Comparison of Fish Communities in Open and Occluded Freshwater Tidal Wetlands in the Hudson River Estuary

A Final Report of the 1997 Tibor T. Polgar Fellowship Program

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ABSTRACT

Original nearshore fish community data was collected using beach seines in open shallows and pop nets in *Trapa natans* beds in the freshwater tidal Hudson River at Norrie Point (NP) and Tivoli South Bay (TSB) to determine if the occlusion by the railroad bridges caused a difference in the fish community structure in these areas. The data collected allow the detection of changes in the fish communities of these nearshore habitats of the Hudson River. The two sampling methods at two sites resulted in four different fish community assemblages in open shallows and vegetated shallows. Fourspine sticklebacks and common carp were dominant in *T. natans* in TSB, but brown bullheads, redbreast sunfish, and tessellated darters were the main fishes in the NP *T. natans*. Cyprinids and moronids were dominant in the open water at TSB, while clupeids, cyprinids, and centrarchids dominated the open water at NP. Our TSB pop net data are consistent with previous work, but this does not imply that the fish community in the *T. natans* is representative of the rest of the river. Catch per unit effort differed significantly between the pop net efforts at the two sites and with the two sample methods at TSB. Water temperature significantly differed between the beach seines at the two sites.

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INTRODUCTION

Tidal wetland management is an important aspect of the mission of the National Estuarine Research Reserve (NERR) Program. The Hudson River NERR manages four sites including over 1295 ha of brackish and freshwater tidal wetlands. Tidal fresh wetlands are relatively rare globally and are located primarily along the Atlantic coast of the northeastern United States (Mitsch & Gosselink 1993).

Tidal wetlands are important as areas of high diversity and productivity. A number of economically and ecologically valuable freshwater and anadromous fish species are dependent upon the spawning and nursery habitat of marshes and vegetated shallows (Mitsch & Gosselink 1993). In the freshwater Hudson River, these include forage fish (river herrings, Clupeidae and shiners, Cyprinidae), as well as game fishes (basses and sunfishes, Centrarchidae; and striped bass, *Morone saxatilis*). The forage fish are important for exporting marsh productivity to the main river as fish biomass (Smith & Schmidt 1987). Fish community data exist for a number of fresh tidal marshes on the Hudson River.

The majority of the coastal wetlands of the Hudson River were affected by railroad construction along the shores in the mid-1800s. Cara Lee, environmental director of Scenic Hudson Inc., believes the railroad was second only to the construction of the Federal Dam at Troy as a significant impact upon the river (1996, personal communication). Both projects affected tidal flow and historic spawning areas. The railroad bed added approximately 800 ha of land to connect islands and fill in small coves (Young & Squires 1990). Causeways were constructed in order to straighten the track. Open channels in the causeways allow for water and material exchange between these embayments and the river. In many instances, the channels proved inadequate, constraining circulation and creating sediment traps (Squires 1992). As these embayments filled with sediment, they became sites of new growth of emergent vegetation. These former vegetated shallow water bays have become emergent marshes and later successional stages.

Vegetated bays will gradually fill with sediments as the vegetation decreases the kinetic energy of suspended materials within the currents and tides. This increases the succession rate as the open bay succeeds to a wetland with emergent vegetation replacing the submerged and floating-leafed vegetation. Areas where free current flow and material exchange are inhibited will make this change more rapidly. Kiviat (1978) believed that limited tidal circulation was the greatest threat to the existing open water and low marsh in the Tivoli Bays ecosystem. Pools in Tivoli North Bay (TNB) have been filling in since 1971 (Kiviat 1991).

European water chestnut (*Trapa natans*) is an exotic, floating leafed plant with a distinctive spiked seedpod. It was inadvertently introduced to the Hudson River watershed in the 1860s. It thrives in calm, shallow, nutrient-rich waters and is now established in a majority of these areas on the Hudson, including Tivoli South Bay (TSB). *T. natans* provides significant habitat and provides for a complex food web within the vegetated bays (Yozzo & Odum 1989). The stand of water chestnut in TSB has caused this wetland to begin to act as a more efficient sediment trap (Goldhammer & Findlay 1988). This increasing sedimentation in TSB could result in an emergent marsh like TNB in "several decades" (Kiviat 1978, 1991).

Do occlusions to marshes and bays affect fish communities?

We hypothesized that fish community diversity will be lower in partially occluded sites in comparison to open sites. Species density will be affected by the causeway by trapping fish within the occlusion. This research involved the collection of original ecological data on fish community structure in tidal wetlands and a review of the existing Hudson River fisheries literature. This information can be used to determine potential trends in the fisheries and fish ecology in the Hudson River. Implications for management of resource species can be drawn from the results. This information can also be used for tidal wetland management. We compared the fish communities among vegetated bays and within fresh tidal marshes in an open tidal flow area (Norrie Point) to a partially occluded area

METHODS & MATERIALS

Description of the Study Area

The Dutchess Community College Norrie Point Environmental Site (NP) is located in Mills-Norrie State Park in Staatsburg, N.Y. (lat 41°49.80' N, long 73°56.40' W) (Figure 1). The site is on a peninsula on the east bank of the Hudson River, 85 mi. (137 km) north of the mouth of the Hudson River at the Battery (Manhattan). Norrie Point has a beach at the east cove with a soft silty bottom that is filled with *T. natans* and watermilfoil (*Myriophyllum spicatum*) from May through October.

Tivoli South Bay (TSB) (lat 42°01.22' N, long 73°55.20' W) (Figure 2) is located at Hudson River Mile (HRM) 98 (HRKM 158). It has a soft silty mud bottom with a small area of rock and gravel at the mouth of the Saw Kill and a small deeper pool at each railroad bridge. This is similar to the east cove at NP. With the exception of restrictions and barriers to tidal flow, the sites are very similar; both have southern exposures, exposed mud flats at low tide, a similar tidal range (ca. 1.2 m) and similar vegetation.

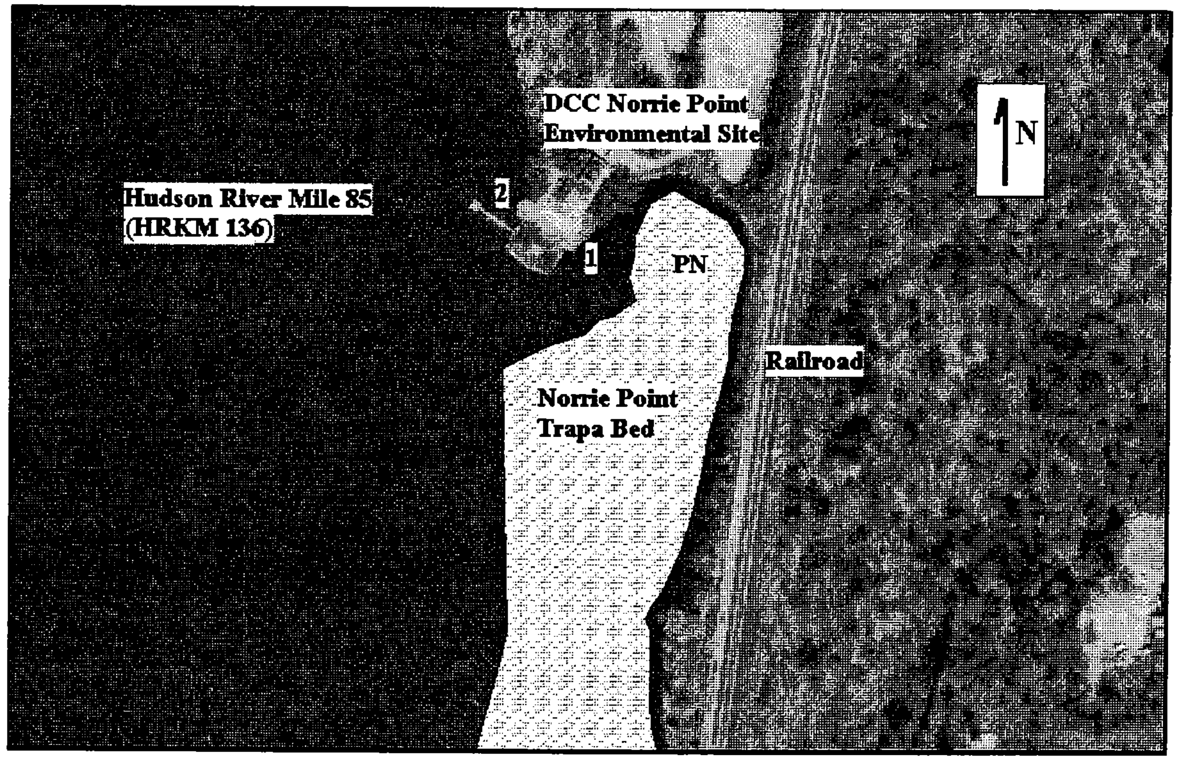

Figure 1: Norrie Point Study Site. The *T. natans* bed is crosshatched and the open water and channel are solid. The number 1 indicates the seining beach and PN indicates the area where pop netting occurred.

TSB is approximately 115 ha. Of this, *T. natans* covers about 95% of the surface from mid-May through October (Anderson & Schmidt 1989). The *T. natans* can grow quite dense. Goldhammer & Findlay (1988) determined the peak dry biomass was 400 $g \cdot m^{-2}$; this is denser than most other submerged aquatic vegetation (SAV).

Tidal exchange between the river and TSB is restricted to three bridge openings across the railroad causeway, which represents 3% of the original linear interface. Tidal flow comprises approximately 90% of the annual water budget for the bay (Lickus &

Barten 1989, Zelewski & Armstrong 1997). During sampling, it became evident that differences in tidal flow and scouring existed between NP and TSB. Many logs, trees, and anthropogenic debris presented hazards to wading at TSB. The lack of barriers to tidal flow at NP allows the flotsam and jetsam to typically wash freely in and out of the coves.

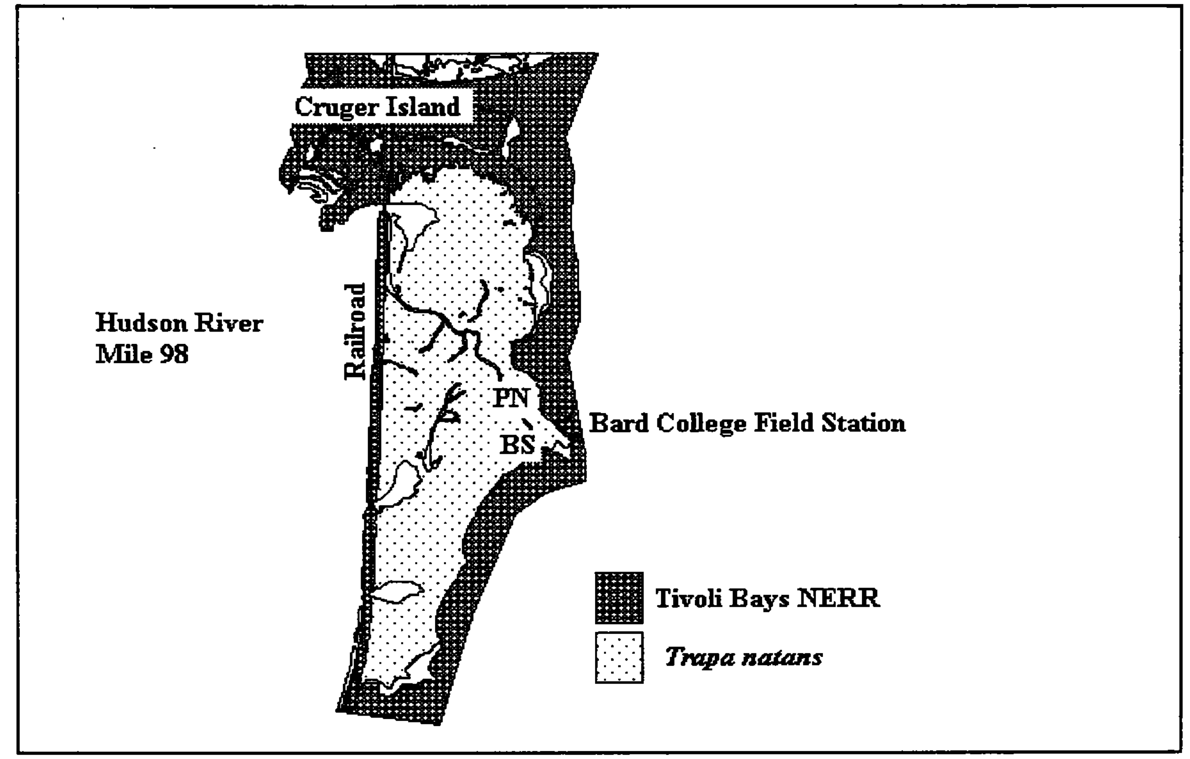

Figure 2: Tivoli South Bay Study Site. PN and BS denote the pop net area and beach seine beaches respectively. The *T. natans* bed is lightly shaded and the open water and channels are solid white.

Collection of Fish in Vegetated Shallows

Modification to Pop Nets

Using the existing pop nets (Figure 3) constructed by my predecessors (Pelczarski & Schmidt 1991; Hankin & Schmidt 1992), I modified the weighted hoop to provide added submerged weight with no carrying or transportation weight penalty. The 1" (2.54 cm) I.D. plastic water pipe and steel reinforcement rods were replaced by 1.5" (3.81 cm) PVC and 3 kg of pea gravel per length. The PVC pipes were drilled through perpendicular axes with ¼" holes at 5 cm intervals. The ends of the tubes were fitted with 3.8 cm diameter x 5 cm long wooden plugs to prevent the gravel from migrating around the elbows during storage and transport (Figure 4). Before setting the net, we shook it to distribute any gravel that had settled in the ends throughout the lengths of the pipes. This modification eliminated any inherent buoyancy of the previous designs. The water added weight to the bottom of the pop net when submerged, but readily drained when lifted to allow easier movement and transport.

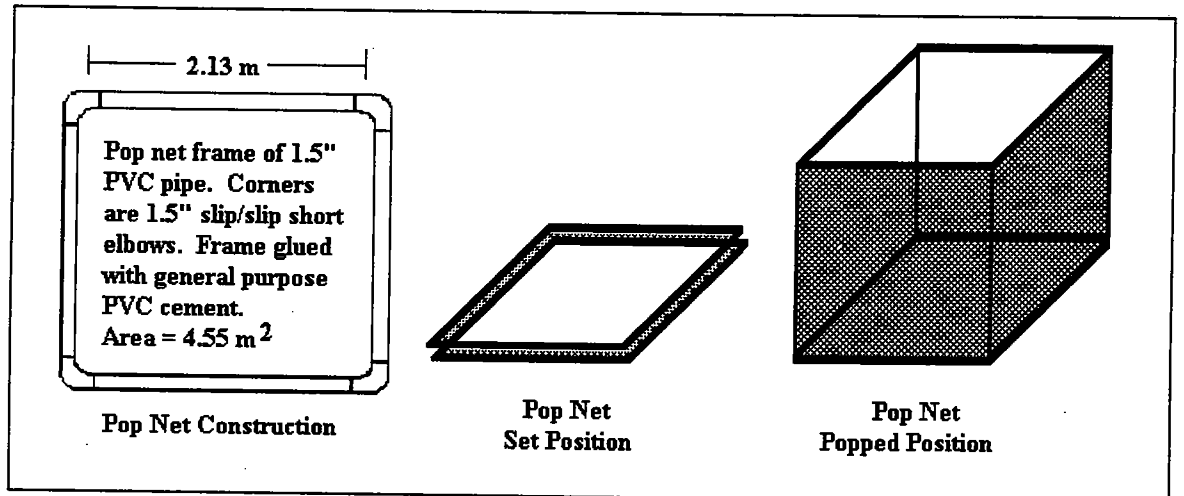

Figure 3: Pop net (L to R) Construction and top view; side views (set and popped).

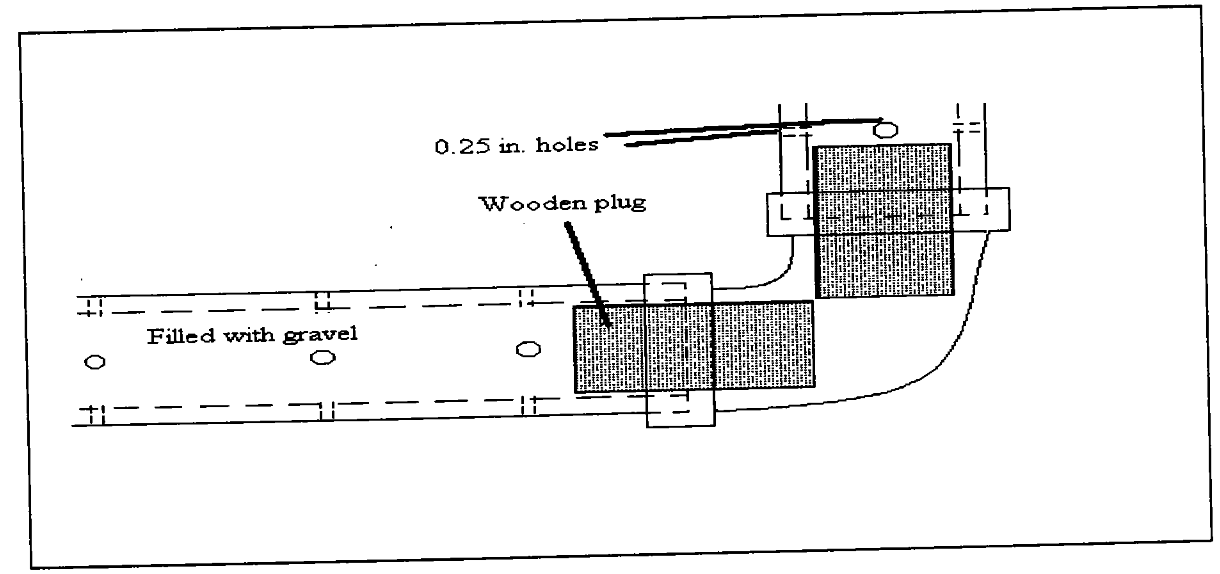

Figure 4: Cross section of pop net modifications to bottom frames.

The trigger clips were also redesigned after speaking with Dennis Mildner (HRNERR) about a potential safety factor. Galvanized U-bolts were previously used and the threads were covered with duct tape. On one occasion, the tape or threads stuck on the netting; when the trigger was pulled, the bolt became a ballistic projectile and injured someone. The new triggers were constructed of 3 x 25 mm aluminum plate bent to fit the pipe frame (Figure 5). The aluminum provided a lower friction surface and easier trigger release. Rubber bands were used to secure the clips to the nets.

Figure 5: Trigger design for pop nets

The trigger release technique was also modified to eliminate possibilities of injury. Rather than pulling the trigger line upward from shoulder height, the trigger pullers would place a foot on the line and hold the buoy. By sliding the foot away from the net and pulling the line using the foot as a pivot point, the clips would release underwater without any possibility of cranial impact.

Collections with Pop Nets

The modified pop nets (after Hankin & Schmidt 1992) were used to sample the fish communities in the densely vegetated areas. The pop nets were set at low tide at random locations within a predetermined sampling area (Figs. 1 and 2). When setting the net, care was taken to clear any debris that may tear the netting. The frames had to be set on the bottom and not upon any vegetation. All *T. natans* rosettes had to be moved either to the inside or outside of the net to prevent the bottom frame from floating or pulling up when the net was popped.

The nets remained in place for approximately 8 h, and were popped 2 h after high tide. Once the net was popped, the *T. natans* was cleared from within the net and around the perimeter to allow sampling with seines. A 6 x 1.2 m nylon seine with 2 mm mesh was used to sample the interior of the pop net. The pop net was seined four times in one direction and then rotated around the pop net in a clockwise manner. The sampling continued until we hauled five consecutive empty seines. This allowed the sampling to be quantitative.

This sampling was most efficient when done by at least three people. This allowed two to pull the seine and the third to collect the fish. Small dip nets were used to make catching of fish in the corners of the pop net easier. Sampling, cleanup, and fish counting typically took 2 to 3 h. A foam "boogie" board served as an effective floating work and transport platform.

Collection of Fish in Open Shallows

Open water sampling was done with a 25 x 1.5 m bag seine of 5 mm square knotless nylon mesh in shallow open waters. Seines were pulled in flowing water at two

hours after low tide. The seine was extended perpendicular to shore and then encircled to the starting point. The seine hauls covered approximately 300 m^2 of water surface area at NP and 150 m^2 at TSB. Seining is a qualitative sampling method used to document species not caught in the pop net (Hankin & Schmidt 1992). This can help to provide a better picture of the species composition within the overall fish community. Additional surveys were also attempted using snorkeling and documenting with underwater still photography (Whitworth & Schmidt 1980; Kirker 1989).

We sampled for seven weeks, between 8 July and 21 August 1997. The sites were sampled on an approximately weekly basis. Sampling times were based on the tides and the total process time (pop net set to pop net clean and count), which required up to 13 h. The times were chosen so that the net could be popped and sampled during daylight. This allowed comparison to previous Polgar efforts, which were all diurnal surveys.

Data Quantification

Fish were transferred to pails of river water, identified, and counted. Common fish were identified on sight. Unknown fish were identified using Smith (1985). Recognized experts on regional fish fauna (Tom Lake and Robert Schmidt) verified fish identifications. A representative subsample was preserved in 10% formalin and the fish were measured to the nearest millimeter in total length.

Water temperature, state of tide, and other observations were gathered for each collection. Voucher specimens were maintained at the Dutchess Community College Norrie Point Environmental Site. Additional specimens will be provided to the New York State Museum.

Data were analyzed by comparing relative abundance by species using chi-square analysis. I compared my TSB and NP pop net data against those of my predecessors (Pelczarski & Schmidt 1991; Hankin & Schmidt 1992). At NP, I have a weekly beach seine data set (unpublished) from ice-out to ice-in (4 March 1996 to 6 January 1997) for 1996. Since this is the most comprehensive data for the site, this was set as the expected composition against the NP pop net and beach seine Polgar data. Densities (fish·m^{-2}), catch per sample effort, and water temperatures were analyzed with student *t*-tests. Significance was determined at an $\alpha = 0.05$ level for all tests.

RESULTS

Seven sets of weekly samples (beach seine and pop net) were done at each site (TSB and NP). A total of 1987 fish representing 11 families and 23 species were caught (Tables 1 and 2). Overall, more individuals, species, and families were found at NP than TSB. TSB pop net densities were higher than NP. Pop net densities at both sites were one to two orders of magnitude greater than the densities of the beach seines. Pop netting at both sites caught an equal number of species (13), but the community composition was different. Species diversity in beach seines was higher at NP compared to TSB.

Table 1: Summary of fish caught by location and sampling method. NP = Norrie Point, TSB = Tivoli South Bay, BS = Beach Seine, PN = Pop Net

Sample Location	Sample Method	Number Of Fish	Mean Fish per Sample	Number of Species	Number of Families	Mean Density (fish/m^2)
NP	BS	1270	181.4	20	10	0.61
NP	PN	219	31.3	13	7	6.88
NP	**Total**	**1489**	**106.4**	**20**	**10**	**3.64**
TSB	BS	133	19.0	12	7	0.13
TSB	PN	365	52.1	13	7	11.46
TSB	**Total**	**498**	**35.6**	**17**	**9**	**10.89**

The two sample methods at the two different locations resulted in four different fish communities (Table 2). The fish community assemblages were expected to be different between the two sampling methods since they sample different areas and water conditions. Anderson & Schmidt (1988) found a difference between the ecotone community and the TSB *T. natans* beds and open water areas in both species composition and density due to current. Due to the limited area covered, the ecotone was determined to not present a significant habitat in TSB.

This is not necessarily the case at NP. The ecotone at NP, because of the lack of the railroad causeway, is the entire interface between the main river and the channel. NP has 4.25 ha more open shallow water than TSB. Our hypothesis was that the overall communities would differ between NP and TSB due to the difference in occlusion of tidal flow by railroad bridges and isolation from the main river.

Table 2: List of families and species by location and sampling method. (NP = Norrie Point, TSB = Tivoli South Bay, BS = Beach Seine, PN = pop net)

	Location / Sampling Method	NP BS	NP PN	TSB BS	TSB PN
Anguillidae	**Freshwater Eels**				
Anguilla rostrata	American Eel	♦	♦		♦
Clupidae	**Herrings**				
Alosa aestivalis	Blueback Herring	♦			
Alosa pseudoharengus	Alewife	♦	♦		
Alosa sapidissima	American Shad	♦			
Cyprinidae	**Carps & Minnows**				
Cyprinus carpio	Common Carp	♦	♦	♦	♦
Luxilus cornutus	Common Shiner	♦	♦	♦	
Notemigonus crysoleucas	Golden Shiner	♦	♦	♦	♦
Notropis hudsonius	Spottail Shiner	♦	♦	♦	♦
Catostomidae	**Suckers**				
Catostomus commersoni	White Sucker	♦		♦	
Ictaluridae	**Bullhead Catfishes**				
Ameiurus nebulosus	Brown Bullhead	♦	♦		♦
Belonidae	**Needlefishes**				
Strongylura marina	Atlantic Needlefish	♦			
Fundulidae	**Killifishes**				
Fundulus d. diaphanus	Eastern Banded Killifish	♦	♦		♦
Fundulus heteroclitus	Mummichog			♦	♦
Gasterosteidae	**Sticklebacks**				
Apeltes quadracus	Fourspine Stickleback			♦	♦
Moronidae	**Temperate River Basses**				
Morone americana	White Perch	♦		♦	
Morone saxatilis	Striped Bass	♦		♦	
Centrarchidae	**Sunfishes**				
Ambloplites rupestris	Rock Bass			♦	♦
Lepomis auritus	Redbreast Sunfish	♦	♦		♦
Lepomis gibbosus	Pumpkinseed Sunfish	♦	♦		♦
Lepomis macrochirus	Bluegill Sunfish	♦	♦		
Micropterus salmoides	Largemouth Bass	♦	♦	♦	♦
Percidae	**Perches**				
Etheostoma olmstedi	Tessellated Darter	♦	♦	♦	♦
Perca flavescens	Yellow Perch	♦			

The fish communities in the TSB *T. natans* beds have been studied in two previous Polgar Fellowships (Pelczarski & Schmidt 1991; Hankin & Schmidt 1992). These were the only two Hudson River *T. natans* pop net surveys I was able to find. This proj-

ect attempted to determine if TSB's fish community was representative of the rest of the Hudson River *T. natans* beds. We compared our data (Table 3) to those of Hankin & Schmidt (1992) using a chi-square test. They were not significantly different (α= 0.05). Our community data, however, were significantly different (X^2=27.46) from those of Pelczarski & Schmidt (1991). Our pop net sampling caught more fish per netting effort, more total fish, and more species than my predecessors, but we are unable to explain why this was the case.

Table 3: Fish caught in pop nets at Tivoli South Bay. RA represents Relative Abundance (percent) of fishes caught. Catch frequency is the frequency that a species was caught in seven samples. The 1991 data are from Hankin & Schmidt (1992) and 1990 data are from Pelczarski & Schmidt (1991).

Species	Common Name	Catch Freq.	Total Fish	1997 RA	1991 RA	1990 RA
Apeltes quadracus	Fourspine Stickleback	7/7	204	55.9	64.0	75.3
Cyprinus carpio	Common Carp	7/7	99	27.1	29.0	18.5
Fundulus d. diaphanus	Banded Killifish	2/7	31	8.5	1.3	2.5
Notropis hudsonius	Spottail Shiner	5/7	11	3.0	---	0.7
Ambloplites rupestris	Rock Bass	4/7	5	1.4	4.0	---
Micropterus salmoides	Largemouth Bass	1/7	4	1.1	---	---
Ameiurus nebulosus	Brown Bullhead	2/7	2	0.5	---	---
Etheostoma olmstedi	Tessellated Darter	1/7	2	0.5	---	2.2
Lepomis auritus	Redbreast Sunfish	1/7	2	0.5	---	---
Lepomis gibbosus	Pumpkinseed	2/7	2	0.5	---	---
Anguilla rostrata	American Eel	1/7	1	0.3	---	0.4
Fundulus heteroclitus	Mummichog	1/7	1	0.3	---	---
Notemigonus crysoleucas	Golden Shiner	1/7	1	0.3	1.3	---
Morone americana	White Perch	---	---	---	---	0.4
Carassius auratus	Goldfish	---	---	---	1.3	---
	Total Fish Collected		**365**	**365**	**75**	**275**
	Mean Catch/Pop Net		**52.1**	**52.1**	**9.4**	**30.6**

The species composition and relative abundance comparisons of the NP beach seine to the NP pop net and the comparisons of NP to TSB all failed the chi-square analysis at an α = 0.05 level of significance (Tables 4-6, Fig. 6). Catch frequencies (frequency that a species was caught in seven samples) did not necessarily reflect the relative abundance. American eels were caught in each pop net at NP, but they were ranked sixth of 13 species. Brown bullheads were caught in only two samples, but ranked first.

Table 4: Fish caught in pop nets at Norrie Point. Mean catch per sample was 31.3 fish.

Species Name	Common Name	Catch Frequency	Total Fish	Relative Abundance
Ameiurus nebulosus	Brown Bullhead	2/7	71	32.4
Lepomis auritus	Redbreast Sunfish	2/7	30	13.7
Notropis hudsonius	Spottail Shiner	4/7	28	12.8
Etheostoma olmstedi	Tessellated Darter	6/7	26	11.9
Lepomis gibbosus	Pumpkinseed	2/7	16	7.3
Anguilla rostrata	American Eel	7/7	12	5.5
Cyprinus carpio	Common Carp	3/7	10	4.6
Fundulus d. diaphanus	Banded Killifish	3/7	9	4.1
Micropterus salmoides	Largemouth Bass	4/7	6	2.7
Alosa pseudoharengus	Alewife	2/7	5	2.3
Notemigonus crysoleucas	Golden Shiner	1/7	3	1.4
Lepomis macrochirus	Bluegill	1/7	2	0.9
Luxilus cornutus	Common Shiner	1/7	1	0.5
			219	**100.0**

Table 5: Fish caught in beach seines at Tivoli South Bay. Mean catch per seine was 19 fish. No fish were caught on 22 July 1997.

Species Name	Common Name	Catch Frequency	Total Fish	Relative Abundance
Notemigonus crysoleucas	Golden Shiner	2/7	47	35.3
Morone saxatilis	Striped Bass	2/7	37	27.8
Notropis hudsonius	Spottail Shiner	4/7	16	12.0
Morone americana	White Perch	1/7	8	6.0
Luxilus cornutus	Common Shiner	1/7	6	4.5
Catostomus commersoni	White Sucker	2/7	6	4.5
Ambloplites rupestris	Rock Bass	1/7	4	3.0
Apeltes quadracus	Fourspine Stickleback	1/7	3	2.3
Cyprinus carpio	Common Carp	1/7	2	1.5
Etheostoma olmstedi	Tessellated Darter	1/7	2	1.5
Micropterus salmoides	Largemouth Bass	1/7	1	0.8
Fundulus heteroclitus	Mummichog	1/7	1	0.8
			133	**100.0**

On 8 July 1997, a school of 988 juvenile spottail shiners (*Notropis hudsonius*) was caught in the NP beach seine. The fish averaged 9 mm TL and approximately 1 mm

dia. The majority of these fish would typically be able to swim through the mesh, but the site was filled with filamentous green algae (*Spirogyra*) that clogged the net. These are forage fish, the majority of which would probably have become food for a piscivorous fish in the next few months. This catch skewed the overall catch ratio of the beach seine. After conferring with Bob Schmidt and Dr. Mark Halsey, Professor of Mathematics at Bard College, this school of fish was excluded from the statistical analysis. The revised NP beach seine results are in Table 6 as "Adjusted Total" and "Adjusted Relative Abundance."

Table 6: Fish caught in beach seines at Norrie Point. Total Fish = All fish caught in this survey; RA = Relative Abundance (%); Adj. Total = total of fish without the anomalous spottail shiner school; Adj. RA = Adjusted Relative Abundance (%), recalculated without the shiner school. Mean number of fish per seine was 181.4 and 40.3 without the shiner school.

Species Name	Common Name	Catch Freq.	Total Fish	RA (%)	Adj. Total	Adj. RA
Notropis hudsonius	Spottail Shiner	3/7	1012	79.7	24	8.5
Alosa aestivalis	Blueback Herring	5/7	89	7.0	89	31.6
Lepomis gibbosus	Pumpkinseed	5/7	35	2.8	35	12.4
Micropterus salmoides	Largemouth Bass	5/7	27	2.1	27	9.6
Notemigonus crysoleucas	Golden Shiner	3/7	26	2.0	26	9.2
Luxilus cornutus	Common Shiner	3/7	19	1.5	19	6.7
Alosa pseudoharengus	Alewife	4/7	17	1.3	17	6.0
Fundulus d. diaphanus	Banded Killifish	5/7	14	1.1	14	5.0
Lepomis auritus	Redbreast Sunfish	2/7	7	0.6	7	2.5
Alosa sapidissima	American Shad	1/7	6	0.5	6	2.1
Cyprinus carpio	Common Carp	4/7	6	0.5	6	2.1
Morone saxatilis	Striped Bass	1/7	3	0.2	3	1.1
Ameiurus nebulosus	Brown Bullhead	1/7	2	0.2	2	0.7
Anguilla rostrata	American Eel	1/7	1	0.1	1	0.4
Catostomus commersoni	White Sucker	1/7	1	0.1	1	0.4
Etheostoma olmstedi	Tessellated Darter	1/7	1	0.1	1	0.4
Lepomis macrochirus	Bluegill	1/7	1	0.1	1	0.4
Morone americana	White Perch	1/7	1	0.1	1	0.4
Perca flavescens	Yellow Perch	1/7	1	0.1	1	0.4
Strongylura marina	Atlantic Needlefish	1/7	1	0.1	1	0.4
			1270	**100.0**	**282**	**100.0**

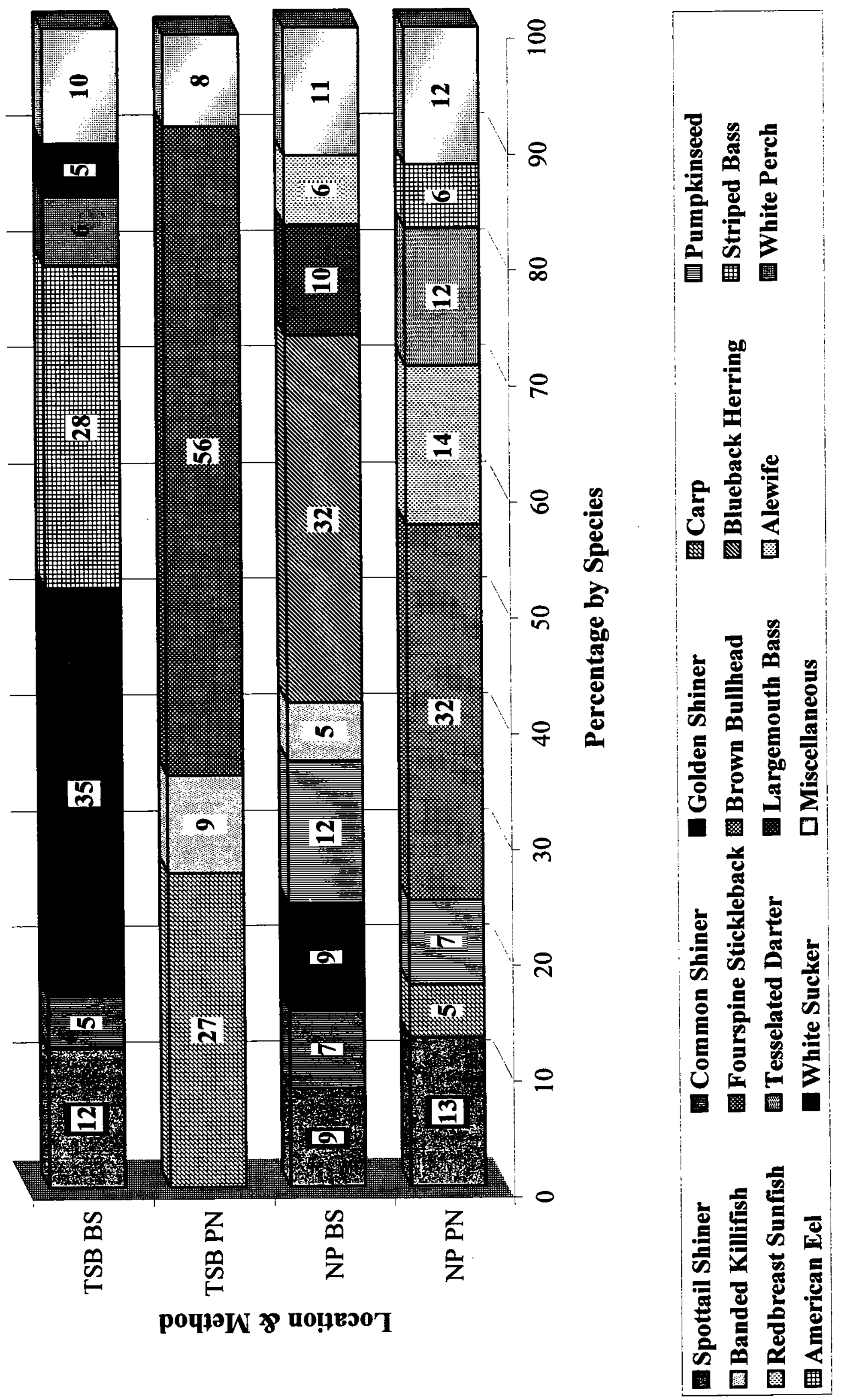

Figure 6: Comparison of fish communities by location and sampling method. TSB = Tivoli South Bay, NP = Norrie Point, BS = Beach Seine, PN = Pop Net. Species ranking 5% or greater are graphed. "Miscellaneous" accounts for the remaining species.

Catches per unit effort (seine or pop net) were analyzed using two-tailed student *t*-tests. On 1 August 1997, a large hole was torn in the perimeter netting of the pop net at NP. This may have been the cause of the low number of fish (14) caught in that particular sample. The fish catches in the pop nets at the two sites were significantly different (t = -2.488). The mean fish catches in the two methods at TSB were also significantly different (t = 3.579). No significant differences were found between the two sampling methods at NP (t = -0.919) and the beach seine sampling at the two sites (t = -2.032). The results are summarized in Table 7.

Water temperature data were recorded with each sampling effort (Fig. 7). The statistical analysis was done on these data using student *t*-tests (Table 8). There was a significant difference between the mean temperature during the beach seines at the two sites (t = 2.746). All other comparisons were considered statistically insignificant.

Table 7: Summary of statistical comparison of fish catch efforts. (NP = Norrie Point, TSB = Tivoli South Bay, PN = pop net, BS = beach seine, SIG = significant, NSD = no significant difference). The *t* values were considered significant at $\alpha_{0.05(6)}$ Δ ±2.447.

Comparison	*t* value	Significance
NP PN v. TSB PN	-2.488	SIG
NP PN v. NP BS w/o spottail shiner school	-0.919	NSD
TSB PN v. TSB BS	3.579	SIG
TSB BS v. NP BS w/o spottail shiner school	-2.032	NSD

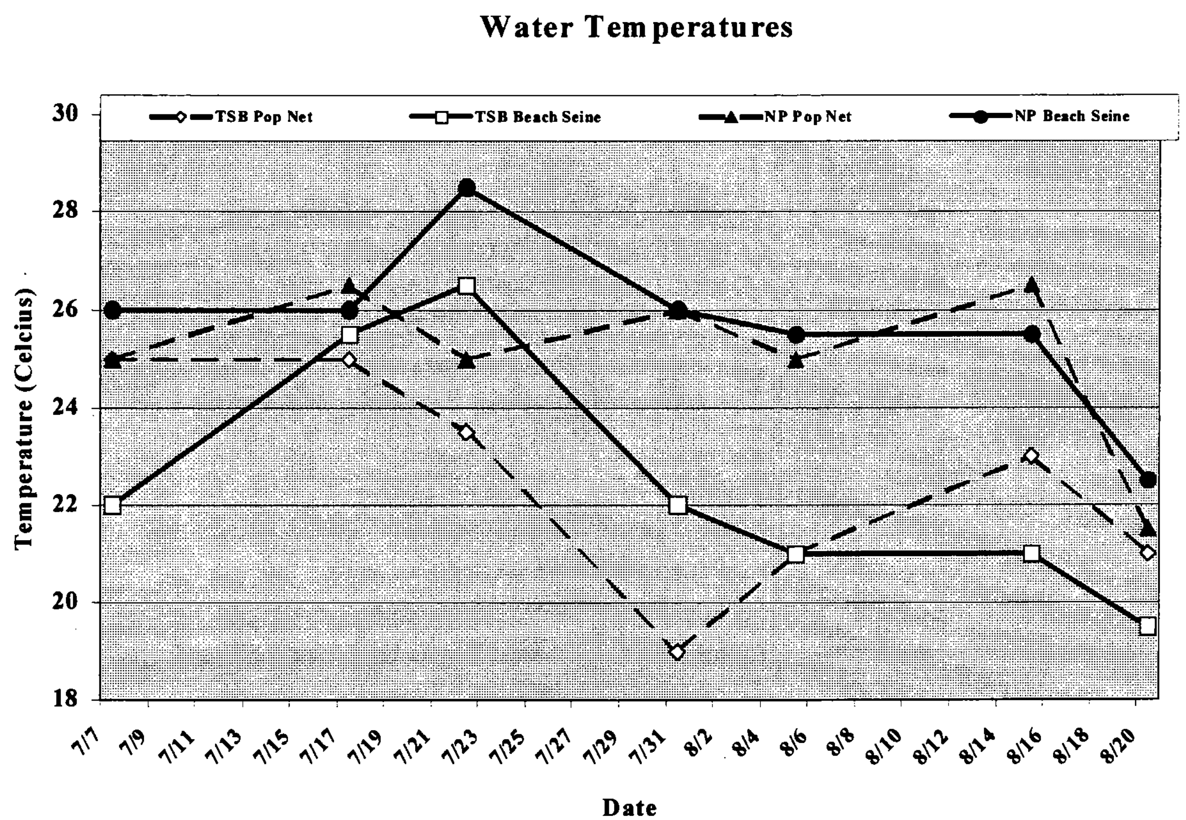

Figure 7: Graph of water temperatures by location and sampling method. A rain squall on 31 July 1997 at TSB lowered the PN temperature by 3° C.

Table 8: Summary of statistical comparison of water temperature during sampling. (NP = Norrie Point, TSB = Tivoli South Bay, PN = pop net, BS = beach seine, SIG = significant, NSD = no significant difference). The *t* values were considered significant at $\alpha_{0.05(6)}$ Δ ±2.447.

Comparison	*t* value	Significance
NP PN v. TSB PN	2.397	NSD
NP PN v. NP BS	-0.693	NSD
TSB PN v. TSB BS	0.000	NSD
NP BS v. TSB BS	2.746	SIG

DISCUSSION

By determining if occlusions and impoundments affect fish communities, this research can be used to determine habitat requirements for maintaining resource species. If railroad beds and bridges truly represent blockages to spawning and nursery areas in the majority of Hudson River tidal wetlands, approaches to restore natural and proper hydrology must be planned and implemented.

Our TSB pop net data are consistent with those of Pelczarski and Schmidt (1991) and Hankin and Schmidt (1992). This implies that this fish community has been relatively stable for the last eight years. TSB has been the site for the majority of Hudson River *T. natans* research. It does not necessarily imply that TSB accurately represents the fish communities in other *T. natans* beds.

Our data at NP show a significant difference in overall communities when compared to TSB (Fig. 6). NP had more adult and larger fish (primarily spawning centrarchids) than TSB in the open water and channel areas, particularly earlier in the sampling period. Total fish density was nearly three times higher in TSB than NP (Table 1).

Our pop net data show that most of the fish found in the *T. natans* beds are juveniles, thus confirming the hypothesis that these areas serve as nurseries. A number of adult banded killifish (*Fundulus d. diaphanus*), fourspine sticklebacks (*Apeltes quadracus*), and a 38 cm American eel (*Anguilla rostrata*) were present at TSB during the first two weeks of sampling (7-17 July). At NP, a single 192 mm redbreast sunfish (*Lepomis auritus*) was found on 15 August; all other fish caught were juveniles. No white suckers (*Catostomus commersoni*) were found in the *T. natans* at either site.

The fish species caught in the seines at TSB were more variable than those at NP were. Spottail shiners were found in four of the seines. All of the other fish species were only found in one or two seines. The NP community seems more consistent; six species were found in at least four seines. The summer data are consistent with my 1996 full year data. All fish, except the Atlantic needlefish (*Strongylura marina*), are commonly seen at NP.

The water temperature data show differences between sites, particularly in the beach seine samples. The open water is more apt to fluctuate in temperature due to water exchanges and mixing. The *T. natans* also causes a "greenhouse effect" by trapping heat energy. NP was consistently warmer than TSB. I believe this is due to the cool influx of water from the Saw Kill. A rain squall occurred on 31 July 1997 at TSB that lowered the water temperature by 3°C in about 6 h. This did not statistically affect the comparison between the pop net samples.

I contend that these differences are partly due to the railroad causeway, but I require more data to reach a definitive conclusion. I recommend that this project be continued at additional occluded and open sites to provide more data for analysis. Understanding the ecology of fresh tidal marshes and vegetated bays will allow for more scientifically-sound management practices.

CONCLUSIONS

Maintenance of coastal environments is a primary goal of a number of programs and agencies. The Hudson River Estuarine Management Action Plan (1996) makes managing aquatic resources the highest priority. Commitments exist to "conduct submerged

habitat inventor[ies] to define nursery areas most in need of protection for Hudson River fishes, blue crab, and food chain species" and to "study the feasibility of restoring Hudson River habitats." I believe that shallow vegetated bays are habitats that are vital to fish species and require management and restoration.

The plan includes provisions for wetland restoration and enhancement as well. "Improving tidal flow" and "removal of exotic nuisance vegetation" are listed as examples. The occlusion of tidal flow in TSB minimizes flushing currents that preclude the heavy growth of *T. natans*. This growth is somewhat controlled at NP by currents from the river, an intermittent stream, and recurrent seining activity. Rozsa (1995) described a number of wetland restorations that involve the return of original tidal regimens to flush sediments and to control emergent vegetation.

Continued community surveying will add to a database that can be used to determine if significant changes to the fish fauna are occurring in the freshwater tidal wetlands and vegetated shallows of the upper Hudson estuary. The most significant changes should be a result of changes to habitat quality. Restoration of historical tidal magnitudes and cycles to occluded areas will slow sedimentation and succession, thus preserving and restoring these disturbed coastal environments that are critical spawning and nursery habitats.

Surveys can also provide information on new exotic or transient species as they enter the Hudson watershed. Collection efforts at NP have discovered the first recorded specimens of two species for the mid-Hudson estuary: (1) bowfin (*Amia calva*) by my predecessor, Mark Warnecke, on 13 April 1988 (Smith & Lake 1990; Lake 1997), and (2) brook silverside (*Labidesthes sicculus*) by Todd Castoe and myself on 4 March 1996 (Lake 1996).

A juvenile walleye (*Stizostedion v. vitreum*) was caught on 29 June 1997 by Todd Castoe and members of the 1997 Norrie Point Summer Scholars Program. These are considered rare species for the mid-Hudson estuary according to Tom Lake (1997; personal communication). These rare occurrences are discovered due to a continuous, long-term sampling effort at NP. Comparable efforts are needed elsewhere to allow documentation of changes in fish fauna communities in the river.

RECOMMENDATIONS

The water at NP was more turbid. This, combined with fewer submerged obstacles, allowed for much better fish catching than TSB. The clearer water at TSB made sampling more difficult. Fish were observed to swim into and then out of the net. Many fish were seen swimming during the seining and were not found in the net. Use of an observed-fish versus caught-fish index, as a qualitative comparison, may be appropriate. Numerous obstacles also frequently hung the net and pulling the seine through SAV caused the net to roll upon itself. Overall, the seine allowed a qualitative look at the open water species.

I recommend the use of a 30-50 m experimental gill net with a number of mesh sizes to attempt to sample nearshore open water in the future (Montgomery & Schmidt 1992; Schmidt & Hamilton 1992). These surveys caught different fish than the seines and pop nets in this research caught (white sucker, *Catostomus commersoni*; white catfish, *Ameiurus catus*; Rudd, *Scardinius erythrophthalmus*; and gizzard shad, *Dorosoma*

cepedianum). I did make one attempt at TSB, but the submerged branches and logs presented significant hazards to the net. There are no gill net data from NP.

Based on differences in community structure between the two sites, I would recommend an additional season of pop netting for further comparisons. The TSB pop net data are consistent with previous work, but more work should be done to determine if either TSB or NP's fish community structure is more representative of a "typical" Hudson River *T. natans* bed. Due to the proximity to NP and TSB, I recommend another season of NP pop netting and additional work at Esopus Meadows (HRM 86-87) (open) and either Vanderburgh Cove (HRM 87) or Roosevelt Cove (HRM 79) (RR enclosed). These additional data should be compared to this work to determine any potential effects of occlusions upon fish communities.

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