# USE OF A PERIODICALLY ANOXIC *TRAPA NATANS* BED BY FISHES IN THE HUDSON RIVER

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## ABSTRACT

*Trapa natans* is an exotic plant that competes with *Vallisneria americana* for habitat along the Hudson River. Previous research demonstrates that one of the differences that have taken place occurred in the associated fish community. In addition, recent research by Nina Caraco has shown that tidal beds of *T. natans* may reach lethal levels of dissolved oxygen at low tide, possibly forcing resident fish into open water. Behavior of local fishermen lends merit to this hypothesis, since it is common knowledge that it is productive to fish the edge of *T. natans* on an ebb tide where, presumably, large predators are utilizing this phenomenon.

We set out to test this hypothesis by setting up a fish weir within the *T. natans* bed of Inbocht Bay, Catskill, NY (RM 109.5). By sampling every hour of the ebb tide we were able to demonstrate the movement of fish out of the bed. Movement of the fishes was not related to low dissolved oxygen levels, but, rather, was uniform throughout the ebbing tide. We did demonstrate that the fish community of Inbocht Bay is different than the other *T. natans* communities that have been studied. It also appears, surprisingly, that the *T. natans* bed at Inbocht Bay is dominated by young of year (YOY) anadromous fishes, mostly blueback herring. These fishes were feeding heavily on epiphytic invertebrates on *T. natans*.

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## INTRODUCTION

*Trapa natans* is an exotic aquatic plant, which since its introduction in the 1860s, has invaded much of the shoreline of the Hudson River (Gilchrest and Schmidt 1998). Prevented from moving south of Iona Marsh due to the increased salinity of the river (Schmidt and Kiviat 1988), its range is otherwise not constrained except by high water velocities and water depth. Due to its considerable reproductive capabilities combined with an abundance of appropriate habitat, it has managed to cover a great deal of what was once native submerged aquatic vegetation (SAV) community habitat. The primary species that it appears to have replaced is *Vallisneria americana*, resulting in a fundamentally different community.

A distinct difference between the two communities is the presence of sub-surface oxygen producing structures in *V. americana* beds, whereas *T. natans* is primarily producing oxygen on the surface, thus not contributing to oxygen production within the water column. Also, *T. natans* produces very dense surface mats, preventing the penetration of light and reducing or eliminating the presence of sub-surface autotrophs. One possible result of this change in habitat structure is an associated change in the fish community. Several researchers have addressed this issue and have demonstrated that there are, in fact, differences between *V. americana* and *T. natans* fish communities (Gilchrest and Schmidt 1998; Hankin and Schmidt 1992; Pelczarski and Schmidt 1991). Their work has also demonstrated that there are differences among *T. natans* communities, which we address here as well.

It has been known locally for sometime that an outgoing tide is a good time to fish the edges of *T. natans* beds for largemouth bass. *T. natans* may provide excellent cover for smaller fish due to its thick growth, which might prevent larger fish from entering and which provides protection from birds. In addition, Nina Caraco (unpublished data) has been looking at various environmental factors within *T. natans* beds and, in 1999, recorded lethal dissolved oxygen (DO) levels within tidal *T. natans* beds at low tide. The question was then raised whether low DO levels were forcing fish out of *T. natans* beds, possibly explaining the presence of predators on the edges of the beds during ebb tide.

Originally the *T. natans* bed at Esopus Meadows was selected for this study. However, due to problems with the Esopus site, a new site was picked at Inbocht Bay. The point of this project was to address two main questions. First, are fish being forced out of the bed by declining levels of dissolved oxygen and second, what is the fish community within the Inbocht Bay *T. natans* bed. The specific question of the presence of predatory fish utilizing the edges of the *T. natans* bed was not investigated other than by casual observations of sport fishing behavior at the site.

## METHODS

Selection of Esopus Meadows was based on the previous year's extensive bed of *T. natans* combined with oxygen data recorded from Esopus Meadows in 1999. We first inspected Esopus on July 7$^{th}$ expecting to find an extensive *T. natans* bed. It turned out to be quite thin for reasons unknown, although we speculated that high spring flow or disease were possible explanations. We decided to change locations to Inbocht Bay, which we also had data for and where there was an extensive *T. natans* bed. As it turned out, Inbocht Bay was an ideal location, being protected from the wind and the Hudson's current; from the north and west sides by surrounding land, from the south by a jetty, and partially protected from the east by an island (Figure 1). In 1995 the *T. natans* bed within Inbocht Bay covered 100 ha, based on aerial photos (Nieder, pers. comm.). Caraco took additional aerials during this project and the bed appears to have increased by about 20%. The bed actually extends further north beyond the bay for an additional 3,000 m but we do not include that portion of the bed in our discussion. We chose one of the small channels cutting into the bed northwest of the island to set up our sampling station. The purpose of utilizing the channel was to reduce the possibility of picking up fish that may have wandered into the *T. natans* from the main river versus those fish that routinely inhabit the weeds for food or protection on a prolonged basis. The channel extended approximately 50 m into the bed and tapered from 15-m wide, at the opening, down to 3-m wide where the box trap was placed.

The sampling method consisted of a weir type netting system where fishes within the *T. natans* were funneled into a removable box trap (Figure 2). All netting was ¼-inch mesh, weighted on the bottom with floats on the surface. Each wing was 50-ft long by 6-ft deep and double leaded and extended into the *T. natans* from the box trap at about a 45° angle. Once on site we anchored the boat a few feet from the edge of the *T. natans* and slipped into wets suits used to conserve our energy but also to protect us from the *T. natans* nuts. Before or during peak high tide, 1-inch diameter slotted pvc pipe anchor posts were driven into the sediment. The ends of the wings, which were attached to ½-inch diameter pvc pipe with duct tape, were slid into the anchor posts (Figure 2). The wings were dragged through the plants until taut, with the ends left unanchored but well tangled within the *T. natans*. Once set, the wings were cleared of any obstructions such as logs and *T. natans* and we carefully checked to be sure the lead line was on the bottom. When the tide began to ebb, the box trap was slipped into the slotted anchor posts in the same manner as the wings. The box trap itself was 4-ft wide by 6-ft tall and 6-ft deep ¼-inch mesh, with two vertical wings extending into the center of the trap creating a slotted

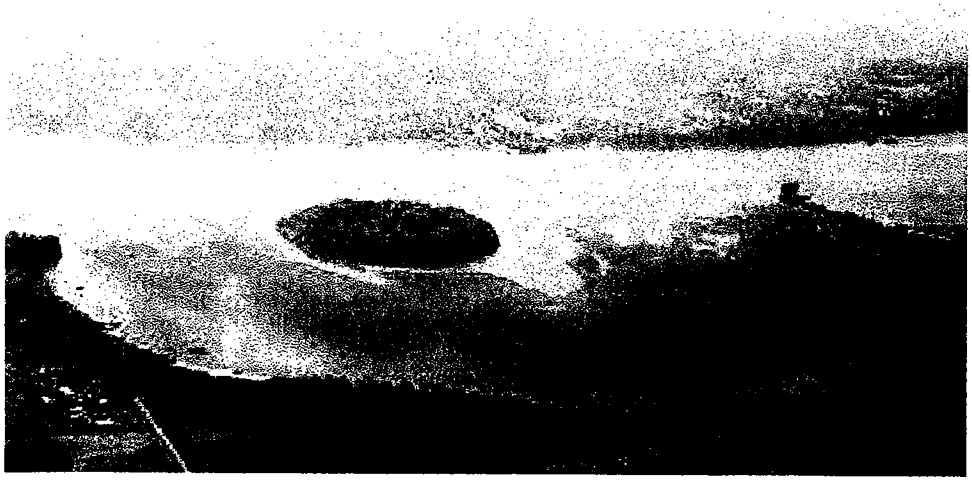

Figure 1. Inbocht Bay, Hudson River, NY, August 2000. This aerial is looking southeast across the river. The sample site is northwest of the island at the end of the shallow channel. The cement jetty is located at the far right. (Photo courtesy Nina Caraco).

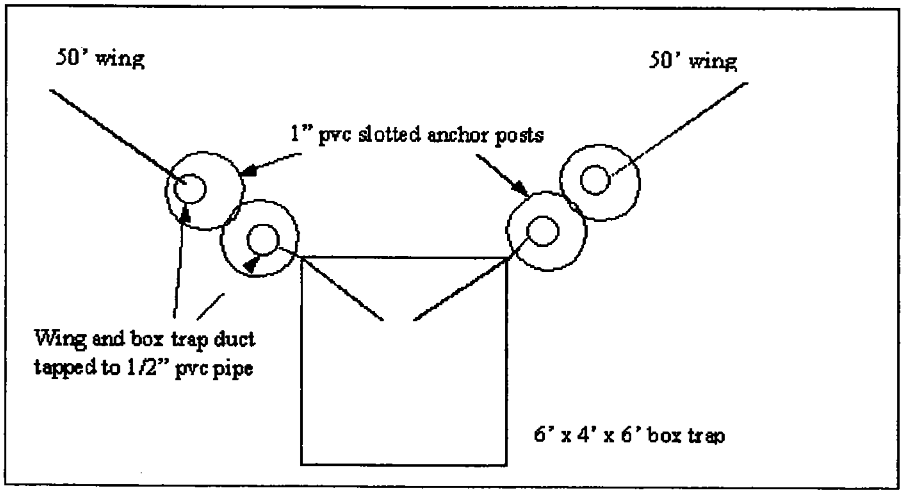


Figure 2. Diagram of the weir from above. The anchor posts were set right on the edge of the *T. natans* with the wings extending into the bed.

opening from top to bottom. This vertical slot was 15-cm wide, keeping fish in the box once entering but also allowing fish to enter at all tide levels. To collect fish from the box trap we stepped over the wings a few feet away from the box trap and approached the trap on its open side. We then quickly slipped the trap up until the bottom was just out of the water. Fish were removed from the box trap using a dip net and placed in a bucket for transport to the boat. As soon as the trap was empty we slipped it back down, the entire process taking less than 10 minutes.

While initially two hours were allowed to pass before pulling the box trap, after the first sampling day the routine was switched to pulling it every hour. Due to concerns about getting stranded on the mud flats the first three samples were only taken 4 hours into low tide. On the fourth sampling day we were caught in a thunderstorm and had to leave the site after the fourth hour. On the fifth sampling day we kept the boat at the site through the fourth hour, as we had done on previous sampling days, then pulled anchor and walked the boat over 1,500 ft around the island and anchored it on the edge of the open river. We then had to walk back and forth from the boat to the nets, carrying gear and fish. Once back on the boat the fish were identified and measured if they were to be released, or preserved in 10% formalin. Generally the larger fish were measured and released. We kept records for each pull of the box trap recorded at the hour the net was lifted. Once back in the lab the original identifications were confirmed, lengths were recorded, and the stomach contents of the anadromous fishes were removed and identified. All specimens were transferred to alcohol and labeled. Besides the collection of fish there was some effort to record temperature and dissolved oxygen levels on site but the main data were collected by a sonde (water quality data logger). The sonde was set on a fixed post 0.5 m above the sediment. It was located approximately 3 m into the *T. natans* bed just off the channel next to the cement jetty. Depth, temperature, and dissolved oxygen measurements were taken every ten minutes from 6-12 days at a time.

## RESULTS

Our hypothesis that low levels of dissolved oxygen are driving fish out of the beds was not satisfactorily supported by this study. Due to a month long delay in the delivery of the nets, collection of data did not begin until early August. The impact of that delay was that only a limited amount of sampling could take place, for a total of 8 sample days, before the *T. natans* began to senesce. The last two questions; fish composition and the diets of herring and striped bass within *T. natans* can be addressed insofar as we can present our capture data and the results of stomach content analysis.

There are clear cycles of low and high DO throughout the tides in Inbocht Bay (Figure 3). Temperature and DO both change with tide height but there is no causal relationship between them; a change in temperature would have an inverse affect on DO. The DO levels drop slowly throughout the ebb tide, only dropping precipitously during the last hour, and the rising tide quickly drives DO back up (Figure 3). Levels that we think would have affected the fishes (>3 ppm) occur only in the last 1-1.5 hours of the ebb tide.

The fishes caught (Table 1) were within the *T. natans* and were moving out of the bed during the ebb tide (Figure 4). Because the majority of water quality data were collected by the sonde, which was located next to the cement jetty, it is not possible to link fish movement data with that water quality data directly. All of the water quality data were linked to our capture data as closely as possible and the results are interesting, with some patterns emerging. The weak correlation between tide hour and total-fish-captured demonstrates that movement took place throughout ebb tide, but that more fish left at high tide (Figure 4). There is a possible correlation between dissolved oxygen levels and total fish caught, but not the one we expected (Figure 5). The majority of fish

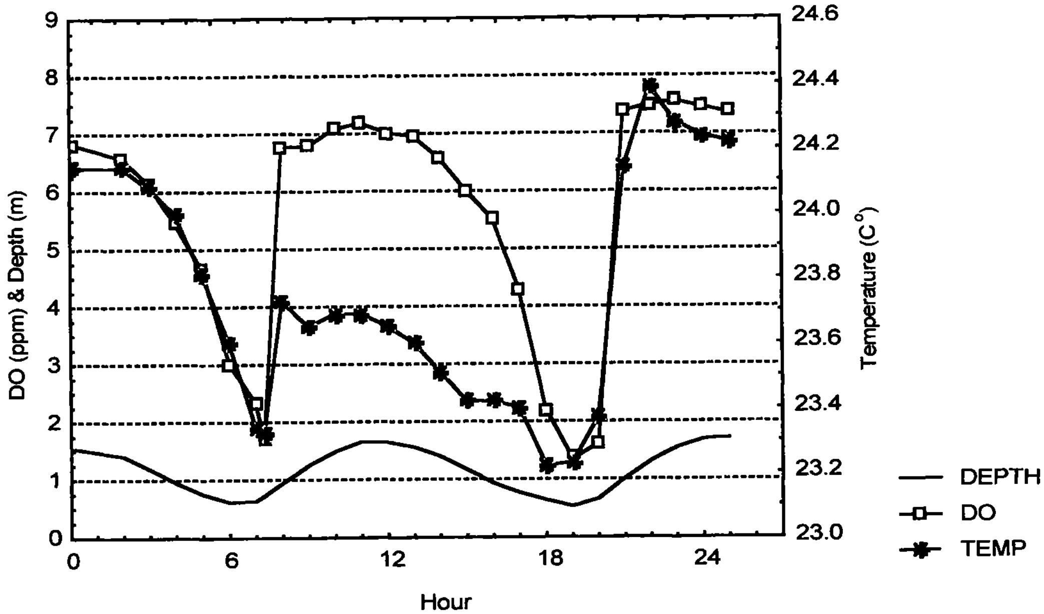


Figure 3. Water quality data from the sonde in Inbocht Bay from 8/4-8/5.

Table 1. Species captured throughout the study. Relative abundance (% of total captured) is reported in parentheses.

| Species | Total Captured | Mean Length (mm) | Range(mm) |
|---|---|---|---|
| *Alosa aestivalis* | 57 (.39) | 53 | 46-66 |
| *Morone americana* | 15 (.10) | 136 | 14-220 |
| *Morone saxatilis* | 14 (.10) | 61 | 53-72 |
| *Notropis hudsonius* | 14 (.10) | 65 | 30-112 |
| *Alosa pseudoharengus* | 12 (.08) | 60 | 50-66 |
| *Fundulus diaphanus* | 11 (.07) | 60 | 23-80 |
| *Alosa sapidissima* | 9 (.06) | 74 | 59-83 |
| *Ameiurus nebulosus* | 9 (.06) | 61 | 42-152 |
| *Carassius auratus* | 2 (.01) | 45 | 41-48 |
| *Micropterus dolomieu* | 2 (.01) | 61 | 55-66 |
| *Brevoortia tyrannus* | 1 (.006) | 46 | - |
| *Etheostoma olmstedi* | 1 (.006) | 59 | - |

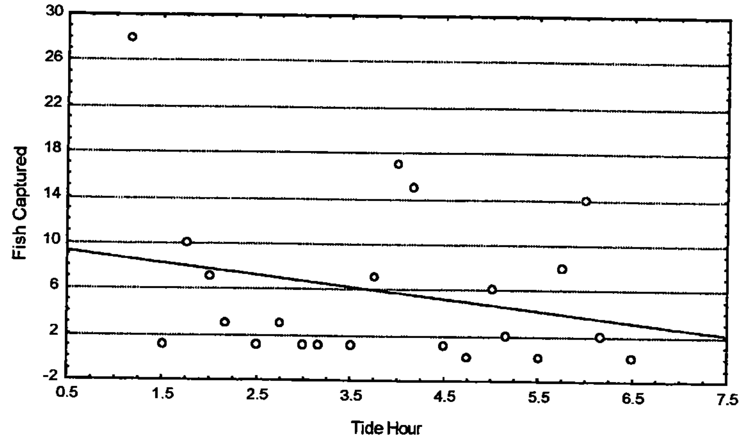


Figure 4. The distribution of the total number of fish captured per hour into ebb tide (not including the first 4 sample dates, which did not go past hour 4) ($p<0.02$, B=-0.23).

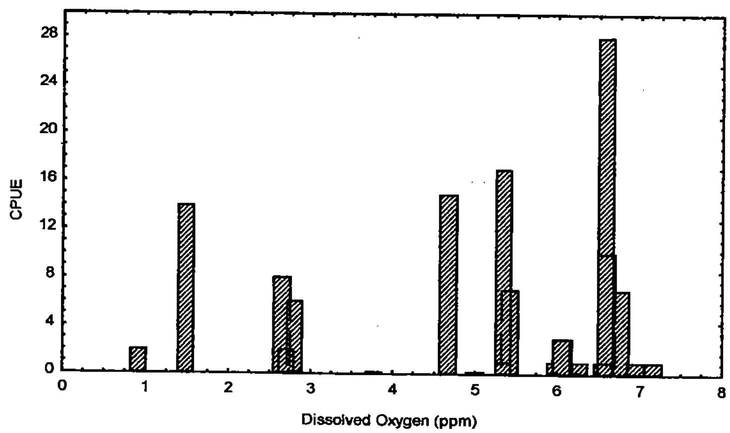


Figure 5. Number of fish captured per hour at various dissolved oxygen levels recorded by the sonde. The majority of fish were captured at greater than 4 ppm (not including the first 4 sample dates, which did not go past hour 4).

were captured above 4 ppm; not an indication that they are responding to low DO.

Of significant interest is the abundance of blueback herring (Table 1) which were clearly the dominant species in terms of numbers. The diet of the blueback, alewife, American shad and the striped bass consisted of insects and virtually no plankton (Table 2, 3 and 4). The insects they were eating are associated with *T. natans* and the abundance of those insects in the guts of the clupeids and the striped bass clearly suggests that those fish are utilizing the *T. natans* as a food resource. Grabe (1996) found that alewifes and American shad were feeding primarily on epiphytic chironomids, which our results corroborate. His results showed bluebacks preying on copepods, particularly during daytime, then shifting to chironomids during evening hours. We found very few copepods and a large number of chironomids in blueback herring stomachs. The diets of the blueback herring and the striped bass are also of interest since at Inbocht Bay they are very different from what has been recorded elsewhere on the Hudson River (Table 2 and 4).

Table 2. The stomach contents of blueback herring at various locations in descending order of abundance. Data from Tivoli Bay are from Limburg and Strayer (1988).

| Inbocht Bay (n=57) | Tivoli South and North Bay |
|---|---|
| Chironomidae (pupae, larvae and adults) | Chironomidae (larvae and adults) |
| Odonata | Calanoid Copepoda |
| Aphids | Cyclopoid Copepoda |
| Calanoid Copepoda | *Bosmina* |
| Ostracoda | *Sida* |
| | Other Cladocerans |

Table 3. The stomach contents of 12 alewifes and 9 American shad from Inbocht Bay *T. natans* beds in descending order of abundance.

| Alewife | American Shad |
|---|---|
| Chironomidae | Chironomidae |
| Ostracoda | Beetles |
| Notonectidae | Aphids |
| Calanoid Copepoda | Spider |
| Beetles | Plecoptera |
| *Gammarus* | Hemiptera- *Mesovelia mulsanti* |
| Ephemeroptera | |

Table 4. The stomach contents of striped bass at various locations in descending order of abundance. Data are from Jordan and Juanes (1999) in the mid-Hudson and Schmidt (1993) in Manitou Marsh.

| Inbocht Bay (n=14) | Mid-Hudson | Manitou Marsh |
|---|---|---|
| *Gammarus* | *Gammarus* | Calanoid Copepoda |
| Chironomidae | Decapoda | Decapoda |
| Unidentified fish | *Nereis* spp. | Cirripedia |
| Ephemeroptera larvae | Isopoda | Cumacea |
| Calanoid Copepoda | *Anchoa mitchilli* | Chironomidae |
| | *Morone* spp. | Ephemeroptera |
| | | Isopoda |
| | | Unidentified fish |
| | | *Gammarus* |

There are also distinct differences in the fish community within the *T. natans* of Inbocht Bay versus the beds at Tivoli South Bay and Norrie Point (Table 5). Noticeably absent from Inbocht were carp and sunfish. While there were only two specimens, the presence of smallmouth bass in Inbocht Bay is new to *T. natans*. Although alewifes have been captured in *T. natans* at Norrie Point (Gilchrest and Schmidt 1998) there were only 5 individuals that made up only 2.3% of the total fish captured. It is very clear from our data that clupeids, specifically blueback herring, were not only present but also dominant. Of unknown significance was the repeated presence of brown bullheads, all of which were dead or near death. Even though they were the only fish collected that are by definition bottom dwellers, except the one tessellated darter, the extent of the disease and the necrosis we observed is disturbing. With the exception of the white perch and one bullhead, the rest of the fish were young of the year (YOY).

Table 5. List of species found in various *T. natans* beds on the Hudson River. Tivoli South Bay: Pelczarski and Schmidt 1991; Hankin and Schmidt 1992; Gilchrest and Schmidt 1998. Norrie Point: Gilchrest and Schmidt 1998.

| Species | Inbocht Bay | Tivoli SB | Norrie Point |
|---|---|---|---|
| *Anguilla rostrata* | - | x | x |
| *Alosa aestivalis* | x | - | - |
| *Alosa pseudoharengus* | x | - | x |
| *Alosa sapidissima* | x | - | - |
| *Brevoortia tyrannus* | x | - | - |
| *Carassius auratus* | x | x | - |
| *Cyprinus carpio* | - | x | - |
| *Notemigonus crysoleucas* | x | x | x |
| *Notropis hudsonius* | x | x | x |
| *Luxilus cornutus* | - | - | x |
| *Ameiurus nebulosus* | x | x | x |
| *Fundulus diaphanus* | x | - | x |
| *Fundulus heteroclitus* | - | x | - |
| *Apeltes quadracus* | - | x | - |
| *Morone americana* | x | x | - |
| *Morone saxatilis* | x | - | - |
| *Lepomis auritus* | - | x | x |
| *Lepomis gibbosus* | - | x | x |
| *Lepomis macrochirus* | - | - | x |
| *Micropterus salmoides* | - | x | x |
| *Micropterus dolomieu* | x | - | - |
| *Ambloplites rupestris* | - | x | - |
| *Etheostoma olmstedi* | x | x | x |

## DISCUSSION

While the nature of this study prevents us from conclusively answering the questions surrounding the role of the ebb tide and the decreasing oxygen levels within the *T. natans* at Inbocht Bay, it has lead to some very interesting information, some of which hints at these interactions. Certainly the fishes we captured are utilizing extensive parts of the *T. natans* bed and not just the edges. It is also clear that the species utilizing it most (if we assume that presence in numbers so indicates) are the anadromous fishes, making up 63% of all fishes captured. Their presence alone may be very significant if we can compare this study to previous ones on fish communities within *T. natans*.

We acknowledge that different collection methods result in variations of species captured. But if we assume that those differences are minor, then there are clear differences between Inbocht Bay (open to the main river), Tivoli South Bay (occluded, sectioned off from the main river by the railroad), and Norrie Point (open). Pelczarski and Schmidt (1991) sampled *T. natans* within Tivoli South Bay, an occluded site, using a pop net and determined that the dominant species were carp and fourspine sticklebacks. Hankin and Schmidt (1992) re-sampled the *T. natans* in Tivoli South Bay and came to the same conclusion as Pelczarski and Schmidt (1991). Gilchrest and Schmidt (1998) sampled both Norrie Point, an open site, and re-sampled Tivoli South Bay. Once again they came to the conclusion that carp and fourspine stickleback dominated Tivoli South Bay. At Norrie Point however, brown bullhead, redbreast sunfish, spottail shiner, and tessellated darter dominated the *T. natans*.

It seems clear that Tivoli South Bay, being an occluded site that drains nearly completely at low tide, is not available to anadromous fish in the same way as Inbocht Bay or Norrie Point. However, despite these factors, YOY striped bass have been observed in the waters of the Saw Kill. Its relatively depauperate fish community also suggests relatively poor water quality, low DO and high turbidity (Schmidt and Kiviat 1988), compared to the fish communities found at the other sites. But what are the differences between Norrie Point and Inbocht Bay? There are three main ecological differences; one is that while both sites are open to the Hudson River, Norrie Point is a peninsula with greater exposure to lateral flow of the river. A second difference is the mean height at low tide. While both sites have exposed mud flats, the main bed at Inbocht Bay has a mean low tide of ½ ft while the mean low tide at Norrie Point is 2 ft (Nautical chart #57, Waterproof Charts Inc. 2000). A third factor is the relatively narrow *T. natans* bed at Norrie Point, having significantly less coverage than Inbocht Bay. The combination of these factors likely prevents the dissolved oxygen profile found in Inbocht Bay from occurring at Norrie Point. While these differences have an important impact on water quality these factors alone do not explain the lack of anadromous fish at Norrie Point. We have found no satisfactory explanation for the lack of anadromous fish in the *T. natans* at Norrie Point other than collection method.

The presence of resident insects, of Inbocht Bay *T. natans*, in the stomachs of the anadromous fishes is compelling evidence that they are utilizing the *T. natans* as a major food resource. Plankton was virtually non-existent as part of the anadromous fish's diet but it was certainly present within the bed. Clearly the fish we were sampling were selecting prey based on size. This raises an interesting point of comparison between *V. americana* and *T. natans*; does *T. natans* provide a unique structure that promotes epiphytic insects that are then an easier food source to exploit? While feeding on insects is not necessarily a surprise (Grabe 1996), the specific components of the anadromous fish diets are different from those found in other studies. We suspect that these differences reflect both differences in habitat and in annual variations in insect abundance.

An interesting change in diet took place towards the end of the study. During the last two sample days the *T. natans* bed was beginning to break up and on the last sample day the bed was clearly senescing with open water developing in spots. The diets of fish collected during this period shifted to include aphids. Our interpretation of this change is that while the *T. natans* was healthy there was little chance of aphids entering the water. As the bed began to senesce, aphids started to enter the water becoming available to the fish. Presumably, once the bed has completely broken down it will cease to act as a food resource, forcing most of the species captured in this study to look elsewhere for food. At the same time a major source of cover and protection will no longer be available.

In completing this project some confounding factors became readily apparent. The first was the impact of tidal magnitude on changing DO levels. During the study the magnitude of the tide ranged from 3.4 ft – 5.1 ft, presumably affecting the degree to which the bed was re-oxygenated after low tide and the degree to which the DO would drop going into low tide. However, data collected during the study showed no difference in DO levels from one tide magnitude extreme to another. Another confounding variable became very obvious on sampling day 7 (9/5/2000) when we captured virtually no fish. We were sampling in the morning after an evening of near frost temperatures, the first of the season. The water temperature the week before had been around 22° C but that morning at high tide the temperature was down to 18° C. As the tide went out the water temperature quickly dropped, eventually reaching 16° C. We assume that during the evening low tide, when the air temperature dropped into the single digits, the entire bed chilled. As fish started returning to the bed on the rising tide they ran into a wall of very cold water, sufficient to prevent them from re-entering the bed.

## CONCLUSION

Despite early logistical problems and a late starting date, this project has yielded some important and interesting ecological information. While we are unable to statistically test our hypothesis that low DO is driving fish out of the *T. natans* at Inbocht Bay, we feel that the data clearly indicate that most of the fish are leaving at higher levels of DO and are not staying in the bed long enough to experience low DO. Although we have demonstrated that fish within the bed are leaving during the ebb tide, the specific hour seems to be irrelevant. Most importantly, it is clear that anadromous fish, particularly blueback herring, are utilizing the bed as a food resource; in fact their diets indicate that they are preferentially feeding on insects taken from the bed. Their ready movement out of the bed, with no clear reason, also suggests that they are not utilizing the bed as a source of protection from predation.

The *T. natans* bed at Inbocht Bay is very different from other beds that have been sampled on the Hudson River. While one might expect the beds to support similar communities it is becoming clear that the wide array of factors influencing each bed are significant enough to result in entirely different fish communities. It seems logical therefore, to conclude that while *T. natans* has had negative impacts on the Hudson River ecosystem, it none the less is currently supporting a wide range of fish communities.

## RECOMMENDATIONS

In order to accurately test the hypothesis that low DO is driving fish out of *T. natans* further research with sufficient replication must be completed. Additional work should utilize the weir net system to address the issue of movement out of the bed but it should also include the simultaneous use of pop nets to better assess fish composition within the bed. At the same time it would make sense to set up gill nets on the edge of the bed to determine the extent to which predators are using the bed as well. While continuous monitoring of water quality by sondes is an added benefit, DO measurements on site during sampling are a must.