zone and offshore. It is a detritus-algal feeder but is also attracted to dead animals, so it may be predaceous upon amphipods and insect larvae. It is a scavenger.

Edotea montosa/triloba

Edotea spp. are found offshore in mud and fine sand, on muddy shores and pilings, and among decaying eelgrass and seaweeds.

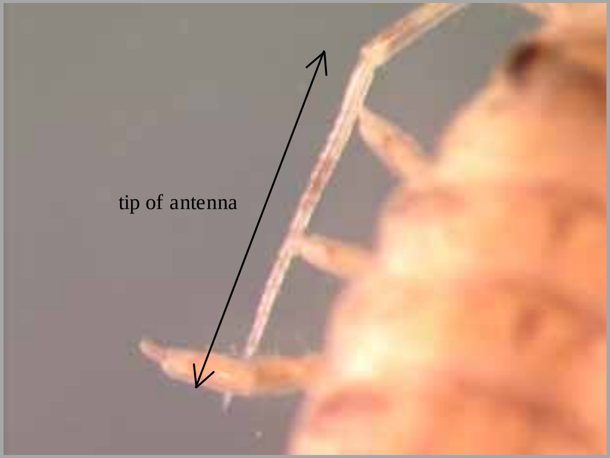


eyes are on the sides of the head, and sides of head are not notched; second antennae are <u>only two times as long</u> as the first antennae (compare to *Erichsonella attenuata*)

uropods fold under the ventral surface of the telson, forming a chamber that encloses the swimmerets (defining characteristic of all Valviferan isopods); no abdominal segments are in front of the telson; grows up to 9 mm long

side edges at tip of telson have a simple (*E. montosa*) or compound (*E. triloba*) curve leading to the point at the end

Idotea metallica



second antennae have a multi-segmented tip

3 abdominal segments in front of telson

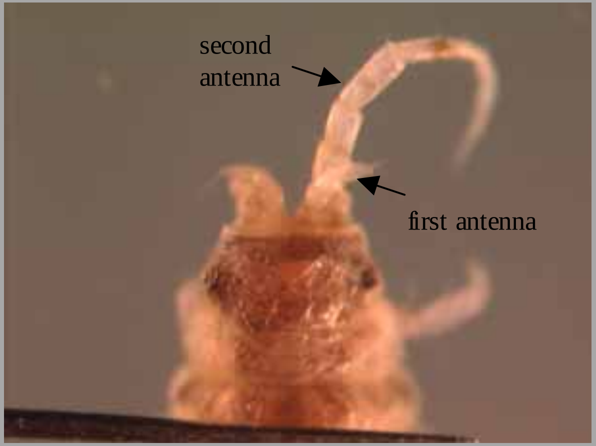
like all Valviferan isopods, uropods fold under the ventral surface of the telson, forming a chamber that encloses the swimmerets; end of *I. metallica* telson is almost straight across with no obvious points; color and pattern vary – may have stripes, bands, blothces of color, but often green or brown

I. metallica isopods are often found swimming offshore.

Erichsonella attenuata

E. attenuata isopods are commonly found on eelgrass beds and in algae. They are preyed on by several fish species, including northern pipefish.

Like all Valviferan isopods, the uropods on *E. attenuata* fold under the ventral surface of the telson, forming a chamber that encloses the swimmerets.

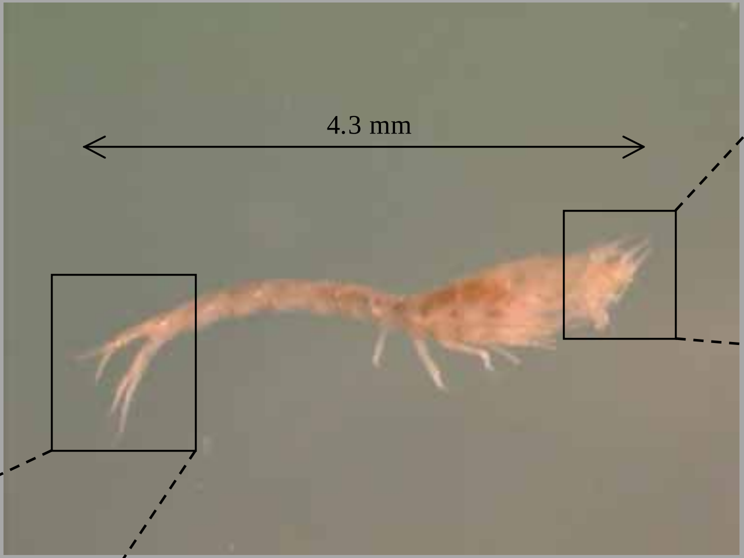


eyes are on the sides of the head, and sides of head are not notched; second antennae are at least three times as long as the first antennae (compare to *Edotea montosa*) and is not multi-segmented

no abdominal segments in front of telson; telson does not have tubercles on either side

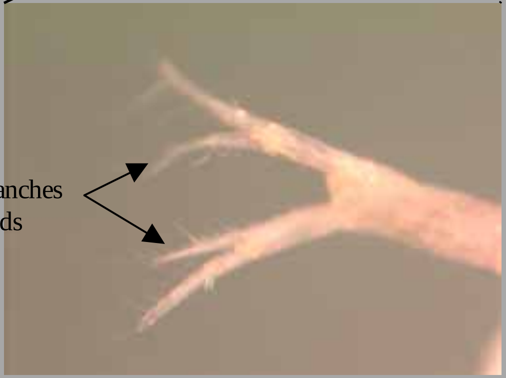
Leucon americanus

L. americanus is found in brackish water. It and other cumaceans usually burrow in bottom sediments.



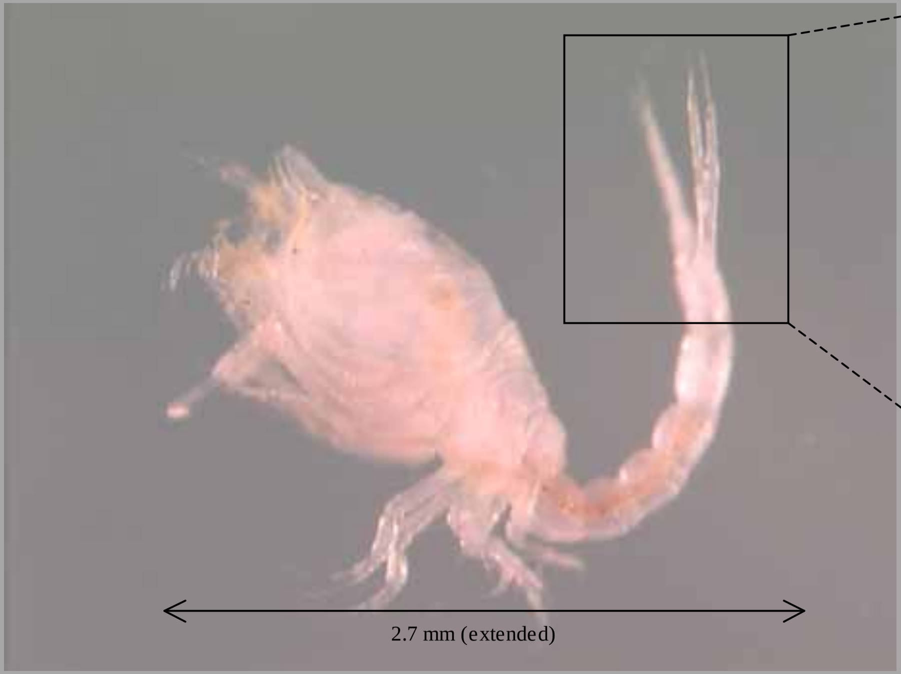
Like all cumaceans, *L. americanus* has a short carapace, its thorax is much wider than its abdomen, and its eyes are tiny or lacking.

head comes to a beak-like point

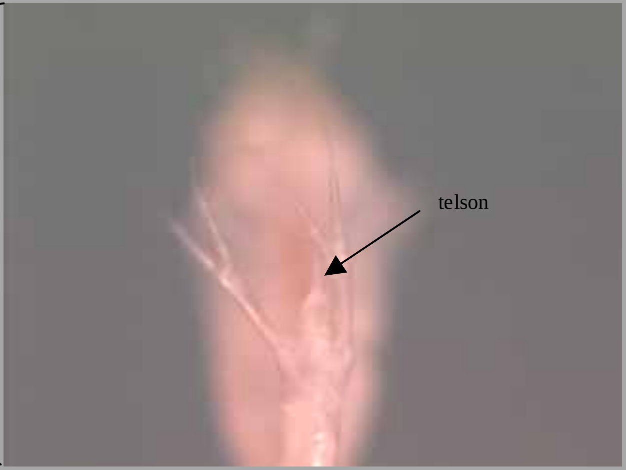


telson is small and divided; inner branches of uropods have 2 segments

Oxyurostylis smithi



carapace is short; thorax is wider than abdomen; eyes are tiny or lacking; grows up to 7 mm long (dorsal view)

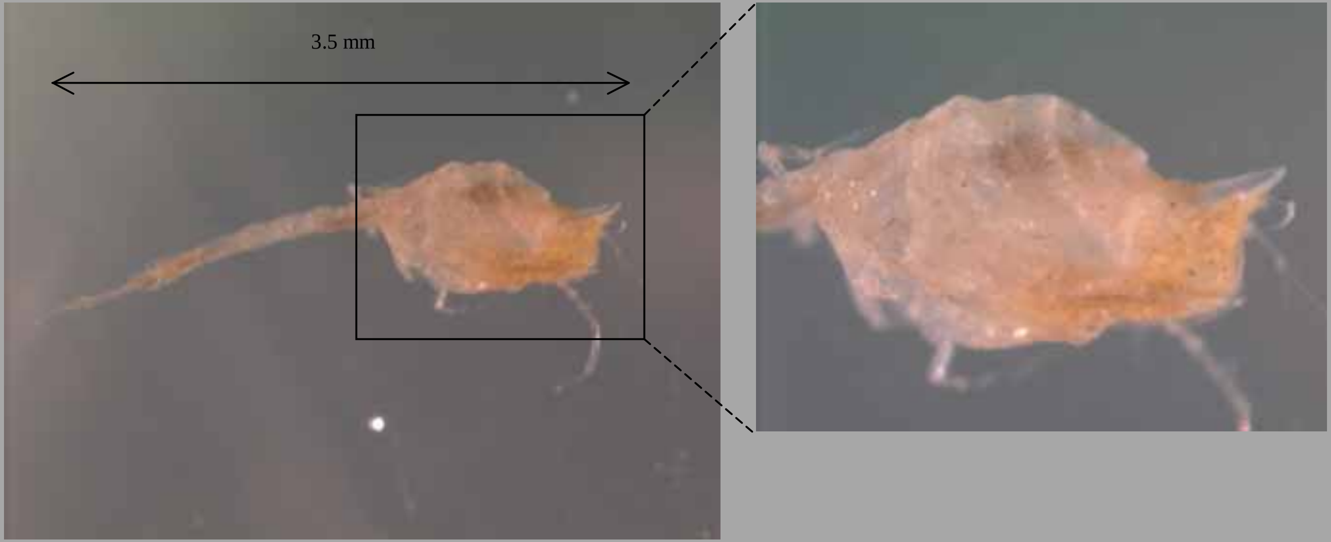


telson tip curves upwards and has no spines (ventral view)

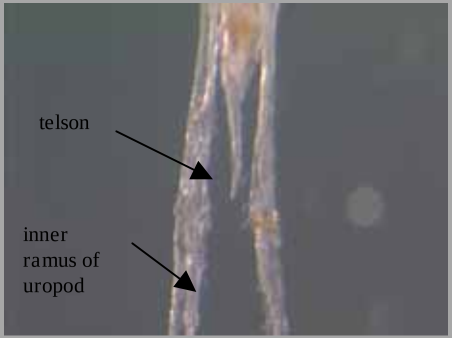
O. smithi is a very common shallow water species. Like other cumaceans, is usually burrows in bottom sediments.

Diastylis sculpta

D. sculpta is common in both shallow and deep water. It burrows in bottom sediments.

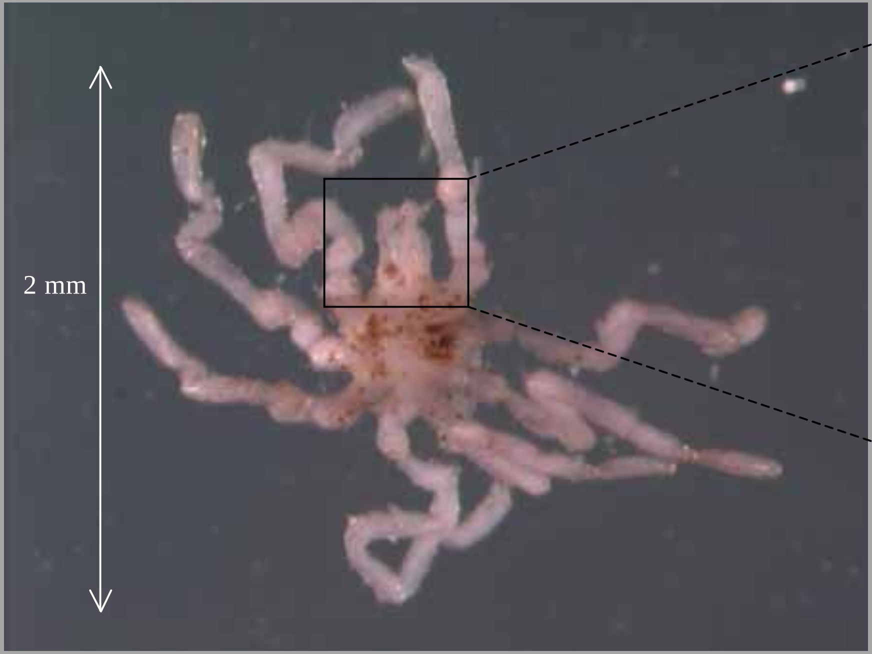


short carapace; thorax is much wider than abdomen; eyes are tiny or on stalks; side of carapace has 4 grooves; grows up to 14 mm long

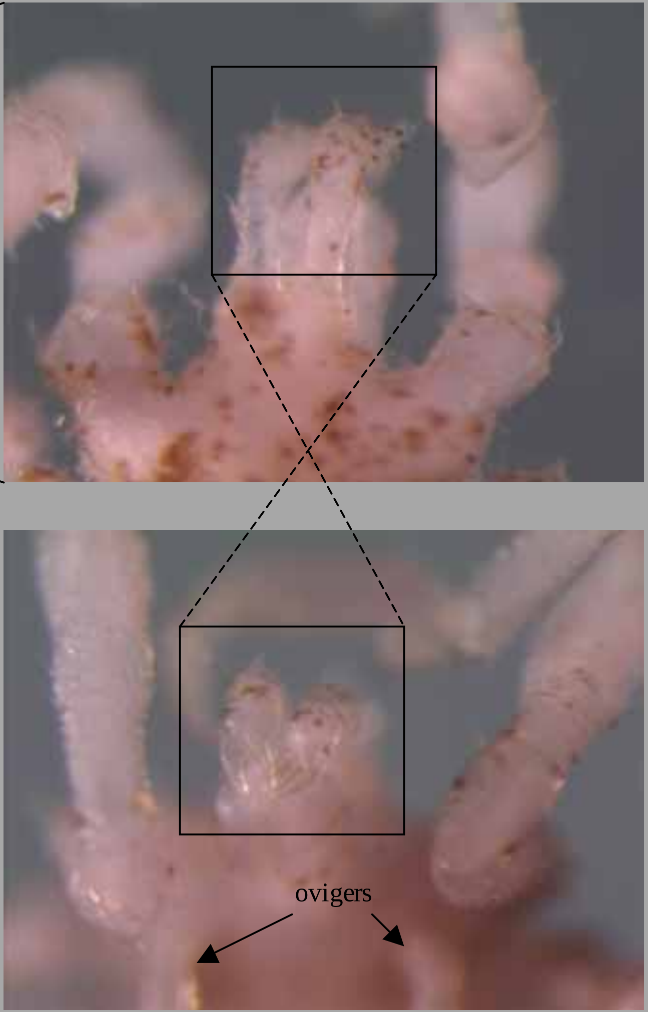


tip of telson is flat and has 2 spines; inner ramus of uropods has 2-3 segments

Phoxichilidium femoratum



spider-like body with 4 pairs of long legs that have 8 segments each, slender body



head has no neck, well-developed chelifores (top); underside of chelifores shows obvious claws (bottom); males have ovigers

P. femoratum, like all sea spiders, is strictly aquatic. It is found in the intertidal zone and in deep water, commonly associated with the hydroid *Tubularia*. It is carnivorous, as are all pycnogonids, and its larvae are parasitic.

* Insecta *

Anurida maritima

Marine Collembola, or spring-tails, are one of the few saltwater representatives of the phylum Insecta. Like all insects they possess six legs, and a head, thorax, and abdomen. Collembola are small, wingless insects that group in surface aggregations. *Anurida maritima* are most commonly found along rocky shorelines and supralittoral pools where there is calm, slack water.

Porifera

Poriferans draw in water through pores in their outer walls. Food is filtered by cells as the water passes by them. Flow through the sponge is one-directional, guided by flagella that line a series of internal canals

Sponges are common but taxonomically difficult to identify. Color is often a sound aid, but any color in this specimen has been bleached from the ethanol preservative.

* Tunicates *

Molgula sp.

Molgula spp. are known as sea grapes, or tunicates. The most common species south of Cape Cod is *M. manhattansis*, a tunicate with a smooth surface that is often encrusted with sand and othe debris. Tunicates are very common on eelgrass, pilings, boats, and many other substrates.

References

Fauchald, K. 1977. The polychaete worms. Definitions and Keys to the Families and Genera. Nat. Hist. Mus. of Los Angeles County, Sci. Series 28.

Gosner, K. L. 1971. Guide to Identification of Marine and Estuarine Invertebrates. Wiley Interscience, New York.

Pollock, L.W. 1998. A Practical Guide to the Marine Animals of Northeastern North America. Rutgers University Press, New Brunswick, New Jersey.

Weiss, H.M. 1995. Marine Animals of Southern New England and New York. State Geological and Natural History Survey of Connecticut.