SIGNIFICANCE OF SMALL IMPOUNDMENTS TO AMERICAN EEL (*ANGUILLA ROSTRATA*)

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

This project was designed to assess the populations of American eel (*Anguilla rostrata*) inhabiting two impoundments on the Saw Kill, a small Hudson River tributary entering the river at Annandale, New York. A great deal of work has been done regarding eel populations in Hudson River tributaries, including the Saw Kill; however, the body of this work centered around wadeable creek areas. Since these impoundments represent significantly different habitat from the flowing parts of the creek, we believed that American eel would make different use of them as well. We captured 45 American eel in the impoundments and the plunge pools below the dams using baited traps. No eels at all were caught in the larger impoundment, despite additional sampling effort. Our data clearly demonstrated that the population densities of American eel were very similar below both dams and consistently higher than in either impoundment. This leads us to believe that impounded areas are less desirable habitat for American eel and that at least one of the impoundments provides a resting area for eels moving upstream rather than a permanent habitat for resident eels.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

American eel is a long lived, catadromous North American fish ranging from Labrador south to the West Indies (Werner 2004). They are of commercial importance in many parts of their range and a historically important fishery existed for them in the Hudson River prior to the closing of the eel commercial fishery in 1982 (Anonymous 1999). However, some harvest continues for recreation, subsistence, and for bait (Anonymous 1999). This species has been in decline, with recruitment failure noticed in several watersheds (Haro et al. 2000). Despite minimal fishing pressure, declines in recruitment may be occurring in the Hudson River (Schmidt, unpublished data).

There are two habitats important to American eel in the Hudson River, the tidal estuary and the upland tributaries. Morrison and Secor (2003) documented the biology of American eel in the tidal estuary and several studies have shown that tributaries can harbor very large populations of American eel (Petersson and Schmidt 2004; L. Machut, SUNY ESF, *pers. comm.*). The Saw Kill, a small Hudson River tributary, was shown to have densities of at least 13,000 eels/ha in the mouth of the creek (Petersson and Schmidt 2004). Most of the tributaries to the Hudson River have barriers to upstream movement of eels (Schmidt and Cooper 1996), about half of which are anthropogenic.

American eel do ascend barriers, but recent data from a project funded by the Hudson River Foundation show that barriers do reduce the density of eels by about an order of magnitude (L. Machut, *pers. comm.*). These densities were measured in flowing rocky stream habitat but stream segments often had an impoundment between them and impoundments were not wadeable and, therefore, were not sampled in that study.

American eel may well inhabit these small impoundments. If eels are present in high densities, that fact would require that we reassess the role of dams in eel migrations and our current understanding of preferred eel habitat. Our goal was to thoroughly sample impoundments on one otherwise well studied tributary, the Saw Kill, to better gain an understanding of American eel usage of these habitats. We were most interested in obtaining population estimates for two of these impounded areas and comparing them to those of the contiguous stream habitat. We hypothesized that, although American eel do probably inhabit these areas in limited numbers, that this is not their preferred habitat and their population densities will be significantly lower than in the rocky, flowing part of the creek.

METHODS

Study Area

This study was conducted on the Saw Kill (Dutchess County), a small (6800 ha) Hudson River tributary that enters the estuary in Annandale, New York. We chose this tributary because it is easy to access and we have considerable information on the fishes (Schmidt 1991, L. Machut unpublished data), macroinvertebrates (Budd and Strayer 1997), and water quality (W. Nieder, unpublished data) of this tributary.

We chose to concentrate on two impoundments (Fig. 1); a small one (0.4 ha) on the Bard College/Montgomery Place property and a larger one (2.91 ha) extending from Annandale Road east to beyond the Rt. 9G bridge (Fig. 1). These impoundments are

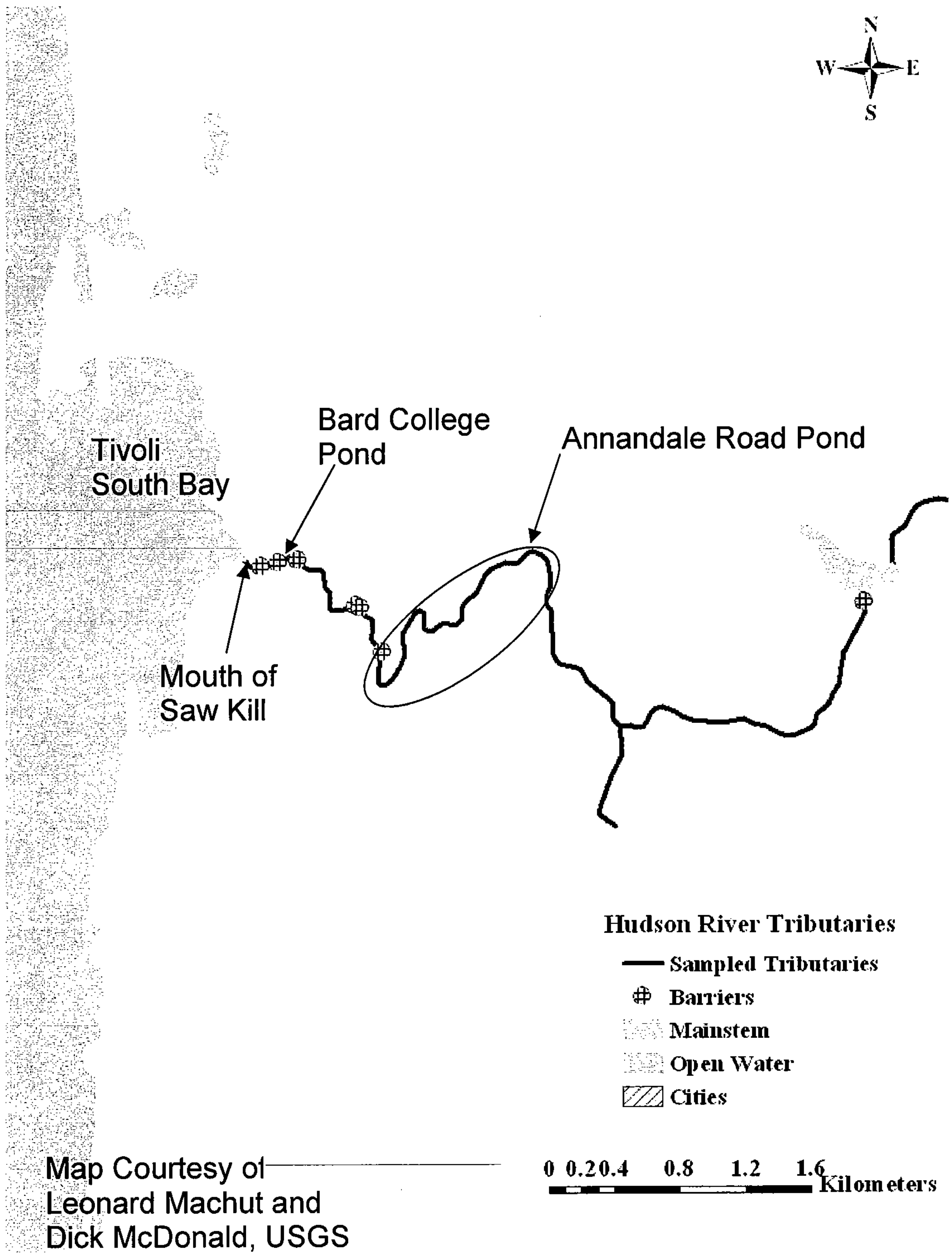

Figure 1: Map of Saw Kill showing barriers and study sites. The plunge pools sampled were directly below the dam at each pond. Bard College pond is between the second barrier (a dam) and the third barrier (a natural waterfall)

formed by dams and are the second and fourth barriers on the Saw Kill, respectively. The first and third barriers are natural waterfalls.

Field Methods

Eels were collected in 1-m long double-funnel eel pots with 13 mm square mesh. This size trap captures and holds eels >30 cm total length (Morrison and Secor 2003, Petersson and Schmidt 2004). After the first week of sampling, turtle exclusion devices were installed on the opening of the pots using 2.5 cm square chicken wire with meshes cut so that large eels could still fit through while preventing the entry of even small turtles.

We also deployed several different types of small mesh traps in an effort to retain eels <30 cm TL. Most of them were made using window screen.

Large traps were baited using canned cat food, with the cans punctured to release scent. Small traps were set using several different baits, including frozen herring and frozen shrimp. Four large traps were deployed at the Annandale Road site between 20-25 May 2005, and five large traps between 28 June-15 August, for a total of 260 trap nights. Four traps were deployed at the Bard College site from 28 June-1 August, and three traps from 4-15 August 2005, for a total of 178 trap nights. In addition to the traps in each of the impoundments, one trap was set in the plunge pool of the dam at each site for 37 trap nights at the Annandale Road site and for 39 trap nights at the Bard College site. Traps were also set at the mouth of the Saw Kill (within the tidal influence) for a total of 70 trap nights. Traps were checked twice weekly, all fish were identified and measured, and the traps were rebaited.

In addition to eel traps at the Annandale Road site, the pond was also sampled using a Coffelt backpack electroshocker in several shallow sections of the pond. Areas with varying flow and substrate characteristics were sampled by this method. Qualitative night snorkeling in the plunge pools below both dams was done to determine if there were significant numbers of eels too small to be retained in the commercial traps inhabiting these pools.

All fish collected by trap were identified and total length (TL) was measured. Eels were anaesthetized with clove oil (Petersson and Schmidt 2004), measured, fin-clipped, and released.

Lab Methods

Population size was estimated by the Schnabel multiple-capture method. This method worked well for Petersson and Schmidt (2004), giving about the same estimate and density in the lower Saw Kill as a removal method (L. Machut, unpublished data- Fig. 1). Densities were calculated based on map measurements of pond area taken using the program ArcView 3.2a. Areas for plunge pools were calculated by direct field measurement. Size frequency and population sizes were compared to similar data from the Saw Kill (L. Machut, unpublished data) collected in contiguous stream sections.

RESULTS

Many of the traps we designed to catch small eels were destroyed, probably by turtles. No eels were taken in small mesh traps.

A total of 45 American eel was taken in the two ponds and the plunge pools, including recaptured individuals. No eels were taken in the Annandale Road pond despite 260 trap-nights of effort (Table 1). Catch per unit effort (CPUE) in the two plunge pools were the same in both places (0.45 eels/trap-night) and an order of magnitude higher than CPUE in the Bard pond (Table 1). These data alone suggest that the American eel populations in the two ponds are considerably smaller than the populations just below the dams. The CPUE in the plunge pools was very similar to catches in tidal Tivoli South Bay (0.4 eels/trap-night, Petersson and Schmidt 2004). CPUE in the mouth of the Saw Kill was 0.21 eels/trap-night.

The average total length of all eels caught was 56.2 cm. The largest eel caught was 79 cm TL, caught in the pool below the Annandale dam, and the smallest eel was 36 cm TL caught in the Bard pond (Fig. 2).

Our lowest recapture rate was in the Bard pond (20%); however, we also caught many fewer eels at this location (Table 2). Our highest number of recaptures was in the Bard plunge pool where 18 eels were caught and 10 were recaptures (56%). Likewise, in the Annandale plunge pool, 17 eels were caught and 7 were recaptures (41% - Table 2).

Schnabel mark and recapture population estimates indicate that the highest populations observed between the two pond sites were in Bard pond where we estimated that 13.7 eels inhabited the area. Given the area of the pond, density was 32.5 eels/ ha with a standard deviation of 0.175, much lower than populations inhabiting either plunge pool (Annandale = 437.9 eels/ha with a standard deviation of 0.048; Bard = 324.9 eels/ha with a standard deviation of 0.055). We could not estimate the population for the mouth

Table 1. Catch per unit effort (American eel/trap-night) in baited eel pots from two ponds and pools below two dams in the Saw Kill, Hudson River, New York.

	Ponds		Below Dams	
	Annandale Rd.	Bard Campus	Annandale Rd.	Bard Campus
Total Caught	0	10	17	18
Effort	260	182	38	40
CPUE	0	0.06	0.45	0.45

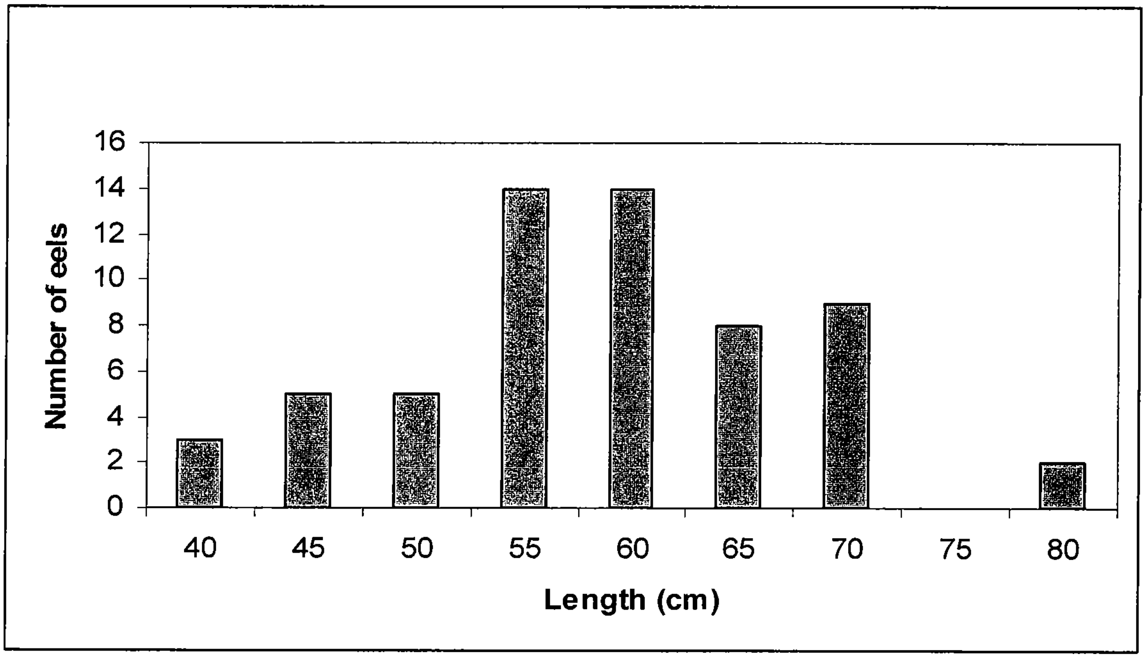

Figure 2. Length frequency distribution of American eel captured in baited traps from the Saw Kill, Hudson River, New York, in summer 2005.

Table 2. Numbers, Schnabel population estimates and 95% confidence intervals (CI), densities, and sizes (cm) of American eel caught in baited pots in the Saw Kill, Hudson River, New York.

	Ponds		Below Dams		
	Annandale Rd.	Bard Campus	Annandale Rd.	Bard Campus	Mouth of Saw Kill
Number Caught	0	10	17	18	14
Recaptures	0	2	7	10	1
% recapture	0	20	41	56	7
Population size	--	13.7	12.7	10.7	--
95% CI	--	5.1-25	6.7-85	6.3-36	--
Area (ha)	2.91	0.4	0.029	0.033	--
Density (eels/ha)	--	32.5	437.9	324.9	13,000*
Average TL	--	50.12	59.7	54.9	51.38
Range TL	--	36-67.8	41.8-79	36-62	39.5-64

*Petersson and Schmidt (2004) estimate

of the Saw Kill; however, Petersson and Schmidt (2004) estimated a density of 13,000 eels/ha (Table 2).

The densities we calculated compare well to the densities reported for the Saw Kill by Machut (unpublished data). His estimates were made in the rocky riffle sections of the Saw Kill by a sequential removal method, calculated parametrically and with a Baysian estimate (Table 3).

In addition to American eel we caught 152 other fishes (10 species) in the baited trap (Table 4). The bycatch was dominated by centrarchids, as may be expected in ponded habitats. We did collect a yellow bullhead (*Ameiurus natalis*) in the Annandale Pond, the first record of this species from the Saw Kill (Schmidt 1991). Yellow bullhead appear to be expanding their range in the Hudson Valley (Schmidt, unpublished data). We did not collect the exotic warmouth (*Lepomis gulosus*) in this study, despite its documented presence in both ponds and the lower Saw Kill (Schmidt 1991, Smith 1985, Schmidt unpublished data).

On July 26, 2005, we shocked four areas in Annandale Pond. This effort was made to determine if eels were in fact present but were not being sampled by the baited traps. We sampled in vicinity of the easternmost two traps and made an effort to shock around rocks, logs, and vegetation as well as in silty substrates. Because the pond was relatively deep, we were confined to the shoreline at three sites, but we were able to shock a rocky habitat under the Rt. 9G bridge (location of easternmost trap) from shore to shore. We shocked from 18-30 m of shoreline at three sites (average 23.4 m) and 66.3 m^2 under the Rt. 9G bridge. We saw no eels in any of the areas shocked. We observed cutlip minnow (*Exoglossum maxillingua*), white sucker (*Catostomus commersonii*), redfin pickerel (*Esox americanus*), rock bass (*Ambloplites rupestris*), and tessellated darter (*Etheostoma olmstedi*); tessellated darters being the most abundant species.

On 23 August 2005, the plunge pools were examined qualitatively by snorkeling at night. Each pool was thoroughly explored and several eels were observed. The only

Table 3. Comparison of American eel density (eels/ha) in the Saw Kill between Machut's 2003 unpublished data and our estimates. Data are presented starting at the nontidal mouth of the Saw Kill and moving upstream.

Location	This Study	Study by Machut
Between head of tide and waterfall		14,200-16,900
Above waterfall, below Bard dam	324.9	1,000-1,200
Bard pond	32.5	
Above Bard pond, below Annandale Pd.	437.9	170-554
Annandale pond	0	
Above Annandale pond		62-129

Table 4. List of the bycatch in baited eel traps in the Saw Kill, Annandale, New York.

	Ponds		Below Dams		
	Annandale Rd.	Bard Campus	Annandale Rd.	Bard Campus	Mouth of Saw Kill
White sucker	6			1	1
Cutlip minnow			1		
Brown bullhead		1			
Yellow bullhead	4				
Redfin pickerel	3				
White perch					1
Rock bass	37	7	29		5
Redbreast sunfish		17			
Pumpkinseed	12	2	2		
Bluegill	19	1	1		

small eels that were observed in this session were one of approximately 35 cm and another much smaller eel, approximately 10 cm. The latter was slender and had little pigmentation. Both of these individuals were observed in the plunge pool at the Bard College site. Only these two small eels were seen, despite flipping over rocks and manually sifting through detritus specifically looking for elvers. Several larger eels (undoubtedly large enough to be caught in our traps), were also observed in the plunge pools at both sites. In addition to eels, brown trout, white sucker, and tessellated darter were observed at both sites and largemouth bass were observed at the Annandale site. The Annandale plunge pool was considerably deeper (about 2 m) than the Bard plunge pool which did not exceed 1 m in depth.

DISCUSSION

Our data show that the population of eels was significantly lower in the ponds we sampled than in the plunge pools below the dams, contiguous rocky riffles sampled in a previous study, and orders of magnitude lower than in the mouth of the creek. This leads us to conclude that the impoundments on this creek represent significantly less suitable habitat than that of the unimpounded stream. The stream had faster flowing water, harder substrates, and more benthic complexity than either of the ponds. Although the ponds differed from each other in terms of habitat characteristics, they were both dramatically different from the stream. It is important to note that crayfish, a main prey item for eel in the Saw Kill (Machut, unpublished data) were caught in abundance in both ponds. This leads us to believe that habitat differences and not shortage of food causes these areas to be less utilized by eels. Summaries of American eel biology (e.g., Helfman et al. 1987) emphasize that eels inhabit a wide variety of habitats, including ponds and impoundments. It is likely that, although the ponds we surveyed are habitable for eels, they are not optimum habitat and so are not sought when there is other stream habitat available.

Despite a much larger area than Bard pond, Annandale pond yielded no eels while ten were caught in Bard pond. This could be due to several factors that differ between these two ponds. Bard pond was on average shallower than Annandale pond, but containing a few deep pools. Annandale pond had a channel that was frequently greater than 2 m deep and also had much more submerged aquatic vegetation (SAV) and algae. There were parts of this pond that were so thick with SAV that effective angling was not possible. Bard pond also had a gravelly bottom while Annandale pond was on average much siltier. However, there were areas of Annandale pond that contained a rocky bottom and were similar to a stream in all respects except that flow was slower. These areas were concentrated near the route 9G bridge and were heavily electrofished. Silty areas of the pond were also electrofished and often the sediments were in excess of 30 cm deep and were very soft. Eels were not caught in any of these areas by any method. It is also possible that since Bard pond is further downstream than Annandale pond, and, therefore, adjacent to a stream with higher populations of eels in the first place, that a larger immediate source of eels is available for colonization of the pond and would, in theory, provide more incentive for pond habitation than in areas adjoining parts of the stream with lower eel densities. Since there are higher densities below Bard pond, it may be more attractive for eels to go there than Annandale pond, where stream populations in the immediate vicinity may be lower. We did find a higher population of eels using the

Annandale plunge pool compared to that of the Bard plunge pool; however, this plunge pool was significantly deeper than that of the Bard pond and seemed to provide better habitat for large eels in general. It is also possible that since Bard pond was smaller and therefore, was fished more efficiently, that catch rates were higher. However because eels were attracted to the traps by odor that could draw them from a theoretically large area, this is less likely to be a cause for higher catch rates than other ideas previously suggested.

Bard pond data seemed to suggest that eels were passing through the pond more than using it as a permanent habitat. We are concluding this based upon the fact that eels were caught relatively frequently through the summer, but not at all after late July. This could be explained by eels becoming trap-wise, however, this is highly unlikely since catches remained consistent in the plunge pools and in the mouth of the creek. Also there were fewer instances of recaptures in Bard pond than in the plunge pools, indicating that, although eels were present, perhaps they did not stick around to be recaptured often. Also, according to our population estimates, this pond maintained a very low density of eels despite a large concentration of crayfish, small fish and other prey items. These factors combined have led us to believe that Bard pond serves a resting area for eels making their way further upstream and does not maintain a significant resident eel population.

One issue that remains to be addressed is that of small eels not yet recruited to the size our commercial eel traps are able to target. We had no success in developing a functional trap for small eels. Several designs were tested and all of them proved to be unsuccessful and were destroyed quickly by turtles. Feeding habits of small eels could have made them more difficult to trap. Aquatic insects presumably provide a large portion of their diet and although several baits were tried, it is possible that they were just not attractive to small eels. We did target small eels both by electrofishing in Annandale pond and qualitative snorkeling in the plunge pools and none were found. Effort was made to electrofish in silty areas where small eels could have buried in the sediment and in cobble-strewn areas were they could have hidden between and under rocks and none were observed. On the snorkeling trip, several efforts were made to poke through detritus and overturn rocks where small eels could have hidden and only one very small eel and another slightly larger eel were observed. Both of these were seen in the open, in shallow water under the Bard plunge pool and did not seem to make any attempts at hiding so that it is not likely that we missed most of them rather than that they were not present in large numbers. There is a habitat segregation by size, with larger eels inhabiting deeper water. Small eels may avoid these deeper areas because of potential predation by larger eels.

The fact that the impoundments studied were created by dams that modified former stream habitat has several implications for upstream passage of eels. Even though American eel ascend barriers, it is likely a significant energy drain to do so. Our data indicate that one of the impoundments surveyed provided a resting area for migrating eels. Thus it could be important that the area immediately behind these dams is impounded. However, impoundments also remove possible and historically available prime stream habitat. Our data also strongly suggest that ponds provide less suitable eel habitat. The fact that impoundments have been created in these areas where the creek has been dammed is important to the overall availability of prime habitat. Also, since dams are only ascended by some eels, only a small fraction of the population actually passes these obstructions, and suitable upstream habitat is effectively eliminated to the portion of the population that is unable to bypass the dams. A project to develop eel ladders is currently in consideration for these dams since such a project is relatively cheap and potentially very fruitful in terms of increasing the amount of habitat then available to American eel in the Saw Kill.

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Development of an Upper Hudson River Estuary

GIS-Based Fish Data Resource

A Final Report to the Tibor T. Polgar Fellowship Program

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