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[Article]

Intercept Telemetry of the Hudson River Striped Bass Resident Contingent: Migration and Homing Patterns

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Abstract.—Hudson River striped bass *Morone saxatilis* show highly variable migration patterns, as observed through past tagging studies and otolith microchemical analyses. Recent studies have shown resident, estuarine, and ocean migratory contingents in the Hudson River. We undertook a directed study to more precisely characterize the seasonal migrations of the resident contingent. Remote biotelemetry was conducted on 12 resident striped bass during a 14-month period in 2004–2005. All tagged striped bass migrated downriver from October 2004 to January 2005 and returned upriver from March to May 2005. Observed seasonal migration patterns were similar to those expected from previous tagging and otolith microchemistry studies: directed downriver emigration to brackish-water overwintering habitats was followed by upriver migration to spring–summer freshwater feeding and spawning habitats. Eight of 12 fish showed directed spring migrations upriver to their original tagging site and were repeatedly located there, indicating strong homing behavior and residence. These very specific patterns of homing indicate that local-scale effects (e.g., fishing, pollution) can have persistent effects on components of the Hudson River striped bass population.

Striped bass *Morone saxatilis* show highly variable migration patterns that have consequences to their vulnerability to fishing, contaminant exposure, and anthropogenic effects (Clark 1968; Secor and Piccoli 1996; Secor 1999). Clark (1968) classified this variability into separate contingents, each of which "maintains its integrity by engaging in a distinct pattern of seasonal migrations not shared by fish of other contingents." Clark (1968) defined three migration contingents of Hudson River striped bass: the Hudson–Estuary, Hudson–West Sound, and Hudson–Atlantic contingents. McLaren et al. (1981) also described separate migration behaviors in which one group begins a coastal migration after spawning and the other remains resident in the river. Recent otolith microchemistry studies have verified this migratory behavior and classified three contingents: (1) a resident contingent that inhabits the freshwater and oligohaline tidal portion of the Hudson River; (2) an estuarine contingent that inhabits the lower estuary, including the New York City harbor and western Long Island Sound regions; and (3) a migratory contingent that inhabits marine environments and makes annual excursions into freshwater for spawning (from here on, contingents will be labeled "resident," "estuarine," and "migratory" after Zlokovitz and Secor 1999, Secor et al. 2001, and Zlokovitz et al. 2003).

The Hudson River presents a unique opportunity to study this contingent behavior with intercept telemetry, as these behaviors are only coarsely known for striped bass. Tagging and otolith microchemistry are sufficiently precise to classify these modalities, but do not provide the resolution to discern variable patterns of migration within contingents. Knowledge of fine-scale movements is needed to better understand consequences of this contingent behavior on population vulnerability to fishing, contaminant exposure, and other anthropogenic effects. Biotelemetry has advanced appreciably in the last decade, now permitting large estuarine and coastal systems to be surveyed for individual migration behaviors (Heupel et al. 2006). The Hudson River and striped bass are particularly amenable to these studies: the long, thin, straight southerly course of the Hudson River allows an efficient series of passive acoustic receivers ("gates") to intercept migrating fish, and there is solid precedence for acoustic telemetry and surgical implantation of transmitters in striped bass from other systems (Haeseker et al. 1996; Carmichael et al. 1998; Tupper and Able 2000; Hightower et al. 2001).

Here, we describe seasonal migrations of resident Hudson River striped bass. Remote and manual biotelemetry was conducted on 12 resident striped bass during a 14-month period, 2004–2005. In addition to describing environmental correlates and rates of migration, we sought to determine (1) the seasonal period of residency in the freshwater tidal portion of the Hudson River and (2) the degree of homing to localized up-estuary regions.

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Methods

Fish tagging.—Before any fieldwork was conducted in the Hudson River, tagging methods were practiced and tested on striped bass in June 2004 (see Cooke and Wagner 2004). Fish were collected from a local pound net at the mouth of St. Leonard's Creek, Maryland, and randomly placed into three groups: tagged, incision only, and control. Dummy transmitters (Vemco, Inc., Shad Bay, Nova Scotia; same size and weight as telemetry transmitters) were implanted in "tagged" fish by the tagging procedure described below. Incision-only fish underwent the same procedure, but a dummy transmitter was not implanted. Mean operating time between the two authors ranged from 5 to 7 min. Fish were randomly placed in three 4,000-L, flow-through tanks and held for 30 d. After 30 d, fish were euthanized and examined for external infection or inflammation, condition of incision and sutures, and internal position and condition of the transmitter. All striped bass ($N = 16$; mean fork length [FL] ± SD = 588 ± 52 mm) survived the 30-d trial period in good condition. Incisions were completely closed in all dummy-tagged fish and incision-only fish, despite some sutures missing. Most fish (75%) showed only slight redness around sutures (25% showed moderate redness). No internal infection or organ damage was observed from tagging.

Surgical implantation of telemetry transmitters followed that of Haeseker et al. (1996). Striped bass were anesthetized in a solution of 60 mg of tricaine methanesulfonate (MS-222)/L of water and 30 mg of quinaldine sulfate/L of water. The ultrasonic transmitter was implanted through a 25-mm midline incision located anterior to the pelvic girdle. The incision was then closed with a simple interrupted suture pattern (Summerfelt and Smith 1990) using sterile, absorbable surgical monofilament (Ethicon, Inc., Piscataway, New Jersey; CP-1). The closed incision was treated with triple antibiotic ointment and nitrafurazone powder, and the fish was injected intramuscularly with oxytetracycline (10 mg of oxytetracycline/kg of body weight; Haeseker et al. 1996) to reduce infections.

Field study.—Striped bass were captured from the upper Hudson River through vessel-based electroshocking near Troy and Catskill, New York (river kilometers [rkm] 242 and 184, respectively, as measured from the mouth of the river) in September 2004 (Figure 1). Location and timing of fish tagging ensured collection of resident fish (Zlokovitz et al. 2003). Twelve fish were surgically implanted with individually coded ultrasonic transmitters (Vemco; Model V16-4H-R04K; 65 mm, 10 g, 1.5-year expected battery life, random ping rate = 20–69 s). In the days after tagging, remote receivers (Vemco; Model VR2) were moored underwater at rkm 242 (Green Island Bridge [GIB]), 184 (near Rip Van Winkle Bridge [RVW]), and 76 (Bear Mountain Bridge [BMB]) to intercept tagged fish (one receiver per site; Figure 2). These remote receivers continuously monitored for individual tagged fish and recorded the fish tag identification number, date, and time when fish were within the receiver range (>1 km). Receiver range was tested by placing tags at distances of 0.0, 0.5, 1.0, and 2.0 km from the receiver. Detections per minute were calculated for each distance. Receiver locations were chosen based on two conditions: (1) complete receiver coverage of the river width at that point, and (2) permission from relevant regulatory agencies (i.e., New York State Bridge Authority, New York State Canal System, and U.S. Coast Guard). We assumed 100% detection efficiency of receivers at these locations, as river width was less than 1 km (GIB = 0.2 km; RVW = 0.7 km; BMB = 0.6 km) and receiver tests showed

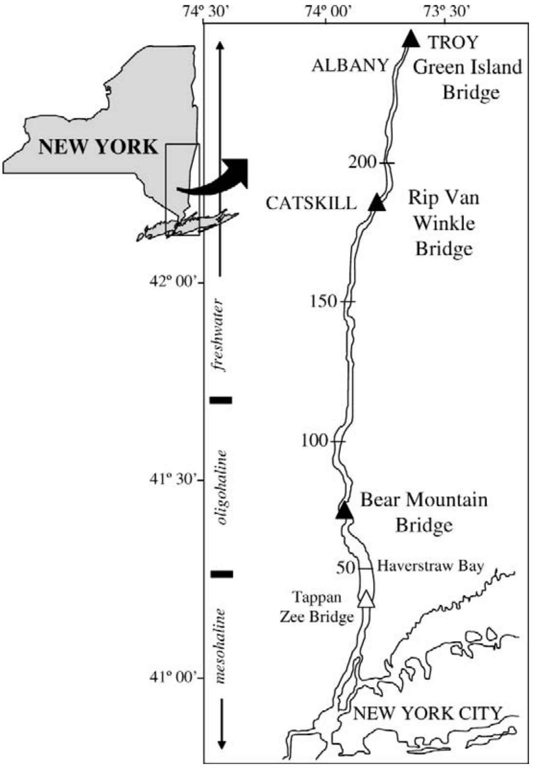

FIGURE 1.—Map showing tagging locations, remote receiver intercept sites, and location of the highest angling effort for striped bass in the Hudson River, New York. Receiver intercept sites and tagging sites are indicated by closed triangles. The highest angling effort occurred from the Tappan Zee Bridge (open triangle) to Albany.

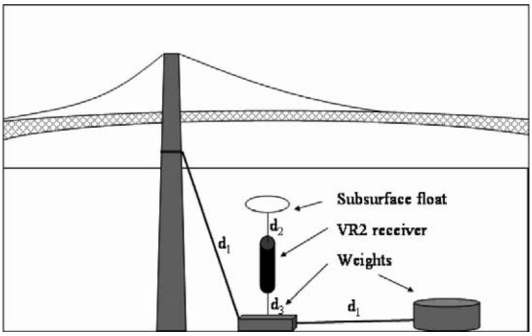

FIGURE 2.—Remote receiver deployment scheme used in a study of striped bass in the Hudson River, New York. Distances between VR2 (Vemco) receivers are indicated as follows: d_1 = distance from the small weight (7 kg) to the bridge structure and distance from the small weight to the large weight (35 kg), determined by water depth at each site; d_2 = distance from the receiver to the float (1 m); and d_3 = distance from the receiver to the small weight (2 m).

detections per minute greater than 0.5 at a distance of 1 km. Remote receivers were retrieved in November 2004 and in May, July, and November 2005; data were downloaded onto a laptop computer, and receivers were returned to their original locations. Manual surveys for tagged fish were also conducted during these 4 months to provide locations of fish between the intercept locations. A surface receiver (Vemco; Model VR60; detection radius $>$ 1 km) was deployed for 5 min every river kilometer from a small vessel. The freshwater tidal extent of the Hudson River (rkm 76–242) was surveyed, and location was recorded when tagged fish were detected. In some areas of the river, two passes were needed to accommodate river width or channel islands. Surface water temperatures for the study period were obtained from the U.S. Geological Survey monitoring sites at Albany (rkm 232), Poughkeepsie (rkm 180), and West Point (rkm 83).

Data analysis.—Fish tagged in this study were first classified by tagging site (Troy and Catskill) and then by contingent subdivision (A- and B-residents [defined later] and transitional residents) for statistical and descriptive purposes. Final status of tagged fish was determined as follows: fish remaining in the tidal freshwater portion of the river (BMB to GIB, rkm 76–242) at the end of the study (November 2005) were defined as "active"; fish that completed their second fall migration downriver, past BMB, were defined as "downriver"; and fish that completed a spring migration upriver past BMB and established residence at their tagging site but that were not subsequently detected were defined as "lost."

The seasonal period of residency in the freshwater tidal portion of the Hudson River for 2005 was calculated for all tagged fish ($n = 12$) with the use of event analysis and the Kaplan–Meier estimator, $S(t)$. In this case, residence was defined as the time elapsed between entry into the freshwater tidal portion of the river (migration upriver past BMB) and subsequent exit (migration downriver past BMB). This method estimates residence times based upon the entire distribution of event times using data from individuals that completed their residence (downriver fish) as well as those that are still present in the river (active fish) or lost from the study (Castro-Santos and Haro 2003; Schroepfer and Szedlmayer 2006). The Kaplan–Meier estimator represents the proportion of individuals remaining at time t and is defined as

$$S(t) = \prod_{j:t_j \leq t} (1 - d_j/n_j)$$

where for each time t_j, there are n_j striped bass at risk of an event (i.e., leaving the freshwater tidal portion of the river) and d_j striped bass that have already experienced the event (Allison 1995; Castro-Santos and Haro 2003). The origin of time was defined as the up-estuary entry past BMB in the spring of 2005. All striped bass with a final status of downriver were considered to have experienced the event, while striped bass with a final status of active or lost were not considered to have experienced the event (i.e., these were right-censored observations). The length of residence for censored fish was the time elapsed between entry into the freshwater tidal portion of the river and the last detection in the river. The mean and median residence times were calculated.

We used a chi-square contingency table analysis to determine whether the final location of summer residence was independent of tagging site (i.e., homing behavior to original tagging site). The final location of summer residence was defined as the location of the northernmost receiver detection for each individual.

Migration rates were calculated for individual fish traveling between receiver intercept locations. For example, rate of movement between GIB and RVW was calculated as the difference between the date and time of the last detection at GIB and the first detection at RVW. Migration rates are only approximated, as this calculation assumes constant straight-line travel between receiver locations. Migration rates were compared between tagging sites and seasons with analysis of variance (ANOVA). Migration rates were also compared with fish size (correlation analysis). We also used a chi-square contingency table analysis to determine whether fish traveled on outgoing tides during the fall migration downriver and on incoming

TABLE 1.—Summary of telemetry data from resident striped bass that were tagged and tracked in the Hudson River, New York, between September 2004 and November 2005. Date of entrance indicates date of first detection at Bear Mountain Bridge (BMB) in the spring of 2005. Date and site of last detection at receiver intercept sites (BMB; Rip Van Winkle Bridge [RVW]; or Green Island Bridge [GIB]) or during manual surveys (location reported in river kilometers [rkm] as measured from the mouth of the river) in 2005 are indicated. Length of freshwater residence is the difference between the date of last detection and the date of entrance.

Fish number	Tagging site	Subdivision	Fork length (mm)	Date of entrance	Date of last detection	Site of last detection	Length of freshwater residence (d)	Final status
1	Troy	A-resident	567	20 Apr	15 Nov	BMB	209	Downriver
2		A-resident	630	20 Apr	9 Jun	GIB	50	Lost
3		A-resident	464	24 Apr	17 Nov	rkm 114	207	Active
4		A-resident	675	11 Apr	27 Oct	BMB	199	Downriver
5	Catskill	A-resident	490	22 Apr	12 Oct	RVW	173	Active
6		A-resident	585	21 Apr	1 Nov	BMB	194	Downriver
7		A-resident	480	13 Apr	4 Oct	BMB	174	Downriver
8		A-resident	565	30 Apr	26 Oct	BMB	179	Downriver
9		B-resident	555	2 May	16 Nov	rkm 174	198	Active
10		B-resident	530	6 Apr	29 May	RVW	53	Lost
11		Transitional	564	24 Mar	22 Jun	BMB	90	Downriver
12		Transitional	600	20 Apr	2 Jun	BMB	43	Downriver

tides during the spring migration upriver. All tests in this study were considered significant at P-values less than or equal to 0.05.

Results

Twelve resident striped bass were tagged with ultrasonic transmitters and tracked throughout the freshwater tidal portion of the Hudson River for 8–14 months (Table 1). Mean FL (±SD) of tagged striped bass was 559 ± 62 mm (range = 464–675 mm) and did not significantly vary between tagging locations (P = 0.34). Total detections for individual fish on the remote receivers were variable, ranging from 106 to 22,441 (mean ± SD = 3,034 ± 6,145). Manual surveys resulted in 17 additional fish positions (Figure 3). Fish were resident in the freshwater tidal portion of the Hudson River for 43–209 d. The Kaplan–Meier estimator showed a mean (±SD) residence of 172 ± 17 d and a median residence of 194 d (95% confidence interval around median = 174–209 d; Figure 4).

Tagged striped bass showed variable migration patterns that were divided into three subdivisions of the resident contingent, as described below. All tagged striped bass emigrated downriver past the lowest intercept site at BMB from October 2004 to January 2005 and returned upriver during March–May 2005 (Figure 3). Eight of 12 fish, termed A-residents, showed directed fall and spring migrations and were repeatedly located at their original tagging site. A contingency table analysis showed that the final location for summer–fall residence was not independent of location tagged, indicating strong homing behavior for these fish (likelihood ratio chi-square: $P < 0.01$). The A-resident fish spent 51–154 d at their original tagging site before beginning their fall migration downriver. Two striped bass exhibited a wandering behavior and were termed B-residents. During fall and winter, the two fish repeatedly moved up and down the river. The following spring, one of these fish moved upstream past its tagging site and spent approximately 1 month near the GIB intercept site before returning to its original tagging site for the remainder of the summer. Additionally, two fish migrated into and out of tidal freshwater during the spring migration (transitional residents).

Temperatures at time of migration were variable between fish and between years but were similar during both spring and fall migrations (Figure 5). Fish began the 2004 fall emigration at a mean (±SD) temperature of 15 ± 4°C and left the freshwater tidal portion of the river at a mean temperature of 10 ± 7°C. Similarly, fish began the spring upstream migration at a mean (±SD) temperature of 10 ± 2°C and returned to their original tagging location at a mean temperature of 15 ± 3°C. Eleven of 12 fish returned upriver in the period after the highest river flow (Figure 6). The timing of migration was similar between tagging sites (Figure 5). In the fall of 2005, fish began emigrating at higher temperatures (mean ± SD = 19 ± 7°C) and left the freshwater tidal portion of the river at a mean temperature of 13 ± 6°C. Because the emigrant sample size in 2005 was small, temperatures between years were not statistically compared.

In fall of 2004, most fish moved downstream past receiver intercept locations on ebbing tides (66%; $P < 0.01$), while only small percentages moved on flood or slack tides (24% and 10%, respectively). Conversely, in the spring of 2005, most fish moved upstream on flooding tides (70%; $P < 0.01$). Again, small

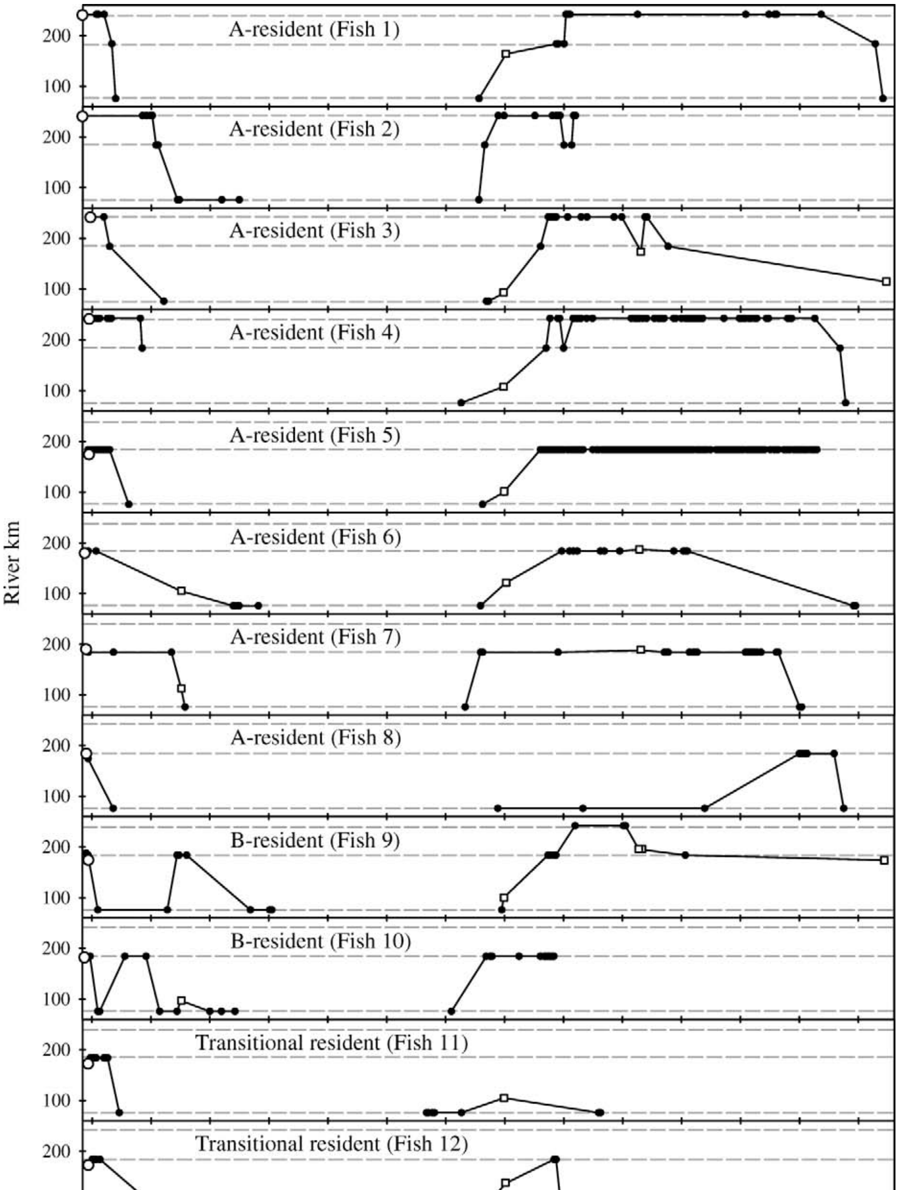

FIGURE 3.—Migration patterns of tagged striped bass in the Hudson River, New York, from September 2004 to November 2005. Open circles indicate dates of tagging, closed circles represent dates of individual receiver detections at intercept sites, and open squares indicate dates of surface detections made during manual surveys. Horizontal dashed lines indicate remote receiver intercept locations (Green Island Bridge, rkm 242; Rip Van Winkle Bridge, rkm 184; and Bear Mountain Bridge, rkm 76).

percentages of fish moved on ebb or slack tides (27% and 3%, respectively).

Tagged striped bass moved between receiver intercept sites at varying rates (mean ± SD = 0.61 ± 0.63 km/h; range = 0.06–2.66 km/h; Table 2). Troy fish moved between sites at a significantly faster rate than Catskill fish in both fall and spring migrations (ANOVA: $P_{\text{overall}} < 0.01$, $P_{\text{fall}} < 0.01$, $P_{\text{spring}} < 0.01$). However, no difference was detected between seasons for all fish combined ($P = 0.20$). Also, the rate of movement between intercept sites was not related to fish size ($P = 0.23$).

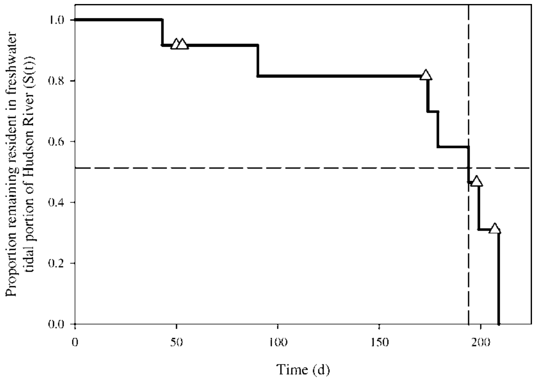

FIGURE 4.—The Kaplan–Meier survival function ($S[t]$) for Hudson River (New York) tagged striped bass, 2004–2005. Open triangles indicate censored observations; dashed lines indicate time when 50% of tagged striped bass remained resident in the freshwater tidal portion of the river.

Discussion

This study verified that a contingent of striped bass resided in the freshwater tidal portion of the Hudson River for most of the year, as shown indirectly by past otolith microchemical studies (Zlokovitz and Secor 1999; Secor et al. 2001; Zlokovitz et al. 2003). Intercept telemetry uncovered diversity in migration behaviors within this single contingent. The A-residents best illustrated the seasonal patterns of migration within the resident contingent: a directed emigration in the fall and winter to brackish-water overwintering habitats was followed by an upriver migration to spring and summer freshwater feeding and spawning habitats. A minority of striped bass showed wandering behaviors (B-residents), repeatedly moving up and down the tidal freshwater portion of the river before a final migration south in the fall and winter of 2004. Further, transitional residents exhibited a pattern much like that of the migratory contingent of Hudson River striped bass described in otolith microchemical studies. Two fish showed a typical directed downriver migration in the winter of 2004, but upon returning upriver in the spring of 2005 they quickly returned downriver. Zlokovitz and Secor (1999) showed that in some individuals, lifetime salinity chronologies indicated a habitat shift from low to high salinity. We may have observed this habitat shift, as these fish were both resident in upper portions of the Hudson River upon tagging in the fall of 2004 and seem to have shifted to more migratory behaviors in 2005. This shift in migration behavior provides evidence that contingents do not have static designations and may shift over time.

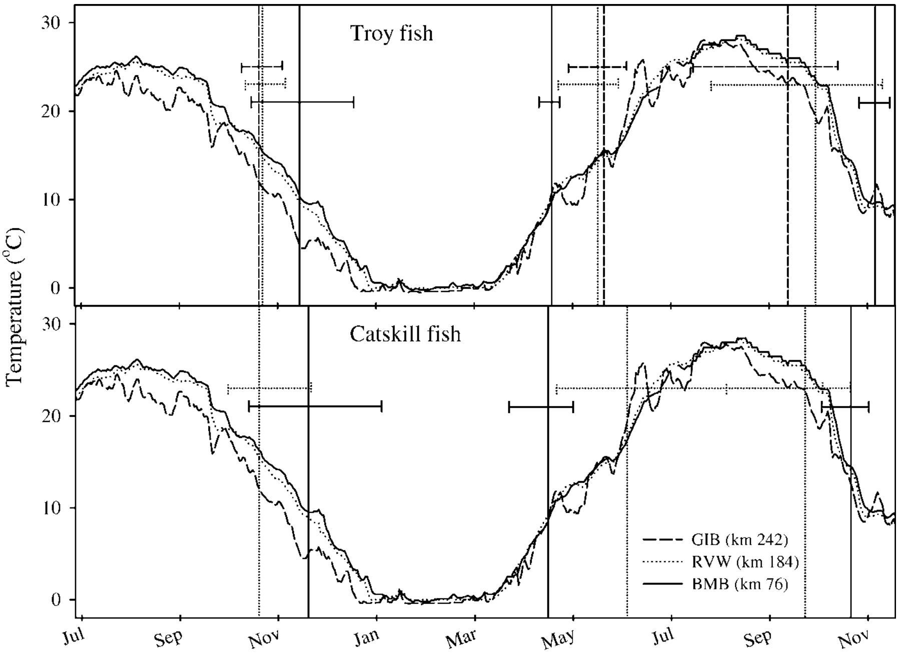

FIGURE 5.—Mean water temperature (°C) recorded at three sites (Green Island Bridge [GIB], Rip Van Winkle Bridge [RVW], and Bear Mountain Bridge [BMB]) in the Hudson River, New York, during a study of striped bass in June 2004 to November 2005. Data are presented separately for fish tagged with ultrasonic transmitters at Troy and Catskill. Vertical lines indicate mean dates of striped bass migration past each intercept site; horizontal lines indicate the range of dates.

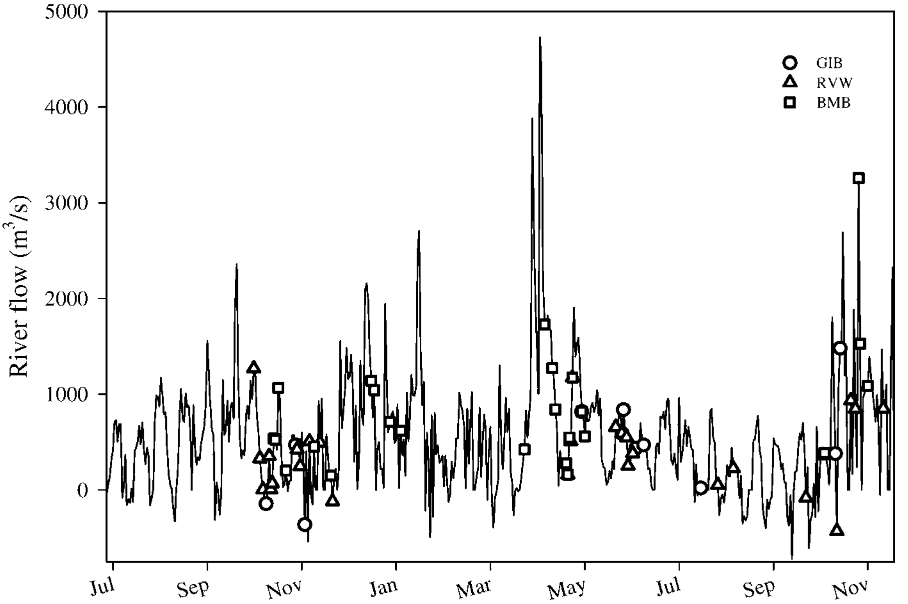

FIGURE 6.—Hudson River flow recorded in Poughkeepsie (rkm 180), New York. Symbols represent timing of striped bass migration past each of three receiver intercept locations (Green Island Bridge [GIB], Rip Van Winkle Bridge [RVW], and Bear Mountain Bridge [BMB]).

We documented a winter downstream migration to brackish tidal regions south of BMB in 2004 and 2005. Due to logistical constraints of sampling points south of BMB, we only documented an emigration south of our lowest intercept site, and our understanding of winter habitat use by the resident contingent is therefore incomplete. It is likely that resident striped bass overwinter in Haverstraw Bay based upon past tagging studies and the historical fishery that occurred there (McLaren et al. 1981, 1988). Further studies of winter habitat use in the areas of Haverstraw Bay are needed to confirm this expectation.

On a finer spatial scale, the resident contingent showed strong homing behaviors. Most fish showed directed migrations upriver to their original capture site and were repeatedly located there during the summer months (A-residents). These fish spent from 1.5 to 5.0 months at their original capture site with little or no movement between receiver intercept sites. Secor and Piccoli (1996) also found evidence for cohesive group

TABLE 2.—Rates of movement (km/h) between intercept sites for Hudson River (New York) tagged striped bass, 2004–2005. Asterisks denote significant differences (ANOVA) between fish tagged at Troy and Catskill during fall, spring, and combined seasons. For site abbreviations, see the Table 1 caption.

	Fall			Spring			
Tagging site	GIB–RVW	RVW–BMB	Mean	BMB–RVW	RVW–GIB	Mean	Overall mean
Troy	0.59	2.66		0.11	1.62		
	1.14	0.43	0.79	1.35	0.39	0.87	0.83
	0.98	0.16	0.57	0.17	0.64	0.41	0.49
	1.72		1.72	0.10	1.64	0.87	1.30
Mean Troy	1.11	1.08	1.18*	0.43	1.07	0.75*	0.96*
Catskill		0.68	0.68	0.26		0.26	0.47
		0.06	0.06	0.11		0.11	0.09
		0.14	0.14	0.19		0.19	0.17
		0.63	0.63	0.53		0.53	0.58
		0.73	0.73				0.73
		0.31	0.31	0.09		0.09	0.20
		0.14	0.14	0.12		0.12	0.13
		0.44	0.44	0.15		0.15	0.30
Mean Catskill		0.39	0.39*	0.21		0.21*	0.33*

behavior in Hudson River striped bass; otolith microchemistry indicated that individuals collected during the same time or from the same area had similar lifetime salinity patterns.

Striped bass began their migration downstream in the fall of 2004, when temperatures dropped from 19°C to 9°C (mean = 15°C); the fish left the freshwater tidal portion of the river when temperatures dropped from 18°C to 0°C (mean = 10°C). No striped bass were present in this portion of the river when temperatures hovered around 0°C. Hurst and Conover (2002) found that the low temperature tolerance for Hudson River striped bass was compromised at low and high salinities, suggesting that intermediate salinities found in the lower Hudson River are important for moderating temperature stress and winter survival. Striped bass re-entered the freshwater tidal portion of the river in the spring of 2005 at a mean temperature of 10°C and returned to their original tagging sites at a mean temperature of 15°C, similar to the temperature range of the fall 2004 emigration. However, the range of temperatures of fish passage through BMB was narrower in spring than in fall (6–12°C versus 0–18°C), suggesting that temperature was a more important cue in the spring. Temperature as a cue to migrate downriver was unclear, as temperatures at the time of migration were higher in the fall of 2005 than in the fall of 2004. However, mean temperatures at the time of migration in the fall of 2005 were calculated with a much smaller sample size, as only five fish had completed their migration downriver at the termination of the study. River flow may also serve as a cue to return upriver. Most striped bass (11 of 12 fish) returned upriver in the period after the peak spring river flow. No clear association was observed between river flow and fall emigration.

Striped bass movements between receiver intercept locations were also influenced by phase of tide. Most striped bass selectively used the tide in both up-estuary and down-estuary migrations. In the fall of 2004, 66% of tagged fish began their downstream migrations on ebbing tides; in the spring of 2005, 70% of tagged fish began their upstream migrations on flooding tides. However, the role of tides in migration should be interpreted cautiously, as fish took several days to weeks to move between intercept locations and thus were influenced by multiple tidal phases.

Tagged striped bass moved between intercept sites at varying rates; some fish moved as fast as 2.66 km/h. For example, one fish traveled from the RVW intercept site to the BMB intercept site (108 km) in less than 48 h. Rates of 2.66 km/h correspond to a sustained swimming speed of 1.3 body lengths/s for the mean fish size in this study (559 mm). During the May 2005 manual survey, one fish was tracked at a rate of 7.5 km/h (3.7 body lengths/s) over a 5-km stretch of river. Most fish, however, moved at slower rates, taking days or even weeks to move between intercept sites. The mean rate of movement (0.61 km/h) corresponds to 0.3 body lengths/s. While the timing of migration was similar between tagging sites, fish tagged at Troy (furthest upriver) moved at significantly faster rates than fish tagged at Catskill, despite statistically similar fish sizes. Estimated rates of movement are mean straight-line vectors and do not incorporate probable excursions related to tide, river bathymetry, and individual behavior. As such, they are probably underestimates of potential sustained cruising speeds during directed migrations by striped bass.

Striped bass contingent behaviors have consequences for fish vulnerability to fishing, contaminant exposure, and anthropogenic effects. More specifically, contingent behaviors play a dominant role in the exposure of Hudson River striped bass to polychlorinated biphenyls (PCBs). The Hudson River commercial striped bass fishery has been closed since 1976, and recreational anglers are warned against consumption owing to elevated levels of total PCB concentrations in edible portions of striped bass (>2 mg/kg; Brown et al. 1985; McLaren et al. 1988). Zlokovitz and Secor (1999) and Ashley et al. (2000) have linked habitat use by the three contingents to PCB contamination in Hudson River striped bass. In particular, the resident contingent showed extremely elevated levels of PCBs (mean = 3.5–8.3 mg/kg) relative to the more migratory contingents. This study showed that resident striped bass resided in proximity to the contaminated source for as long as 7 months (median residence = 6.5 months), indicating high levels of exposure to PCBs.

Although the commercial fishing ban continues, the recreational fishery on the Hudson River plays an important social and economic role (Kahn and Buerger 1994; Peterson 1998). Peterson (1998) estimated that the recreational fishery supported over 600,000 angler-hours. The highest angling effort occurred from the Tappan Zee Bridge to Albany during weekends in May. Despite high levels of fishing, few striped bass were harvested (approximately 13% of total catch), mainly because of angler concerns about PCB contamination. Although the season is open from March to November, most striped bass fishing occurs from early April to late June (Peterson 1998; NYSDEC 2005), coinciding with the ingress of coastal striped bass in the spring (Clark 1968; McLaren et al. 1981; Waldman et al. 1990). We have shown that resident striped bass spend over half of the year in freshwater tidal waters, in contrast to migratory striped bass, which spend 1–2 months in this region during their spawning run (Clark 1968; Waldman 2006). Therefore, Hudson River anglers are more likely to consume a contaminated resident striped bass during summer and fall months after most migratory fish have emigrated.

Despite the limited number of resident striped bass investigated ($N = 12$), high survival (100%) of tagged fish allowed us to track all fish for 8–14 months and to document seasonal patterns of migration over 150 rkm of the Hudson River. Passive acoustic receivers efficiently recorded passage through intercept locations. Indeed, only one fish was unaccounted for at BMB during fall of 2004. All other fish were successfully detected as emigrating and returning to the tidal freshwater portion of the Hudson River. Intercept telemetry allowed us to verify the presence of a resident contingent of Hudson River striped bass and measure its residence time in the freshwater tidal portion of the river. Within the resident contingent, we discerned several finer-scale modalities related to their fidelity to the tagging site and persistence within the freshwater tidal portion of the estuary. These modalities, particularly the strong homing of the A-residents, suggest that local-scale effects (e.g., fishing, pollution) can have persistent effects on components of the Hudson River striped bass population.

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