DISTRIBUTION, ABUNDANCE, AND REPRODUCTIVE SEASON OF STICKLEBACKS (GASTEROSTEIDAE) IN THE HUDSON RIVER MARSH PRESERVES

A Final Report of the Tibor T. Polgar Fellowship Program

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Kelley, J. and E. Schultz. 2003. Distribution, abundance, and reproductive season of sticklebacks (Gasterosteidae) in the Hudson River marsh preserves. Section V-1 – V-24 *In* J.R. Waldman & W.C. Nieder (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2002. Hudson River Foundation.

1. ABSTRACT

The assemblage composition and distribution of the fishes along the Hudson River estuarine marshes are poorly understood. The objectives of this study were: 1) to identify fish species found within the open water and vegetated habitats of the four Hudson River National Estuarine Research Reserve sites (HRNERR) encompassing a wide salinity gradient; and 2) to determine the breeding cycles of the fourspine (*Apeltes quadracus*) and ninespine (*Pungitius pungitius*) sticklebacks within each marsh. Bi-weekly sampling of the four HRNERR sites (encompassing over 100 miles) of the Hudson River began in late April 2002, ending in August 2002. Collection methods included two-person seine, fyke nets and a throw trap. Few *A. quadracus* and no *P. pungitius* were found. We believe the few four-spine sticklebacks collected are from isolated populations within the Hudson River. Observations in the field led to successful comparative sampling efforts in Connecticut where known populations of both species exist. Additionally, analysis of long-term beach seine data from the Hudson River Estuary Monitoring Program showed a significant decline in fourspine stickleback abundance.

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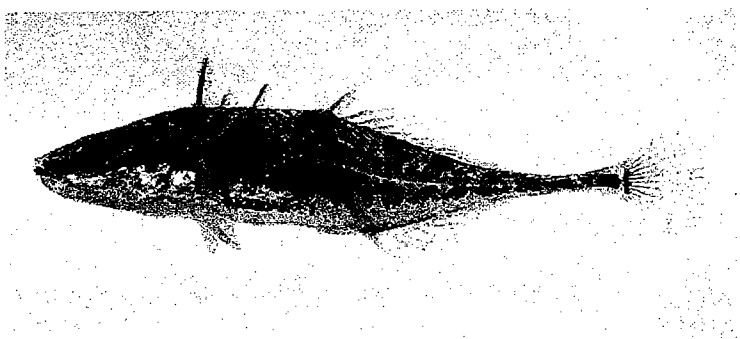
3. INTRODUCTION

Estuaries are physically dynamic and biotically diverse. Nutrient and energy cycles are driven by a combination of tidal inputs of water from the ocean and runoff from the land. Consequent gradients in water chemistry (e.g., salinity, pH, temperature, etc.) and exposure to atmospheric conditions along the estuarine system support a diverse assemblage of flora and fauna. Marsh habitats in estuaries are especially productive, providing food and shelter to many organisms as well as a buffer to pollutants (Adam 1990; Helfman et al. 1997).

Many coastal fishes utilize the marsh habitat of the estuarine environment as a nursery area, which provides a place for rapid growth and refuge from predators. The assemblage composition and distribution of the fishes along the Hudson River estuarine marshes are poorly known. Of particular interest is the ecology of two stickleback species (family Gasterosteidae), the fourspine (*Apeltes quadracus,* Fig. 1) and ninespine (*Pungitius pungitius,* Fig. 2) sticklebacks. Remarkably little published information on the autecology of these species is available.

Figure 1. Fourspine Stickleback (*Apeltes quadracus*)



Size range: up to 6.4 cm
(Picture by Scarola, J.F.)

Figure 2. Ninespine Stickleback (*Pungitius pungitius*)

Size range: up to 9 cm

The fourspine stickleback can be found in the vegetative areas of euryhaline (Bigelow and Schroeder 1953) to freshwater (Rowland 1974) tidal marsh environments along the North Atlantic coast from Virginia to the Gulf of St. Lawrence. The ninespine stickleback is circumpolar in distribution with a range across much of the coastlines in the northern hemisphere (Maksimenkov and Tokranov 1995). Along the North Atlantic coast, it ranges from New Jersey to Newfoundland with an amphidromous population in New York (Smith 1985).

Sticklebacks are nesting brooders. Males construct nests (Wootton 1976) utilizing aquatic vegetation via adhesive type secretions from the kidneys, and defend the nest site vigorously (Worgan and FitzGerald 1981). The male lures a female to the nest to lay eggs. The male then fertilizes, flattens and covers the egg mass with additional vegetation and detritus, repairs the nest and courts another female. The cycle is repeated 4 - 7 times. The male then defends and ventilates the nest until the young leave a few days after hatching (Rowland 1974; Wootton 1976; Wootton 1984).

There are species differences in breeding behavior. Nest site location selection (Courtenay and Keenleyside 1983) and shape (Rowland 1974) differ; the fourspine

stickleback builds a cup-shaped nest predominately at the base of aquatic vegetation whereas the ninespine constructs a barrel shaped nest above the base of aquatic vegetation. It has also been observed, in tidal pools of New Brunswick, that the males of the fourspine will tend multiple nest sites simultaneously (Courtenay 1985). Males ventilate the nest in different ways. The fourspine is the only stickleback known to use opercular pumping action for this purpose (Rowland 1974). The ninespine fans the nest with the pelvic fins. Spawning males of both species exhibit sexual dimorphism through noticeable coloration patterns, the fourspine with bright red pelvics and the ninespine with jet black on the belly and white pelvic fins (Smith 1985).

The reproductive season of sticklebacks in the northeast U.S. is not known. It has been suggested that the fourspine and ninespine breed in early April through May and June based on times when the smallest size classes were collected (Able and Fahay 1998). The reproductive season and behavior for both species has been extensively documented in the St. Lawrence estuaries (Poulin and FitzGerald 1989; Wootton 1976; Wootton 1984; Worgan and FitzGerald 1981).

Sticklebacks migrate into tidal marshes in St. Lawrence estuaries to spawn in early spring (late March or early April) and continue through summer (July), and it has been suggested that the fourspine and ninespine also reproduce in late summer (early August; Poulin and FitzGerald 1989). The timing of reproduction may be influenced by inter- and intraspecific competition for breeding habitat. Evidence collected in tidal pools on the St. Lawrence estuaries has indicated selective or multiple breeding cycles within the reproductive season of both species of sticklebacks (Courtenay and Keenleyside 1983) that may be affecting the variation in distribution. One study

suggested that the ninespine sticklebacks had distinct early and late breeding cycles, possibly to avoid competition with another stickleback (*Gasterosteus aculeatus*; Lachance et al. 1987). Interestingly, Worgan and FitzGerald (1981) showed that ninespine sticklebacks reproduced early where they coexisted with fourspine sticklebacks, and hypothesized that in this case the ninespine was the competitively dominant species.

Two primary objectives of this study were: 1) to identify fish species found within the open water and vegetated habitats of the four HRNERR sites; and 2) to determine the breeding cycles of the fourspine (*A. quadracus*) and ninespine (*P. pungitius*) sticklebacks within each marsh. The four marshes are Piermont, Iona Island, Tivoli Bays, and Stockport Flats and together they constitute the HRNERR system. Information about the reserve program can be found on the web (National Estuarine Research Reserve 2002).

Piermont Marsh is the most southern marsh, situated approximately 23 miles upriver from the Atlantic Ocean, and therefore has the highest salinity (about half that of seawater). It is the largest brackish wetland on the Hudson River with roughly 1,000 acres of salt marsh. Iona Island (45 miles upriver from the ocean) is bordered by slightly brackish tidal marshes. The two bays (Tivoli North and Tivoli South) are located 100 miles upriver from the ocean and are freshwater habitats. Twenty-three miles further upriver, Stockport Flats consists of 1,500 acres of freshwater tidal marshes and dredge spoil islands.

4. METHODS

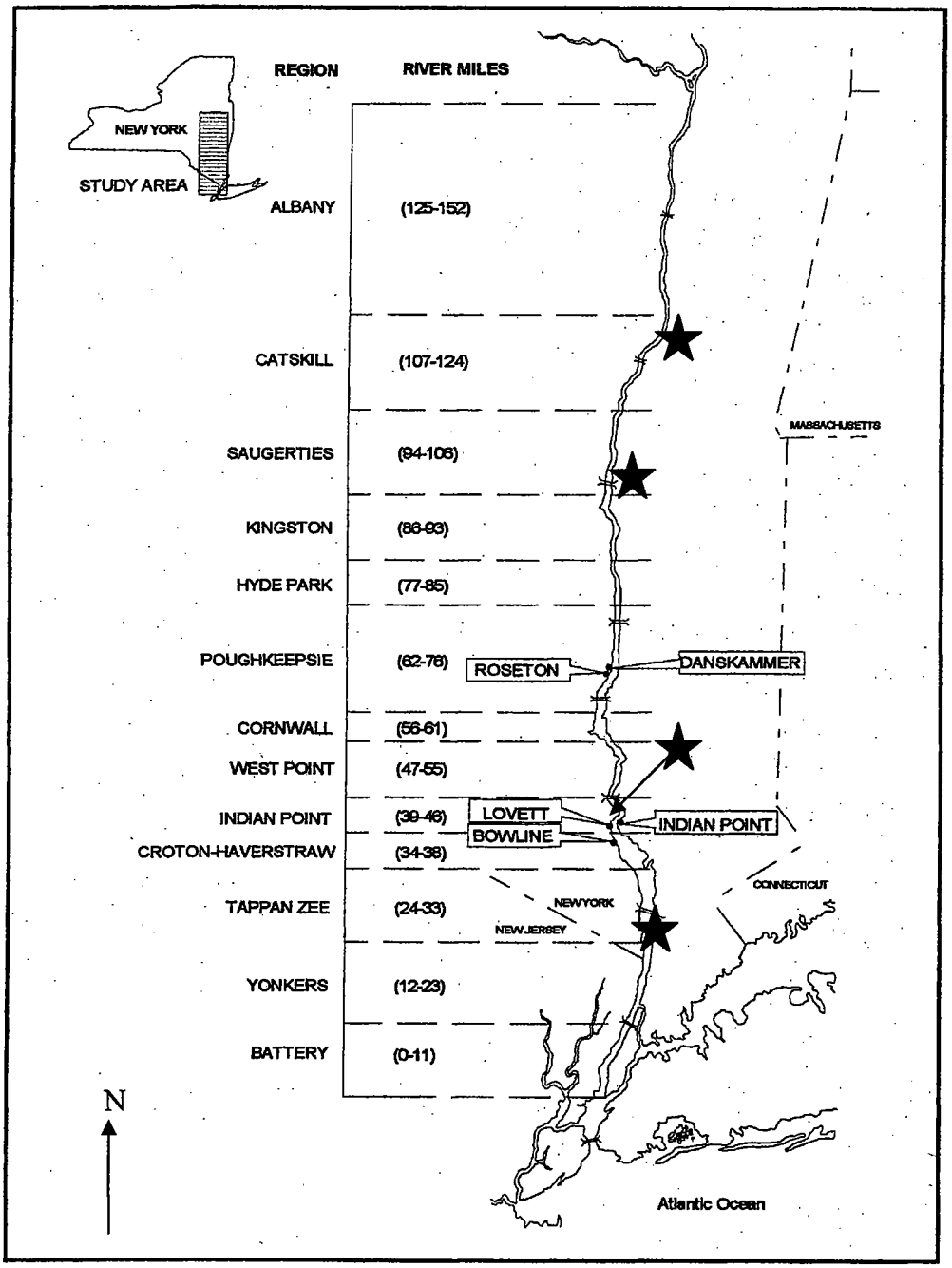
Multiple sites within the HRNERR sites (Fig. 3) marshes were repeatedly sampled on a bi-weekly schedule beginning in late April 2002 and ending in August 2002. All sampling efforts were oriented around the tidal fluctuations (high and low tide) for each site according to the collection method(s) employed.

Three collecting methods were employed to sample the fish assemblage. The first method used a two-person seine (4 m long x 1 m deep with 5 mm mesh). This was principally performed at low tide and when little underwater obstruction was evident that would deter effort. The second method employed fyke nets (1 m hoop x 2 m length with 1 m x 2 m wings off the inlet hoop, all constructed using 5 mm nylon mesh). Each net (two used in a marsh) was set during high tide conditions inside various channels within the marsh. Thus capitalizing on the outward flow of water as the tide receded, the fishes in the water column would move through the mouth of the net trapping fish inside. Collection of fish from the net occurred at low tide conditions. The final method utilized a throw trap (open bottom net approximately 1 m^2 x 1 m deep with 3 mm nylon mesh) for areas of dense vegetation prohibiting adequate seine sampling (Kushlan 1981).

Precipitation during parts of the summer was high and made a few sampling efforts too difficult due to excessive runoff from the watershed. A few of these storm events had also scoured the submerged aquatic vegetation (SAV) from key sample sites.

Figure 3. Map of Hudson River Estuary.

Defined into 13 geographic regions (with river mile boundaries) by the HREMP. Stars show the rough locations of the four HRNERR sites on the river.



All fish collected were counted and identified to genus and species (if possible) and released. When sunfishes (Centrarchidae) were too difficult to identify to species, they were placed together into one category. Measurements of temperature, salinity, and dissolved oxygen were taken at the time of collection. Sticklebacks collected were euthanized and fixed in a 10% formalin mixture for analysis of reproductive status and diet. Other adult specimens were collected as by-catch in another study within Tivoli South Bay (Schmidt 2002).

Due to the low number of collected specimens for analysis, a duplicate sampling effort was performed in Connecticut estuarine systems (e.g., the Neck River in Madison and the Farm River in East Haven, Connecticut) of comparable habitat type (Hagstro 2002). This was done to rule out the possibility that low Hudson River catches were due to inappropriate collecting gear and methods.

Additionally, analysis of the long-term collection of beach seine data (1974-2000) from the Hudson River Estuarine Monitoring Program's (HREMP) Beach Seine Survey was performed. Upon initial review of the HREMPs beach seine survey report, only the presence of a species was indicated (by an X) with more detailed information regarding species of more commercial interest. *Apeltes quadracus* was not among this list but has been indicated as present in the estuarine system since 1974.

5. RESULTS

Piermont Marsh

The fish assemblage in Piermont marsh was low in diversity (Table 1). The mummichog (*Fundulus heteroclitus*) was the dominant species present. The habitat had no SAV present with a substrate of predominately silt/mud. No sticklebacks were found. The appearance of freshwater species followed a significant storm event.

As the seasonal abundance of baitfish species increased, movement patterns of predatory fish became evident. Juvenile striped bass (*Morone saxatilis*) and adult white perch (*Morone americana*) began appearing within the marsh late in June. On site observation of regurgitated stomach content from these fishes confirmed predation on the baitfish.

Table 1. Sample results from Piermont Marsh

Species	Dates (2002) with number of fish sampled.						
Common name	13-Apr	28-Apr	18-May	1-Jun	29-Jun	22-Jul	7-Aug
Mummichog	3	5	15	28	57	394	155
Glass eel		1					
Bluegill Sunfish*			1				
Green Sunfish*					3		
Redear Sunfish*			1				1
American Eel				2			
White Perch					27	4	1
Largemouth Bass*					1		
Striped Bass					7	7	
Menhaden					1		
Porgy					1		
Bay Anchovy						172	
Crappie*							1
Atlantic Silverside							3

* Notes principally freshwater species

Iona Island

Considered slightly brackish, a diverse assemblage of fish was collected (Table 2). The habitat substrate was a mix between silt/mud, sand, gravel/cobble and had an abundance of SAV (principally milfoil). No sticklebacks were found. Dominant species sampled was *F. heteroclitus*. Late summer appearance of juvenile herring species and shad evident followed by predatory species.

Table 2. Sample results from Iona Island

Species	Dates (2002) with number of fish sampled.						
Common name	13-Apr	28-Apr	18-May	1-Jun	29-Jun	22-Jul	7-Aug
Mummichog	6	12	15	108	112	159	65
Creek Chub					1		
Spottail Shiner						47	
Tessellated Darter						3	7
Centrarchidae YOY							5
river herring							21
shad							15
White Perch							1
Striped Bass							2

Tivoli Bays

The dominant species here as in other marshes were *Fundulus* species (*F. heteroclitus* and the banded killifish, *F. diaphanus*, Table 3). We collected one male fourspine stickleback late in the summer and two additional fourspine collected by Schmidt (2002) in another study of Tivoli Bay. Species richness increased as the summer progressed. Increases in baitfish species within the marsh were subsequently followed by migrant predatory species. The substrate varied between silt/mud to gravel/cobble with an abundance of SAV in most areas of the marsh. Water clarity varied with the tide flow due to inlet creeks into both bays of this marsh. As the tides receded, much clearer fresh

water displaced the more turbid river water. Additionally, settling of solids left a thick silt film on SAV that was not easily cleared or displaced.

Table 3. Sample results from Tivoli Bays

Species	Dates (2002) with number of fish sampled.						
Common name	14-Apr	27-Apr	19-May	2-Jun	30-Jun	24-Jul	5-Aug
Banded Killifish	23	19	154			62	10
Mummichog	14	4	63		1	65	1
Spottail Shiner		2					
Tessellated Darter		3	3				10
Largemouth Bass			1				
Glass eel			1				
American eel			1			2	3
American Shad				1			
Golden Shiner				1			
White Perch				5	19	12	
Carp						1	
4-spine Stickleback							1
Green Sunfish			7	1			
Pumpkinseed Sunfish					1		
Bluegill Sunfish			8	1	1		
Centrarchidae YOY						10	16

Stockport Flats

Fundulus was dominant here, as in the other marshes (Table 4). The greatest diversity of species was found within the open shallow water habitats of this marsh. Areas that were primarily silt/mud bottom yielded no sticklebacks during sampling efforts. We collected 13 fourspine sticklebacks (sexual dimorphism evident) along a shallow channel with a sand/gravel in bottom. Heavy SAV was evident throughout this marsh. Unfortunately, a significant storm event early in summer scoured the one location that had to date produced fourspine sticklebacks, removing the bulk of SAV that might have yielded more specimens. Continued sampling at this location produced no sticklebacks during the rest of the summer.

Table 4. Sample results from Stockport Flats

Species	Dates (2002) with number of fish sampled.							
Common name	14-Apr	27-Apr	19-May	2-Jun	30-Jun	7-Jul	23-Jul	6-Aug
Banded Killifish	2	756	214	29	2	148	79	106
Spottail Shiner			8		2	11	19	23
Golden Shiner		3	5				5	
Mummichog		283	26	215		32	57	134
Largemouth Bass			2			3	1	
Smallmouth Bass			1			4	1	
Green Sunfish			5					
Bluegill Sunfish			18			4		
Pumpkinseed Sunfish						2		
Centrarchidae								70
Tessellated Darter			2	2	1	8		6
4-spine Stickleback			4	9				
Longnose Dace			1					
White Sucker			1					
American Eel				1	1	3		
Channel Catfish						1		
Brown Bullhead							1	

Species composition during the final few sampling efforts of all four marsh preserves was dominated by young of the year (YOY) of the sampled assemblage. No ninespine sticklebacks were found in the Hudson River or in Connecticut during the summer of 2002. Moreover, no ninespine have ever been collected in the Beach Seine Survey (2002) since 1974. The Beach Seine Survey is a comprehensive fish collection effort that began in the summer of 1974 and continuing today in an effort to monitor the fishes of the Hudson River.

Sampling Efforts in Connecticut

Seine and throw trap methods were employed successfully in several estuarine systems. Fyke net method was not applicable due to the shallow depth of the sampled river areas. A total of eight sampling efforts was performed and resulted in the collection

of 56 fourspine sticklebacks. Those collected in mid-summer from the Neck River and Hog Brook near Madison, were not readily identifiable to sex due to the lack of any sexual dimorphism display. The next several attempts yielded a few sticklebacks. Upon the final effort on the Farm River, 36 fourspine sticklebacks were collected along 100 feet of the river inside scattered beds of waterweed, *Elodea nuttallii.*

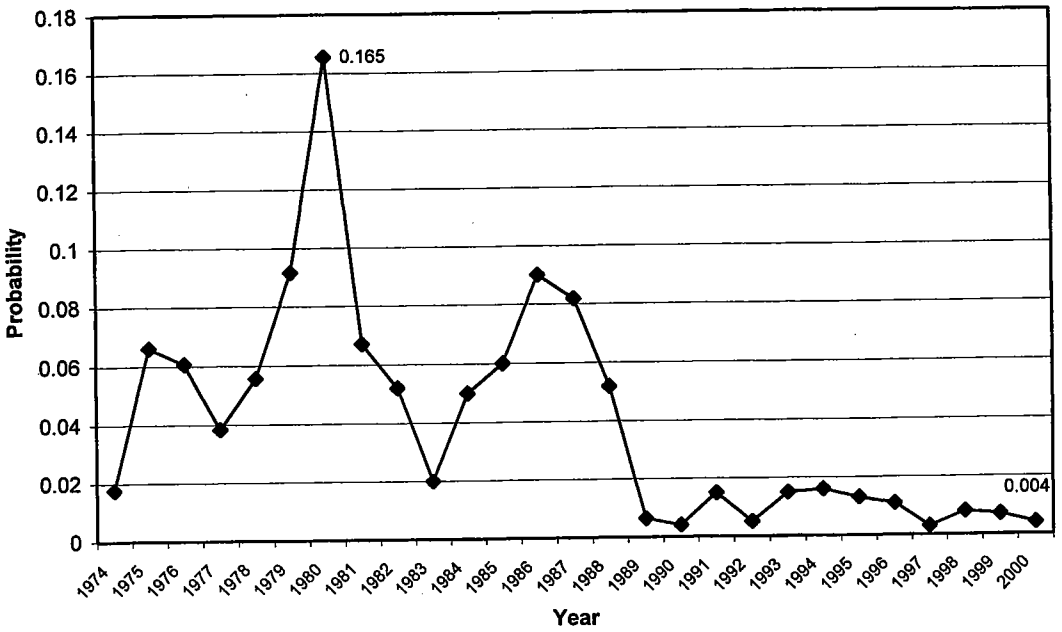
Substrate composition of all locations was a mix between silt/mud and sand with sizable quantities of detritus and SAV. Water clarity was excellent with no suspended or entrained sediments in the water column and no silt film evident on the SAV. Sampling in the Neck River was successful in areas above where the estuary affects the river system (due to man-made dams); below this impediment no sticklebacks were collected.

Beach Seine Survey Results

Careful analyses of the collected data since 1974 to the year 2000 allowed the ability to estimate capture probability (Figure 4). This analysis was accomplished by calculating the capture frequency from the actual collected stickleback specimens among the total sampled fish assemblage along the Hudson.

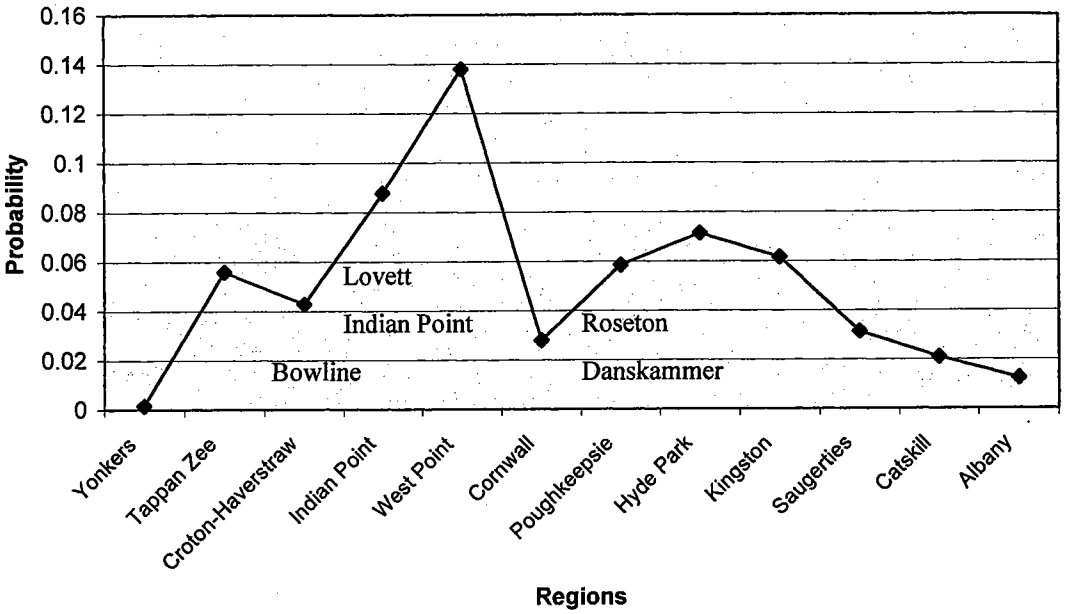
Capture probability varied significantly among years (Chi-Square results: DF = 26, value = 1456.2004, $P < 0.0001$, sample size = 41406). *Apeltes quadracus* has not recovered in the Hudson River since a decline in 1988.

Figure 4. Capture Probability of the *Apeltes quadracus* (1974-2000)



Further analysis was performed to evaluate spatial variability in fourspine stickleback occurrences (Figure 5). The regions of this figure correspond to the geographic regions depicted in Figure 3. Locations were based on frequency of capture per region sampled (total sample 41406 with 2105 fourspine specimens since 1974). Interestingly enough, areas where power plants (listed inside graph) are located along the Hudson River indicated greater probabilities of fourspine capture.

Figure 5. Historical (1974-2000) Probability of *Apeltes quadracus* locations by regions on the Hudson River



6. DISCUSSION

The distribution and abundance of fish species within an estuarine system is a good indicator of ecosystem health. Declining diversity can be a warning of detrimental change. It is not clear whether these recent changes in fourspine (*A. quadracus*) stickleback abundances are a result of adverse environmental conditions or some natural process.

Estuarine ecosystems are transient systems over time, thus, changes in species richness and diversity will occur. Seasonal migration patterns of some species and long-term dispersal of non-migrating fish species will have an effect upon the resident fish populations. This effect will primarily be an increase in competition of natural resources (i.e., food and habitat). Additional pressures in competition for habitat and resource allocation resulting from invasive species of plants and animals (e.g., the water chestnut, *Trapa natans* and the zebra mussel, *Dreissena polymorpha*) can further lower survival chances.

Over the last 30 years since the beginning of the HREMP sampling effort, noticeable changes in the diversity of fishes are occurring. Though species richness is roughly constant, the diversity of freshwater species is declining while the marine species index is increasing (Dey 2002). Potentially, one of the victims of this change is the fourspine stickleback and according to our analysis, their continued presence is in question.

7. CONCLUSIONS

The collected samples of fourspine sticklebacks are believed to be from isolated freshwater populations within the Hudson River estuarine system. With only 16 specimens and roughly half that female, though gravid with mature eggs, defining the reproductive season would be approximate at best. Based on the observed mature egg state of the few collected females it is known that reproduction does occur in late spring (May/June) on the Hudson River for the fourspine stickleback (*A. quadracus*).

Of the collected female fourspine sticklebacks from the Farm River, CT, no evidence of a bimodal reproductive season was evident. All had immature eggs and were in a resting phase even though sexual dimorphism again became apparent in the males (lacking in mid-summer in other CT sample sites). Unfortunately, no ninespine sticklebacks were collected.

Regarding the other fish species sampled early in the sampling effort, as expected most were adult reproducing specimens. Estuarine marshes are habitats utilized for food, shelter and nurseries for the next generation of fishes. The patterns of species appearance within and among the different marshes followed the basic tenets of reproduction and predation upon the fish assemblage. Most notably was the early summer (June) appearance of schools of predatory fish (e.g., the white perch) and the subsequent drop in baitfish species abundance within each marsh.