FINAL REPORT

Abundance and winter distribution of Hudson River black bass

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ABSTRACT

Largemouth bass and smallmouth bass are actively sought by anglers in the Hudson River, but little is known regarding bass habitat requirements in the Hudson and other large tidal rivers, particularly in winter. Local anglers and New York State Department of Environmental Conservation biologists had been aware of 5 wintering concentrations of bass in the Hudson for some time and in 1989 we began a study to further identify and describe use of wintering sites by these species. During spring 1989-1992, largemouth bass were captured by electrofishing in the five known wintering sites and marked. Tournaments on the Hudson were attended to examine largemouth bass for mark and recapture population estimates and to assess tournament activity. Radiotelemetry was used to track largemouth bass from the main river to potential wintering sites. In 1990 and 1991, we examined the habitats in the wintering sites and use of those habitats by fish with an underwater video camera. As part of a continuing study into relative abundance of age-0 bass, electrofishing was conducted at selected sites in 1987-1991.

Tournament activity was quite high with at least 10% of the estimated population of largemouth bass being weighed in at tournaments during the summer. The estimated number of largemouth bass >280mm declined from 22,000 in 1989 to 14,000 in 1991. Population estimates for bass in the 5 wintering areas comprise 50 to 90% of the river-wide total. Only eight out of 25 radiotagged fish were eventually tracked to known wintering sites. The results of the radiotracking may not be indicative of the movement of the population as a whole as fish may have died due to the tagging techniques. Eighteen smallmouth bass were radiotagged in the river from Troy Dam to Kingston and appeared to be more evenly distributed throughout the river in winter than largemouth bass. Underwater surveys of the wintering sites revealed that substantial numbers of largemouth bass and other fish species were present. Bass preferred habitats with structure such as large rocks, stumps and pilings and prefer intermediate depths in the wintering areas (3.0-4.4 m). In 1987-1991, a total of 431 electrofishing samples produced 513 age-0 largemouth bass. Catch rates were highest in bays, followed in descending order by creekmouths, coves, shallow shoreline, and exposed shoreline. Catch rates in 1988-1991 were greater than those in 1987; however, annual differences were not significant between the last four years. Results indicate that the five known wintering sites are extremely important to the maintenance of Hudson River black bass populations.

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Largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*) are two fish species actively sought by sport anglers in North America. Largemouth bass are typically associated with lentic systems and have been exhaustively studied there. Tidal populations of largemouth and smallmouth bass, which can provide excellent sport fishing, have been mostly overlooked. Little information is available concerning black bass habits, density and survival in these systems. The bass populations in the tidal portions of the Hudson river have provided us with a unique opportunity to study riverine populations of black bass and the special requirements of these fish.

A tournament fishery for bass began on the Hudson in the late 1970's and since the mid-1980's, at least 50 - 60 tournaments have been occurring annually. Tournament fishing has become an important economic benefit for the area.

The New York State Department of Environmental Conservation (NYSDEC) routinely monitored tournament activity from 1986 to 1988 for the purpose of developing an index of bass populations and to collect recapture information to estimate bass populations in the river (Carlson 1992). They reported that largemouth bass populations had remained relatively constant throughout these years at a level of 30,000 legal size (≥ 305 mm) bass. They also reported that largemouth bass appeared to congregate in certain areas of the river during winter. Local anglers had been aware of these concentrations for some time and concerns about the limited nature of these sites prompted research into the special habitat requirements of tidal largemouth and smallmouth bass. Little information is available in published literature concerning wintering habitat of largemouth and smallmouth bass.

A key aspect of largemouth bass habitat in the tidal Hudson, spawning and nursery areas, was examined in an earlier paper (Nack et al. 1993). In that paper we found that most of the adult largemouth bass left the wintering sites in May and dispersed throughout the river to various protected sites for spawning. Then the majority of adult fish remained in the main river until the onset of cold weather.

In 1989 we began a study to further identify and describe use of wintering sites by adult largemouth and smallmouth bass. At that time, five sites had been identified. They were the tidal portions of Catskill Creek, Esopus Creek, Rondout Creek, Wappinger Creek and a small cove formed by Rattlesnake Island, called Coxsackie Cove (see appendix figures 1-5). Using radiotelemetry we hoped to identify additional wintering sites and determine the relative importance of the known sites. Using a submersible camera, we have defined the physical habitat found in these sites and described habitat use. Coupled with this study was an investigation into adult abundance and survival using mark and recapture techniques. We have also investigated changes in the largemouth bass population of the Coxsackie Cove wintering site after erosion and subsequent repair of an earthen dike protecting it from river currents.

METHODS

Largemouth bass population estimate

During March and April of 1989-1992, largemouth bass were captured with a 5.8-m hull negative direct current electrofishing boat in the five known wintering sites. Fish were measured, weighed and scales were taken. In 1989-1991 all largemouth bass over 280 mm were marked with a distinct fin clip to identify year marked and a dorsal spine was clipped to designate the wintering site in which the fish was caught. Fish were returned to the water immediately after marking. Age structure and growth rates of bass were evaluated from scale samples taken during this phase of the study. Wintering sites were also electrofished in late fall of 1990 and 1991 to further estimate abundance of adult fish.

Before the start of bass season in June, letters were sent to bass clubs and organizations known to hold tournaments on the river and information was requested on tournaments scheduled for the summer and fall. At the start of the season, tournaments on the Hudson were attended to assess tournament activity and examine largemouth bass for fin clips. Arrangements were made with the tournament directors prior to each "weigh-in" to discuss procedures. Generally, a tournament weigh-in would start with the fishermen arriving at the dock with the fish in live wells in their boats. The fish would then be transferred to large plastic bags full of water and taken to the weighing judge. Often, tanks of water were available to immerse the bags in to keep them cool. The fish would be measured to determine whether they were legal length (305 mm) and weighed. After the tournament officials were finished, we placed the fish in a 100 l round tub situated at the water's edge. The fish were identified to species, measured, examined for marks and immediately released back into the river. Immediately following the tournament, data was obtained from the tournament director such as number of contestants, total hours fished, number of limits entered, total weight of bass entered and weight of the largest bass entered. Additional information was obtained from a mail questionaire sent to tournament directors by NYSDEC.

The information collected at tournaments was used to estimate the adult largemouth bass population and confidence intervals using the Peterson mark and recapture method with the equations:

$$\hat{N} = \frac{(M+1)(C+1)}{R+1}$$

$$V(\hat{N}) = \frac{\hat{N}^2(C-R)}{(C+1)(R+2)}$$

Where:

$\hat{N}$ = an estimate of the population size at time of marking

$V(\hat{N})$ = the variance of the population estimate

M = the number of fish marked

C = the number of fish examined for marks

R = the number of fish recaptured

(Ricker 1975).

Survival rates and confidence intervals were also calculated using:

$$S_1 = \frac{R_{12}M_2}{M_1R_{22}}$$

$$V(S_1) = S_1^2\left(\frac{1}{R_{12}} + \frac{1}{R_{22}} - \frac{1}{M_1} - \frac{1}{M_2}\right)$$

Where:

S_1 = an estimate of the survival rate during year 1

$V(S_1)$ = the variance of the survival rate estimate

R_{12} = recaptures of first year marks in the second year

R_{22} =recaptures of second year marks in the second year

M_1 = the number of fish marked at the start of the first year

M_2 = the number of fish marked at the start of the second year

(Ricker 1975).

Tournament recaptures were used in order to reduce bias due to gear and site selectivity.

Interviews of anglers indicated that they fished the entire river from Troy Dam to approximately Peekskill. Recruitment of fish over the tournament season was compensated for by eliminating smaller fish from the recapture sample collected at tournaments held later in the season. Scale samples were used to determine the average yearly growth increment (55mm) for age-2 to age-3 bass. The season distribution of growth was approximated from Van Den Avyle (1973) and weekly increments were determined to adjust for recruitment of fish that would have been to small to be marked in the spring. Electrofishing recapture data was used to determine population size in the wintering sites. Maps of the wintering sites were digitized and area was computed for density estimates.

Location and Description of Largemouth Bass Wintering Sites

Largemouth bass were collected by electrofishing in segments of the river from Troy (River Mile[RM] 152) to Kingston (RM 92) in October 1989 and from Kingston to Beacon (RM60) in September 1990, prior to movement to known wintering concentrations. Fish heavier than 0.5 kilogram were weighed, measured and fitted with external radiotransmitters wired through the dorsal musculature as described in Nack et al. (1993). Transmitters used in 1989 had an estimated lifetime of 60 days and the models used in 1990 lasted 9 months. After release, fish were initially tracked by boat. Fish were also tracked once a week by airplane. Fish remaining at a site for more than two weeks in water temperatures below 10 °C were considered to be at a potential wintering site. These areas were then electrofished in late fall and/or early the following spring to determine if substantial numbers of bass were using a site.

Location and Description of Smallmouth Bass Wintering Sites

To identify smallmouth bass wintering sites we used techniques similar to those used for largemouth bass. Smallmouth bass were caught by electrofishing in each 10 mile section of the river from Troy to Kingston in 1989 concurrently with largemouth bass radiotagging. Fish over were not sampled at this time due to poor visibility. The camera was kept 1 meter off of the bottom as the boat slowly drifted with the tide. In trials, using the underwater camera and a full-size silhouette of a largemouth bass, 2 m was the average maximum distance at which fish could be observed and identified. Depth of the camera and elapsed time was recorded in the field. All tapes were later analysed in the lab and fish were identified and counted. The number of bass observed was divided by the elapsed time recorded for each creek to result in an index of bass abundance.

The following habitat types, based on predominant substrate type, were identified.

Large Rock	Rocky cliffs and bedrock with rocks generally > 25 cm in diameter
Gravel/rubble	Medium sized substrate with rocks from 0.5 cm up to 25 cm.
Pilings	Man-made structures within the water column: docks, floats, retaining walls, etc.
Natural Cover	Naturally occurring structure within the water column: stumps, logs and various types of vegetative cover.
Flats	Open level areas with little structure present. Substrate generally composed of sand or silt covered with leaves or detritus.
Bank edge	Area within 5 m of water's edge.
Deep holes	Areas with water depths exceeding 10 m.

Number of largemouth bass observed in each habitat was divided by the elapsed time recorded in each habitat to give bass/minute. Similar values were calculated for number of bass/depth interval. Presence of other species was also noted.

<u>Changes in largemouth bass abundance at Coxsackie Cove</u>

Coxsackie Cove is the only one of the known wintering sites that is not associated with a tidal

500 grams were measured, weighed and fitted with external radiotransmitters. After tagging, fish were tracked by boat and by airplane. Fish remaining at a site more than two weeks in water temperatures below 10 °C were considered to be in a potential wintering site. During late fall and the following spring, areas to which radiotagged fish were tracked were sampled by electrofishing to determine the extent of the wintering site.

Underwater Camera Survey and Description of Wintering Sites

In 1990 and 1991, we examined the habitats in the wintering sites and use of those habitats by fish. Initially we attempted to use a remotely operated vehicle (ROV) to observe fish behavior. We suspected that the lights and the noise produced by the ROV propellers frightened fish from the area. We then used a monochrome waterproof video camera to photograph fish in the wintering sites. The camera was connected to a video cassette recorder and attached to a 12 m telescoping pole. It functioned in extremely low light levels (0.5 lux) allowing us to use the camera without lights. The entire camera system, designed and built at Cornell University, was powered by a small rechargable 12v battery pack. This made the system truly portable.

During winter 1991-92, in the Catskill, Esopus and Coxsackie wintering sites, we cut holes in the ice throughout the sites and lowered the camera to the various depths. The camera was slowly rotated 360° to examine the locality, left in a stationary position for 10 minutes and then rotated again before it was removed. Number of fish observations per hole was calculated and then converted into an approximated areal estimate using a viewing radius of 2 meters.

The Rondout and Wappinger wintering sites were not sampled due to hazardous ice conditions. In spring of 1992, after iceout, we made a number of surveys of the fish and habitat using a boat in the Catskill, Esopus and Wappinger wintering sites. The Rondout and Coxsackie wintering sites creek and is formed by a man-made dike connecting Rattlesnake Island to the western shore of the Hudson River (see appendix figure 1). As recently as 1986, Coxsackie Cove was estimated to contain 4000 over-wintering largemouth bass (Carlson 1992). In 1987 the dike was breached and tidal currents began to flow through the site. Associated with this was an observed drop in the population of wintering bass to 20% of their former abundance (Carlson 1992). In late fall 1990 the dike was repaired with the hope that it might restore the wintering populations of bass.

In order to describe changes in the bass population of Coxsackie Cove, we used electrofishing samples collected by NYSDEC before and after the breach of the dike at the northern end of the cove. In 1989 we began taking samples there for marking for our riverwide population estimates. Electrofishing samples were taken in spring 1989-1991 and fall 1990-1992. Abundance estimates and recapture rates from tournaments before and after the breaching and subsequent repair of the dike were used to analyze trends in the fish populations. In addition, length frequency distributions of fish were compared during this period to define changes in the size structure of the wintering population.

Relative abundance of age-0 largemouth bass

As in the previous grant from the HRF we continued to collect information on nursery habitat of black bass in the Hudson River. We collected age-0 largemouth bass at selected sites in 1987-1991 by direct current electrofishing from a boat with a 5.8-m hull cathode. We selected random sections of shoreline representative of each type of habitat. The segment of shoreline judged to be the most suitable habitat within the 0.4-km shoreline unit was electrofished for 15 minutes during daylight hours in August-October. Number and lengths of age-0 largemouth bass were recorded for each site. Scales were taken to determine age of fish collected if age classification by length was not obvious. Catch rates (number of bass/hour) were calculated for each of the five habitats.

RESULTS

Largemouth bass population estimate

Numbers of fish marked in the spring by electrofishing in the five known wintering areas during 1989-1991 are summarized in table 1. Electrofishing catch rates for bass (table 2) were quite variable in the wintering areas depending upon weather conditions and water clarity.

We attended 22 bass tournaments in 1989, 15 in 1990 and 14 in 1991 (table 3). We identified a total of 44 local and regional tournaments in 1989 so we were only able to attend a fraction of those that occurred each year. At least one tournament was scheduled every weekend from the start of the bass season through November 5. The majority of tournaments were held in Catskill, which is ideal due to its central location on the river, ample parking and two modern concrete boat launches. Also, Greene County actively recruits tournaments and often acts as a sponsor. Other locations where tournaments were attended included Coxsackie, Athens, Germantown, Hudson, Saugerties, Kingston, Norrie Point Yacht Basin, Poughkeepsie, Newburgh, Cornwall, Albany and Peekskill. Among those organizations that sponsor tournaments on the Hudson are Redman Chewing Tobacco, American Scholarship, Bassin'America and Bassin'Gals Inc, as well as many state and local groups. All tournaments were catch and release, with anglers taking great care to release fish unharmed. Tournaments varied in size from 9 -218 contestants and most were 8 hours long. Statistics on tournaments are shown in Table 3.

Totals of 2,236 largemouth bass and 650 smallmouth bass were entered in the tournaments attended in 1989, 1,522 largemouth and 687 smallmouth in 1990 and 1,200 largemouth and 374 smallmouth in 1991. Catch rates for both species combined (bass/trip) were 1.9 bass/trip in 1989, 1.3 bass/trip in 1990, and 1.4 bass/trip in 1991. Average weight of bass entered at individual tournaments ranged from 0.72 to 1.25 kg/bass. The largest bass weighed in during the study was

3.1 kg. The percentage of contestants who captured their limit of 5 bass per day averaged 11.4% in 1989, 4.2 in 1990 and 4.6 in 1991. In all three years combined, only 16 (0.3%) of largemouth bass weighed in were dead and 43 (2.4%) of the smallmouth bass were weighed in dead.

Results from the river-wide Peterson population estimate are described in table 4. The number of largemouth bass >280mm was 22,000± 2,900 in 1989, 15,000± 1,800 in 1990 and 14,000± 1,800 in 1991. There was a significant drop in bass numbers between 1989 and 1990 ($\alpha \geq 0.05$). Population size in individual wintering sites was also calculated using electrofishing recaptures in spring 1989-1991 (table 5). They showed that population estimates in the 5 wintering areas encompass 50 to 90 percent of the river wide total and that total numbers of fish in wintering sites have remained relatively constant even during fluctuations in the total population. Estimates of the surface area of the wintering sites combined with population estimates indicate bass densities may approach 500 bass/hectare (table 6).

Average size of bass encountered during electrofishing and in tournaments was very consistent between years (table 7). There were slight differences in mean size of bass between sites but these differences were not significant (table 8). Relative occurrence of marked fish from different wintering sites in the tournament samples were similar for the central sites (Catskill, Esopus and Rondout), however, fish from Coxsackie Cove and Wappinger Creek were under-represented. This indicates that most of the tournament activity occurs in the middle portion of the river.

River-wide survival estimates for adult largemouth bass showed a high degree of variability between years (table 9) however there were no statistical differences between years. Confidence intervals were wide due to the low number of recaptures. Survival estimates from individual wintering sites (Table 10) show a similar degree of variability, although confidence limits are rather wide and limit the conclusions we can draw from the data.

Location and Description of Largemouth Bass Wintering Sites

In 1989 and 1990 a total of 25 fish were captured and radiotagged in the main portion of the river away from the wintering sites (Table 11). In 1989, in the portion of the river from Troy Dam to Kingston, fish showed an affinity for known wintering sites. Over 50% of the tagged fish entered these sites. Of those fish that didn't use the sites, most were tagged in the northern sections of the reach or far from any known wintering sites. One bass was observed to enter Coxsackie Cove, remain there a week and then proceed downriver to Catskill Creek. This fish again moved south to finally end up in Esopus Creek for the winter. Six out of eight largemouth bass tagged in the main river between Kingston and Coxsackie used the five known wintering sites. None of the bass tagged north of Coxsackie used any of the wintering sites to the south.

In 1990, in the southern portion of the reach from Kingston to Newburgh, the results were much different. Only 2 out of 14 fish radiotagged were eventually found in a wintering area. Most fish moved very little if at all and none of the fish moved in a meaningful manner with the onset of colder water temperatures. Concerns over lack of movement of radiotagged fish during the fall prompted us to make a flight over the area on May 10, 1991 in order to determine if these fish had survived over winter. None of the radiotagged fish had changed position between December 1990 and May 1991 so we must conclude that either the fish died or the transmitters were lost, possibly prior to formation of wintering concentrations. This follow-up was not possible with the fish radiotagged in 1989 due to the shorter lifetime of the transmitters. The results of the radiotracking may not be indicative of the movement of the population as a whole.

Location and Description of Smallmouth Bass Wintering Sites

Eighteen smallmouth bass were radiotagged in the river from Troy Dam to Kingston (Table 12). Smallmouth bass appeared to be more evenly distributed throughout the river in winter than largemouth bass. Only two out of ten smallmouth bass tagged in the main river between Kingston and Coxsackie used the known wintering sites. Both fish were from the southern-most section and used Rondout Creek. None of the bass tagged north of Coxsackie used any of the wintering sites to the south.

Most of the fish in the southern portion of the reach remained close to lighthouses, rock piles and other structured habitats in the main river. Three bass were last observed in creeks and three were found in areas that were separated from the main river by islands. Most of the bass from the northern sections moved north into the shelter of bridge pilings and one bass moved several miles north to the vicinity of Troy Dam.

In the spring of 1990, Stockport Creek and Roeliff-Jansen Creek were electrofished to confirm reports of substantial numbers of smallmouth bass wintering there. Approximately 50 smallmouth bass were caught in a pool in Roeliff-Jansen Creek, indicating that there is a small concentration of wintering bass there. The pool was approximately 4 m deep and fish were easily captured. Only 15 bass were captured in Stockport Creek and the fish appeared to be much more dispersed.

Underwater Camera Survey and Description of Wintering Sites

Underwater surveys of the wintering sites revealed that substantial numbers of largemouth bass and other fish species were present. In sampling through the ice at Coxsackie Cove, Catskill Creek and Esopus Creek we observed a total of 179 bass in 414 minutes of videotape (Table 13). In many cases 3 to 4 bass were observed simultaneously indicating that fish densities were quite high. Bass appeared to be oblivious to the camera in most cases, however, some appeared to be attracted to it and approached quite closely, occasionally touching the camera lens. Most of the largemouth bass that were observed were active and seemed to be swimming languidly about in an undirected manner. Occasionally we observed fish which appeared to be resting without fin movement just above the bottom.

Smallmouth bass were observed only at the Catskill Creek wintering site. Twelve individuals were seen at depths greater than 10 meters. Most of the smallmouth bass appeared to be negatively buoyant and were resting on rock ledges. Webster (1954) reported this type of activity on and around limestone ledges in Cayuga Lake, NY.

Other species were seen while bass were being videotaped. Large numbers of sunfish were seen suspended in midwater in association with structured habitat. Extensive schools of common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) were seen on several occasions moving through the camera's field of view. Sunfish, carp and goldfish appeared to be more abundant than largemouth bass. Other species encountered were one black crappie (*Pomoxis nigromaculatus*), one sucker (*Catostomus spp.*) and an unidentified esocid, probably a northern pike (*Esox lucius*).

Similar results were obtained from data collected using the camera from a boat in three of the wintering sites (Table 14). The boat allowed us to cover much more area and sample areas that had been unreachable due to unsafe ice conditions.

Very similar results were obtained for bass observed/minute of taping time and apparent habitat use so results from both methods were combined in the analysis of habitat use. An analysis of the tapes showed that bass in the wintering areas preferred habitats with structure such as large rocks, stumps and pilings (Table 15). Although we don't have estimates of the availability of habitat, it appears that bass avoid deep holes and areas of flat bottom with little or no features. Largemouth bass also appeared to prefer intermediate depths in the wintering areas (Table 16). The highest number of bass observed per minute was located in the 3.0 to 4.5 m depth interval, however, bass were found at almost all depths.

While our estimates of densities of fish using the video camera are imprecise we believe that it helps to illustrate and support the population estimates made by conventional means. When the shallow water and unsuitable habitats are eliminated from the wintering site areal estimates there is approximately 36.5 ha of habitat in the Coxsackie Cove, Catskill and Esopus wintering sites combined. We viewed approximately 0.4 ha of habitat and 179 bass were observed resulting in a estimate of 450 bass/ha. Expansion of this would indicate that 16,000 bass were present in the three wintering sites combined, which is the same order of magnitude as the conventional population estimates (Table 5).

Changes in largemouth bass abundance at Coxsackie Cove

Estimates of the bass population in Coxsackie Cove are found in Table 17 and show that numbers of bass have remained relatively constant for the last four years at 600-700 bass. Spring catch rates have remained relatively constant at 17-18 bass/hour, which is much lower than the catch rates reported by NYSDEC prior to 1986 (40-56 bass/hour). Fall catch rates were much more variable and seemed to show a trend toward improvement of the population. In fall 1990 and 1991, substantial numbers of younger fish appeared in the sample as shown by the length frequency distribution (appendix figure 14) and the average length (table 18).

Relative abundance of age-0 bass

In 1987-1991, a total of 431 electrofishing samples produced 513 age-0 largemouth bass. Catch rates were highest in bays, followed in descending order by creekmouths, coves, shallow shoreline, and exposed shoreline (Table 19). Catch rates in 1988, 1989, 1990 and 1991 were greater than those in 1987; however, annual differences were not significant between the last four years (Table 20).

Densities of age-0 largemouth bass were uneven along the length of the estuary. Catch rates in the northern section of the estuary (River Km 243-192) were lowest among the three river segments (Table 21). Catch rates increased steadily in a southerly direction.

DISCUSSION

Data from the Hudson shows that there is a high level of tournament activity concentrated on a limited population of black bass. In a typical tournament year, 10% or more of the legal population may be weighed in at organized tournaments (Table 4). Practice fishing for tournaments, small local tournaments and recreational fishing account for many more hours of fishing pressure. This indicates that a high proportion of the fish are being handled by fishermen and the large number of fish observed with multiple hook marks and wounds bears this out. Catch rates are similar to other good tournament bass waters even though population density is low. Annual angling catch rates were variable and the 1990 catch rate was the lowest observed since monitoring began. This coupled with a drop in percent limits supports the information from the population estimate. The population of adult largemouth bass has dropped substantially between 1989 and 1990. During the same period, there has been little change in the catch rates for adult smallmouth bass at tournaments. Available tournament catch composition data suggest that the smallmouth bass population is approximately one third to one half of the largemouth bass population and more stable.

Despite the change in the population size and the tournament catch rates, there were no basic changes in the other parameters between years. Average size of bass weighed in remained the same and also average size of bass captured during electrofishing remained the same. Bass size remains relatively high compared to other areas in New York state. Approximately the same number of fish were marked in all years and a similar number of angler trips were observed. There was no apparent change in the distribution or level of fishing activity or tournament procedures between the three years.

Several factors may explain the drop in the river-wide population estimate for adult largemouth bass between 1989 and 1990. Higher than average mortality was observed in Catskill Creek during 1989 and 1990 and there are indications of a similar occurrence in Wappinger Creek. The breaching of the dike in Coxsackie Cove a number of years ago may also have had an effect on numbers of adults. NYSDEC reports have indicated that electrofishing catch rates dropped off considerably after the dike washed out. At present only 5 wintering sites have been identified and a substantial reduction in the number of fish at Coxsackie Cove could affect the river-wide population. Another factor in the reduction of adult bass stocks may have been relatively poor reproduction in 1987 (Table 20). The fish from the 1987 year-class would have reached legal size at the end of the 1989 tournament season and in 1990 would make up the bulk of the tournament catch. Since reproduction was very poor in 1987, then there would be no replacements for older fish experiencing mortality. Repair of Coxsackie Cove and the higher reproduction in 1988 and 1991, is likely to result in population increases.

The five known wintering areas are critical for the maintenance of bass populations in the Hudson. In the three years for which we have data, 60 to 80% of the total riverwide population was accounted for by estimates in the wintering sites. This coupled with estimates of bass density in wintering sites suggest that the fish are highly concentrated and extremely vulnerable to short-term events affecting those areas during winter. Occurrences such as dredging, chemical spills, runoff events or overfishing in these areas could have the effect of reducing the population by 15 to 20%. A national magazine (Bassmaster Magazine, September/October 1992) has identified the wintering sites as good places to fish, which could increase the fishing pressure on these sites. Long-term changes could also affect these areas by reducing the quality of the site, forcing fish to go elsewhere, and possibly increasing the density at the remaining sites. We have seen such an occurrence at Coxsackie Cove resulting in a drastic reduction of the numbers of fish wintering there.

Radiotelemetry work failed to identify new wintering areas for largemouth bass. In 1989, 6 of 11 tagged fish were tracked to known wintering areas. The ones which didn't were tagged far from known sites and may have wintered elsewhere. Based on wintering site and river-wide population estimates we infer that as little as 10% of the population winters in other areas than the known sites and probably are located in small habitats scattered throughout the river. Most of the fish radiotagged in the fall of 1990 didn't move from the place where they were tagged and we surmise that these fish must have died or lost their transmitters before seeking wintering sites.

Results from the radiotagging of smallmouth bass suggest that they remain much more dispersed throughout the river. A few are associated with the known largemouth bass wintering areas which is borne out by the fact that 12 smallmouth bass were observed in the underwater camera survey. There appears to be a small concentration of bass in the Roeliff-Jansen Creek and possibly another in Stockport Creek. Smallmouth bass show an affinity for lighthouses, bridges and other structured habitats on the main river.

Visual surveys with the underwater camera confirmed that bass occupied suspected wintering sites during periods of ice cover and immediately following ice-out. Up to 3 or 4 bass were seen at a time which indicates that there are substantial numbers of bass present throughout the winter in each of these areas. Density estimates of up to 400 bass/ha were found in the wintering sites using the mark-and-recapture data. Smallmouth bass appear to be present on these areas also, but they occupy the deeper water habitats beyond the reach of electrofishing. High densities of sunfish, carp and and other species were observed which suggests areas where largemouth bass concentrate may be important wintering sites for other fish species in the Hudson.

The number of bass wintering in Coxsackie Cove appears to have been reduced as a direct result of the breaching of the dike at the northern end. The opening allowed currents to sweep through the site and apparently reduced its suitability as a wintering site. This indicates that one of the important characteristics of wintering sites is low current velocity. With the subsequent repair of the dike we expected fish to immediately return to the wintering site. However, bass populations were slow to return to the numbers previously found there. One possible reason is that the wintering area must be re-populated by young fish. There were six years between the erosion and repair of the dike and it may be that once the resident fish left they either died or went to another site. Few would have been alive to return after six years. The fall 1991 electrofishing at Coxsackie Cove showed a substantial number of fish in the cove and these fish were smaller on average than fish in the other wintering sites. We continue to follow the progress of the restoration and will be reporting on this in the future.

Catch rates for age-0 largemouth bass in the more protected habitat types (creekmouths and bays) were approximately four times higher than those in unprotected areas (exposed shoreline and shallow shoreline). Cove habitats were less protected than bays and creekmouths and catch rates in this habitat type were intermediate between protected and unprotected areas. Nearly all age-0 largemouth bass were found either in areas with submerged vegetation or some type of structure (dock pilings, logs, etc). Dense weed beds and heavily structured areas held the vast majority of young. Many age-0 largemouth bass were captured near shore in water less than 2.0 m deep.

In the first year age-0 bass were collected (1987), the catch rate was extremely low. Since then catch rates have been considerably higher and may result in good recruitment into the fishable population.

Differences in the amount of suitable spawning and nursery habitats may explain the north to south gradient in age-0 largemouth bass catch rates. The northern section of the study area was narrow and currents were swift with much of the shoreline modified by dikes and fill. Steep sloping exposed shorelines in this area supported little vegetation or structure and suitable spawning areas away from the main river channel were limited. The lack of appropriate spawning habitat north of the Coxsackie wintering site may explain why 80% of the radiotagged fish released there nested south of Coxsackie. In the central segment of the river, more cove, bay, and creekmouth habitats exist than in the northern section. Largemouth bass selected these habitats for spawning and catch rates for age-0 largemouth bass indicate that these habitats also served as nursery areas. In the southern segment of the river, cove, bay and creekmouth habitats were present in percentages similar to the central section. In addition, wide, shallow areas existed. These areas allow for the development of vast expanses of submerged and floating aquatic vegetation which reduce the negative effects of ship- and wind-induced wave action.

It is clear that the Hudson can produce high quality fishing for largemouth bass anglers, however, it is also clear that the population can withstand very little harvest or additional mortality of fish. The winter refugia are critical to the continuation of the Hudson River largemouth bass fishery and to the well-being of other fish species. These factors need to be taken into account when decisions are being made concerning development and utilization of these unique habitats.

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Table 1. Number of adult largemouth bass marked in each wintering site in the Hudson River in spring 1989-1991.

	1989	1990	1991
Coxsackie	42	70	89
Catskill	433	365	458
Esopus	408	496	454
Rondout	363	385	515
Wappinger	421	367	376
Total	1667	1683	1892

Table 2. Electrofishing catch rates (bass/hr) in spring and fall for largemouth bass in each wintering site in the Hudson River.

	Spring				Fall	
	1989	1990	1991	1992	1990	1991
Coxsackie	18.18	17.85	16.67	21.50	52.22	103.50
Catskill	73.69	80.19	75.54	62.00	142.40	87.50
Esopus	91.53	135.43	84.18	92.00	68.50	109.50
Rondout	69.40	85.05	64.50	53.33	72.00	95.00
Wappinger	99.28	87.78	59.12	54.67	22.50	32.66

Table 3. Various statistics from Hudson River bass tournaments from 1986 to 1991 (1986-1988 data from Festa, 1990).

	1986	1987	1988	1989	1990	1991
No. of Trips	1,946	1,443	1,129	1,530	1,704	1,132
% Limit Catches	16.0	6.7	15.1	11.4	4.2	4.6
Largest Bass (kg)	3.1	3.1	2.3	3.0	2.9	3.0
Bass/Trip	2.11	1.43	1.58	1.86	1.30	1.39
Lmb/Trip	1.84	1.00	1.26	1.44	0.90	1.06
Smb/Trip	0.27	0.43	0.32	0.42	0.40	0.33
% Largemouth	87.4	69.9	79.7	77.5	68.8	76.1
Mean Weight (kg)	0.94	0.99	0.99	1.03	0.86	0.94

Table 4. Results of the river-wide mark and recapture population estimate for adult largemouth bass <280 mm in the Hudson River.

	1989	1990	1991
Number of fish marked in the spring	1,667	1,683	1,892
Number of largemouth bass examined	2,039	1,429	1,141
Number of recaptures	147	159	151
Population estimate	21,954	14,503	14,230
90% confidence intervals	± 2,844	± 1,768	± 1,762
Percent of fish examined that were recaptures	7.2	11.1	13.2
Number of smallmouth bass examined at tournaments	663	687	455
Percent smallmouth bass in catch	22.7	31.1	26.3

Table 5. Population estimates and 90% confidence intervals for largemouth bass over 280 mm in five wintering sites of the Hudson River.

	Winter 87-88[1]	Winter 88-89[2]	Winter 89-90[3]	Winter 90-91[4]
Coxsackie	**741**±292	**1,032**±959	**753**±481	**540**±306
Catskill	**4,074**±1,169	**4,363**±1,105	**3,134**±692	**3,333**±1,039
Esopus	**4,722**±1,561	**4,335**±1,060	**5,672**±1,466	**4,095**±1,160
Rondout	**4,428**±1,525	**3,865**±1,023	**3,466**±768	**3,397**±1,029
Wappinger	**3,340**±909	**2,152**±374	**2,024**±363	**1,400**±300
Total	**18,210**±2,716	**13,370**±1,470	**12,158**±1,216	**10,617**±1,343

[1]From fish marked in spring, 1988 and recaptured in spring, 1989.
[2]From fish marked in spring, 1989 and recaptured in spring, 1990.
[3]From fish marked in spring, 1990 and recaptured in spring, 1991.
[4]From fish marked in spring, 1991 and recaptured in spring, 1992.

Table 6. Adult largemouth bass wintering site density estimates for 1990.

Wintering Site	Surface Area (hectares)	Population Est.	Density (bass/ha)
Coxsackie Cove	12.5	68-1824	5-146
Catskill Creek	13.0	2576-4352	200-335
Esopus Creek	11.0	3158-5112	287-464
Rondout Creek	55.5	2626-4506	47-81
Wappinger Creek	25.5	1533-2163	60-85
Combined	117.5	11357-14291	96-121

Table 7. Average length (mm) of largemouth bass sampled by electrofishing and at tournaments on the Hudson River in 1989-1992.

	1989	1990	1991	1992
Electrofishing				
Average Length	381.7	381.4	380.7	383.4
Sample Size	1780	1824	2010	964
Std. Deviation	65.7	64.7	64.5	77.0
Tournaments				
Average Length	380.6	383.7	384.3	
Sample Size	2241	1518	1277	
Std. Deviation	46.7	48.8	49.1	

Table 8. Average length (mm) of largemouth bass sampled by electrofishing in the Hudson River at five known wintering sites in spring 1989-1992.

Site	Average Length	Sample Size	Standard Deviation
Coxsackie Cove	352.0	292	71.9
Catskill Creek	368.0	1576	62.5
Esopus Creek	389.4	1754	66.9
Rondout Creek	374.2	1588	70.1
Wappinger Creek	401.9	1368	59.1

Table 9. Survival rate estimates and 90% confidence intervals for largemouth bass over 280 mm in the Hudson River, 1988-1990.

Period	Survival Rate	Variance	90% CI
88-89	0.45	0.004	0.110
89-90	0.35	0.003	0.088
90-91	0.57	0.006	0.129

Table 10. Survival rate estimates and 90% confidence intervals for largemouth bass over 280 mm in 5 wintering sites in the Hudson River, 1989-1990.

	1989-1990		1990-1991	
	Survival	90% CI	Survival	90% CI
Coxsackie	0.33	0.59	0.85	1.25
Catskill	0.19	0.11	0.68	0.30
Esopus	0.42	0.16	0.47	0.16
Rondout	0.45	0.23	0.67	0.28
Wappinger	0.51	0.39	0.41	0.39
Total	0.35	0.09	0.57	0.13

Table 11. Length, weight and movement of largemouth bass radiotagged on the Hudson River in 1989 and 1990.

Date Marked	Transmitter Frequency (MHz)	Length (mm)	Weight (gm)	Release Location (rm)	Final Location (rm)	Total Distance Traveled (mi)	Wintered in Known Area? (Y/N)
10/20/89	53.851	421	1280	142	148	6.0	N
10/19/89	53.811	308	500	135	145	10.0	N
10/18/89	53.671	451	1600	124	125.5	1.5	Y
10/18/89	53.641	441	1490	124	102	22.0	Y
10/19/89	53.751	318	510	135	135	0.0	N
10/18/89	53.571	409	1110	118	118	0.0	N
10/18/89	53.621	376	760	118	118	0.0	N
10/17/89	53.651	412	1200	109	112.5	3.5	Y
10/17/89	53.602	384	1080	109	102	7.0	Y
10/23/89	53.152	473	1850	101	102	1.0	Y
10/23/89	53.202	387	850	101	91	10.0	Y
9/12/90	53.501	310	510	110.5	111	0.5	N
9/18/90	53.675	423	1380	96.5	97	0.5	N
9/1890	53.650	419	1270	94.5	90	4.5	N
9/18/90	53.625	459	1400	91.7	87	4.7	N
9/10/90	53.351	477	1850	88	90	2.0	N
9/10/90	53.374	411	1160	84.5	87	2.5	N
9/10/90	53.401	432	1480	83.3	84	0.7	N
9/11/90	53.425	317	530	80.5	77	3.5	N
9/11/90	53.448	348	680	76	76.5	0.5	N
9/11/90	53.476	394	1020	73	90	17.0	N
9/12/90	53.526	381	960	69	70	1.0	N
9/12/90	53.550	387	890	67	61	6.0	Y
9/13/90	53.575	458	1690	64	62	2.0	N
9/13/90	53.600	403	1350	61	61	0.0	Y

Table 12. Length, weight and last recorded location of smallmouth bass radiotagged on the Hudson River.

Date Marked	Transmitter Frequency (MHz)	Length (mm)	Weight (gm)	Release Location (rm)	Final Location (rm)	Total Distance Traveled (mi)	Wintered in Known Area? (Y/N)
10/20/89	901	445	1220	146.5	149	2.5	N
10/20/89	831	481	1790	145.5	151	5.5	N
10/20/89	931	352	550	145	144.5	0.5	N
10/19/89	801	435	1205	132	145.5	13.5	N
10/19/89	782	465	1500	132	135	3	N
10/19/89	770	387	800	132	133	1	N
10/18/89	701	439	1260	124	118	6	N
10/18/89	722	339	580	124	125	1	N
10/18/89	691	411	1060	124	125	1	N
10/18/89	452	392	860	121	121	0	N
10/18/89	551	397	975	121	122	1	N
10/18/89	402	390	860	120.5	114	6.5	N
10/17/89	741	403	1040	111.5	110.5	1	N
10/17/89	870	405	980	111.5	110	1.5	N
10/17/89	501	356	720	110.5	110.5	0	N
10/23/89	352	454	1530	100	100	0	N
10/23/89	302	417	900	99	91	8	Y
10/23/89	251	464	1300	98.5	91	7.5	Y