

Evaluation of a Gastric Radio Tag Insertion Technique for Anadromous River Herring

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Abstract.—Anadromous river herring (alewives *Alosa pseudoharengus* and blueback herring *A. aestivalis*), which constitute a historically and ecologically important component of coastal rivers, have declined precipitously throughout the Atlantic seaboard. Suggested causes of river herring decline include commercial fishing and predation by striped bass *Morone saxatilis*. Although the causes of this recent trend are poorly understood, river herring are especially vulnerable to adverse impacts during their spring spawning migration. Radiotelemetry is an especially useful method for addressing potential problems encountered during the movement of these fish from the ocean to freshwater. In spite of frequent calls for evaluation of telemetry methods, controlled tests of posttagging effects are rare for alosids and virtually nonexistent for anadromous river herring. We developed a protocol for gastric tagging of anadromous river herring, and we used hatchery and field studies to evaluate behavior, tag placement, stress response, and posttagging mortality. We also compared tagger effects and quantified posttagging upstream movements of fish in the field. In controlled hatchery trials, no fish died at 10 min, 1 h, or 14 d posttagging. No tags were rejected, and only 1 of 35 ruptured the gut. In field cages, mortality, plasma cortisol, glucose, and chloride measured at 24 h were similar between tagged and untagged fish. In the field, 12 of 14 fish moved upriver after tagging and spent 114 h on average at upriver sites. Using a variety of approaches, we found no evidence that our tagging protocol adversely affected river herring in comparison with untagged fish that were subjected only to handling and holding. Our protocol, evaluated by comparing responses of tagged and untagged fish under controlled conditions, may be useful in future studies that seek to understand causes of decline for anadromous river herring.

Anadromous fish provide recreational and commercial fishing opportunities; serve as an ecological link between freshwater, estuarine, and coastal food webs (Salia et al. 1972; Willson and Halupka 1995); and are components of many coastal watershed restoration and management programs. Anadromous river herring, the collective term for two closely related and jointly managed species (alewife *Alosa pseudoharengus* and

blueback herring *A. aestivalis*; Collette and Klein-McPhee 2002), have historically been important in rivers along the mid- and North Atlantic coast of North America. Recently, anadromous river herring populations have declined precipitously. In response to this crisis, the National Oceanic and Atmospheric Administration designated the alewife and blueback herring as species of concern (NOAA 2007), and several Atlantic states (including Massachusetts, Rhode Island, Connecticut, North Carolina, and Virginia) have instituted a moratorium on the harvest and possession of river herring (MDMF 2005; RIDEM 2006; CDEP 2007; NCDENR 2007; VDGF 2007). Beal (1981) suggested

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Received May 6, 2008; accepted September 10, 2008
Published online April 9, 2009

that declines were initiated by high commercial fishing mortality at sea. Savoy and Crecco (2004) presented evidence that predation by striped bass *Morone saxatilis* could explain the declines of river herring in the Connecticut River. The causes of this coastwide decline are poorly understood, but anadromous river herring are especially vulnerable when they leave the ocean and enter freshwater rivers to spawn. Radiotelemetry may be a useful method of addressing potential adverse impacts on these fish during their upriver spawning migration.

Most anadromous fish telemetry studies focus on salmonids. It is generally recognized that clupeids are more difficult to handle and are more easily stressed than salmonids. Of the peer-reviewed telemetry studies on anadromous alosids, most have been undertaken to describe American shad *A. sapidissima* in a variety of locations (9 of 11 studies; Table 1). In telemetry studies, tag type, tag size, tag weight: fish weight ratio, antenna presence, antenna length, and use or type of anesthetic are important considerations (Winter 1996; Bridger and Booth 2003). These published alosid telemetry studies monitored adult clupeids (mean weight = 0.8 kg) that were tagged with acoustic or radio tags (mean tag diameter = 15 mm, mean tag length = 51 mm, mean tag weight = 8.6 g; Table 1). Acoustic tags produce underwater sounds in the range of 20–300 kHz and are primarily used in salt water, whereas radio tags produce sounds transmitted through the air at 27–300 MHz and are primarily used in freshwater (Winter 1996). The need to evaluate fish response to tagging is well known (Winter 1996; Bridger and Booth 2003), but such evaluations are rarely undertaken systematically. Among the previously published telemetry studies of anadromous alosids, only a few have recorded handling time, recovery time, posttagging mortality, or tag rejection (Table 1). However, most of the studies did record behavioral responses to tags, including the percentage of fish exhibiting fallback and the percentage of fish that did not return upriver after fallback (NR; Table 1). In summary, although gastric radio-tagging is used frequently to examine alosid movement, controlled, systematic evaluations of river herring responses to tagging are rarely reported. In the literature we reviewed for this paper, we found no published alosid studies that (1) compared tagged fish with untagged fish or experimentally documented tag placement, (2) quantified mortality of tagged fish for longer than 1 week, (3) measured physiological responses to tagging, or (4) developed and evaluated tagging protocols for anadromous river herring.

An important assumption of telemetry is that fish are not adversely affected by the tag or tagging procedure

(Rogers and White 2007). While the behavior of untagged fish cannot be easily observed in the field, we can document what happens to tagged and untagged fish under controlled circumstances and how tagged fish behave under relatively simple natural conditions. We developed and evaluated a gastric tagging protocol for anadromous alewives. Specifically, we addressed the following questions: (1) how do anadromous alewives respond to gastric tagging, as assessed by behavior, mortality, and physiological stress response; (2) is there a tagger effect; and (3) how do anadromous alewives behave (upstream movement, time spent upstream) in the river after tagging? We expected that fish not adversely affected by tagging would continue to move upriver to their spawning grounds and stay there for some period of time.

Methods

Overview.—To evaluate gastric tagging protocols for adult anadromous alewives, we used both hatchery and field components. At multiple times in the hatchery, we evaluated swimming behavior, mortality, body orientation, tag placement, and tagger effects for tagged alewives. In field cage experiments, we evaluated mortality and the physiological stress response after 24 h for tagged and untagged fish at two locations. Finally, for alewives tagged while moving upstream to spawn, we quantified upstream movement (a common behavioral assay of tagging effect) and hours spent upstream of the tagging site. Several components of this evaluation were undertaken in conjunction with a large-scale stocking evaluation, but only the components that are relevant to evaluation of tagging protocols are reported here.

Fish and study systems.—To evaluate the response to gastric radio-tagging, we tagged anadromous adult alewives from the Nemasket River in southeastern Massachusetts and the Ipswich River in northeastern Massachusetts (Figure 1A). At both locations, migrating river herring were predominantly made up of alewives. All tagged fish were early spawning adult alewives that were captured during their volitional upstream migration. Alewives that were native to the Nemasket River were used in hatchery trials and field cage experiments. Alewives that were native to the Ipswich River were used to evaluate posttagging movements of natural uprunners in the field to avoid confounding posttagging behavior with the effects of stocking.

For hatchery trials, we collected migrating adult alewives from the Wareham Street Dam fishway on the Nemasket River (river kilometer [rkm] 18) on April 1 and 17, 2006. We used these fish to develop and test a tagging protocol at the Sandwich Fish Hatchery. In the

TABLE 1.—Summary of alosid telemetry studies, including species of interest, study location (loc), fish weight (FW), sample size (N), telemetry tag type (AT = acoustic; RT = radio), tag size (diameter *D*; tag length *L*), tag weight (TW), TW:FW ratio, antenna length (ant), handling time (HT) for tagging, posttagging recovery time (RT), posttagging mortality (*M*), tag rejection (*R*), percentage of fish exhibiting fallback (FB), percentage of fish that did not return after falling back (NR), and study source. Species are allis shad (ALS) *Alosa alosa*, American shad (AMS), and blueback herring (BBH). Locations are France (FR), South Carolina (SC), Georgia (GA), Massachusetts (MA), North Carolina (NC), New York (NY), and Virginia (VA). Fish weight was estimated from length when not reported. Values of *M* were calculated from text and excluded fish that died on spawning grounds or during emigration. Values of *R*, FB, and NR were calculated based on sample size with mortality removed; NR was calculated as a percentage of reported FB.

Species	Loc	FW (kg)	N	Tag type	Tag size (mm)		TW (g)	TW:FW ratio (%)	Ant (mm)	HT (min)	RT (min)	<i>M</i> (%)	<i>R</i> (%)	FB (%)	NR (%)
					<i>D</i>	<i>L</i>									
ALS ^d	FR	1.5	23	AT	6	60	7–8	<2		<2 ^a	40	9	5	9 ^c	39
AMS ^e	SC, GA	1	110	RT	9–11	20–36	1.5–3.4	<1		<2		14	5	98	53
AMS ^f	MA	1	34	RT	30	60	10	1	75	<4	<5			100	47
AMS ^g	NC	0.9	25	AT	16	74	10	1							
AMS ^h	MA	0.7	35	RT	14–16	33–36	5.3–5.6	<1				1		100	32
BBH ⁱ	SC	0.2	45	RT	9	24–29	4.2–2.8	1–2	275		<5 ^b	9		20	100
AMS ^j	NY	1	7	AT	13	64	14.2	<2		<1				14	100
AMS ^k	NC	1	17	RT	13	56	9	<2				<5 ^b		59	70
AMS ^l	NC	0.7	86	AT	16	35				<3				27	100
AMS ^m	VA	0.8	29	AT	11	40	4.3	1			<30			45	15
AMS ⁿ	MA	1	72	RT	10	29	3.9	<1	300	<1				10	71
Mean		0.8	46		15	51	8.6		217			8	5	48	63

^a Used anesthetic during tagging.

^b Estimated time.

^c Fallback fish included in *M*.

^d Acolas et al. 2004.

^e Bailey et al. 2004.

^f Barry and Kynard 1986.

^g Beasley and Hightower 2000.

^h Bell and Kynard 1985.

ⁱ Chappellear and Cooke 1994.

^j Dodson et al. 1972.

^k Hightower and Sparks 2003.

^l Moser et al. 2000.

^m Olney et al. 2006.

ⁿ Sprankle 2005.

hatchery, adult alewives were maintained in a round tank (6-m diameter; 18,000 L) in which water was continuously exchanged with water from an adjacent freshwater pond (approximate flow rate = 1 L/min). This tank was set up outside with a covered roof and open sides; throughout the study, temperature was maintained at about 14°C (a temperature that is typical of river herring ponds in April). For short-term studies, fish were held for 1 d before tagging, observed at 10 min and 1 h posttagging, and then sacrificed within 2 h of tagging to evaluate tag placement. To examine long-term tag-related mortality, fish in the hatchery were maintained for 1 d before tagging and for 14 d after tagging. Fish were not fed during the hatchery component of the study because alewives do not typically eat during their migration.

Tagging protocol.—We evaluated tagging protocols at the Sandwich Fish Hatchery on April 2 and 18, 2006. For hatchery and cage trials, we used Lotek dummy tags (9.1-mm diameter; 22 mm long; 2.8 g in air; 300-mm antenna; Figure 2A) to simulate Lotek Model NTC-6-1 NanoTags. The tagging protocol included a three-member team: tagger, handler, and recorder. First, the handler netted one or two fish from the hatchery tank with a fine-mesh nylon net. The fish were then placed in a round preoperation tank (48-cm diameter; filled to a depth of 35 cm) to ensure that the fish were swimming and were unharmed by netting.

We did not use anesthetic. The handler slowly approached a fish in the preoperation tank and placed a moist, folded cotton shop towel (36 × 31 cm) over the fish's eyes, taking care not to cover the mouth. The handler quickly but gently subdued the fish with one hand at the head and the other at midbody and moved the fish to the rectangular operation tank (31-cm width; 64-cm length; filled with 20 cm of water). While the fish was submerged in the operation tank, its total length was measured to the nearest 0.1 cm by use of a meter stick that was glued to the side of the tank.

To insert the tag, we used the shell of a plastic disposable pen with the ink cartridge removed as a tag holder (12.3-cm long; diameter tapering from 8 to 5 mm; Figure 2B). Using a file, a 1-cm notch was cut at the wider end of the tag holder. The antenna of the tag was threaded through the pen shell, and the antenna was held tautly by pulling it through and locking it into the notch (Figure 2B). When the tag was straight and rigidly attached to the pen, the entire assembly could be easily inserted into the fish's mouth.

For tag insertion, the handler held the fish underwater in the operation tank until the tagger signaled that he or she was ready. The handler raised the fish's mouth out of the water and oriented it towards the tagger. The tagger then pulled down the lower lip and adjusted the fish's angle until the tagger could see directly into the fish's mouth and down the

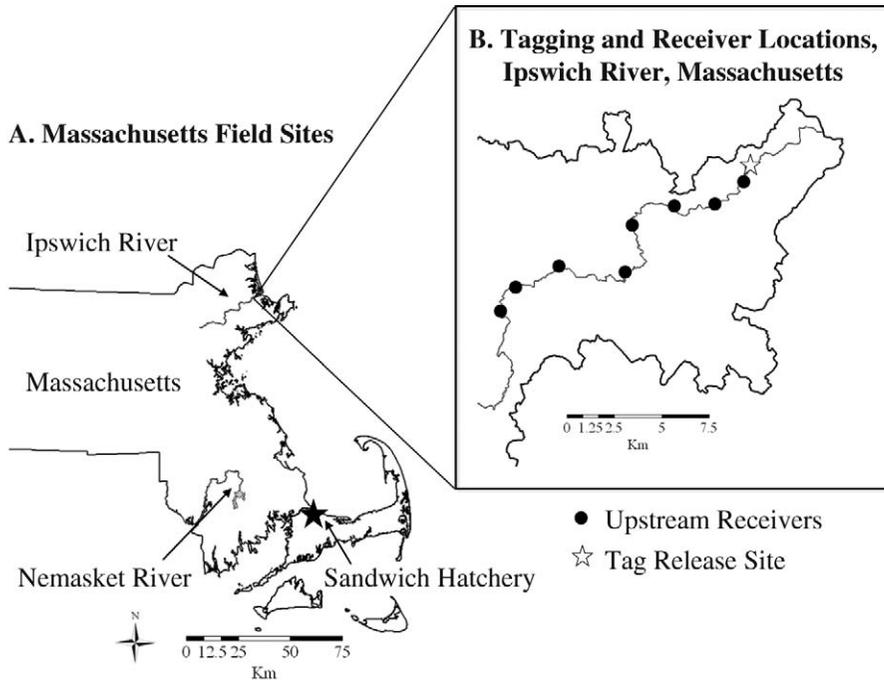


FIGURE 1.—(A) Map of the Nemasket and Ipswich rivers, Massachusetts. Anadromous alewives used in a tagging protocol evaluation at the Sandwich Fish Hatchery (solid star) were obtained from the Nemasket River. Field cage and physiological studies were conducted in both rivers using fish from the Nemasket River. (B) To quantify upriver movements after tagging, adult alewives that were voluntarily migrating up the Ipswich River were tagged and tracked from the first dam (open star; river kilometer [rkm] 6) through nine stationary receivers (rkm 6–30).

esophagus. The tag and tag holder were gently but firmly inserted into the gut until resistance was felt at the pyloric sphincter (Figure 2C). When resistance was felt, the tag was released by removing the antenna from the notch. When the tagging tool was removed, the tag remained in place (Figure 2D). If the tag was not inserted far enough, tag rejection (regurgitation) could occur. If the tag was inserted too far, the gastrointestinal tract could be ruptured. After tagging, the fish was quickly moved by the handler to the recovery tank and was released. If normal, upright swimming was observed, the fish was released into the large hatchery tank described above, and its responses to tagging were collected as detailed below. Our goal was to keep the total handling time to less than 1 min and tag insertion time to less than 30 s.

Hatchery tag evaluation.—Short-term responses to tagging were evaluated in several ways on April 2 ($N = 17$) and April 18, 2006 ($N = 18$). First, fish behavior (swimming around the perimeter of the tank or stationary), orientation (upright or not), and mortality were evaluated at 10 min and 1 h posttagging. We then observed whether the tag was rejected or whether the gut was ruptured at 2 h posttagging. For the latter, each

fish was euthanized with ice (AVMA 2007) and was dissected to assess whether the tag was retained snugly in the gut and whether the gut was ruptured. Upon dissection, length and sex were determined.

To test the role of variability among taggers, three people were trained using the protocol described above. For 35 fish on two dates (April 3, 2006; $N = 17$; April 18, 2006; $N = 18$), each person tagged an individual fish sequentially for five to six trials on 2 d. On each date, fish were tagged in a short period of time (<1 h); sequential tagging of fish was used to ensure that environmental effects were evenly distributed among the taggers. After a fish received a tag, a uniquely colored zip tie was attached to the fish's dorsal fin to identify the tagger so that mortality differences among fish tagged by different persons could be assessed. To assess long-term survival, 10 dummy-tagged fish were observed for 14 d (April 18–May 1, 2006) in the hatchery tank described above. The tank was checked for mortality daily.

Field tag evaluation.—To evaluate field mortality and stress response of river herring subjected to gastric tagging, we tagged upstream-migrating adult fish from the Nemasket River on April 20, 2006, in conjunction

with a yearly program in which alewives are trapped and transferred from the Nemasket River to the Ipswich River. Before any handling or tagging occurred in the Nemasket River, 18 alewives (mean total length = 277 mm; SE = 3.5 mm; male:female ratio = 1:1) were sampled to determine baseline levels of plasma cortisol, glucose, and chloride. For these initial samples, one to two fish were dipnetted from the Wareham Street Dam fishway into a single 15-L round bucket filled to about 30 cm with ambient water. Blood was collected within 5 min of capture in a quiet area where disturbances to the fish were minimized. To collect blood, one person removed a fish from the bucket and the fish was bled by piercing the caudal blood vessels with a heparinized syringe. After blood collection, syringes were stored on ice until all fish were processed. At the same time, total length, sex, and time of processing were recorded for each fish. When all 18 fish were processed, the blood was centrifuged at $2,000 \times$ gravity for 5 min and plasma was decanted, frozen on dry ice, and stored at -80°C for laboratory analysis. In the laboratory, plasma glucose, cortisol, and chloride concentrations were determined as described below.

After initial blood collection, fish were dipnetted from the fishway in the Nemasket River and either were tagged as described above or were handled (i.e., netted and held in a 15-L bucket) but not tagged. For the field cage evaluation of tagged and untagged fish, 10 pairs of fish ($N = 20$ total) were placed in five field cages within the Nemasket River. One fish from each pair was handled, measured, and placed in a 15-L bucket for transport to field cages. The other fish was tagged using the protocol described above. Two pairs of fish were placed in each field cage (61-cm diameter, 6-cm depth, 0.64-cm-mesh material). Field cages were anchored above the fishway at the water's edge at a depth of about 1.5 m in an area that was not tidal; cages were fully submerged and anchored to riparian vegetation.

The cage evaluation of tagged and untagged alewives was repeated for fish that were transported to the Ipswich River. Once the stocking truck with Nemasket River-origin alewives reached the Ipswich River (1,500 fish transported in 5,678 L; transport time = 2 h; transport temperature = 7°C), 20 fish were dipnetted from the stocking truck (1–2 fish/dip net). These fish were placed in individual 15-L buckets filled with Ipswich River water. Half the fish were tagged as described above; the other half were only handled. Two tagged fish and two untagged fish were then placed in each of five field cages as described above. The Ipswich River cage site was at rkm 25.1 at a depth of about 1.5 m (Figure 1B). The cage site was not

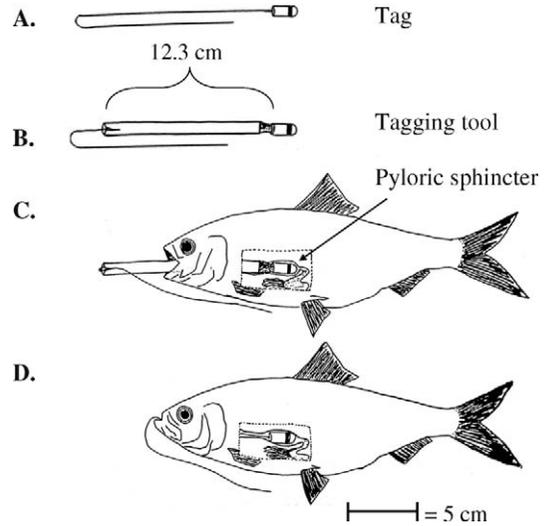


FIGURE 2.—Illustrations of (A) the Lotek NTC-6-1 radio NanoTag; (B) the tag loaded into the 123-mm tag-holding tool with tag antenna locked in the left-hand notch; (C) tag and tagging tool inserted into the gut of an anadromous adult alewife; and (D) tag seated just above the constriction between the alewife's stomach and intestine (pyloric sphincter) after removal of the tag holder. Although results will vary, we generally found that for a 270–300-cm alewife, the tag holder was inserted 80 mm into the fish (i.e., 43 mm of the tool protruded from the mouth).

tidal; cages were fully submerged and were anchored to riparian vegetation.

Survival of Nemasket River-origin alewives was assessed at 24 h in the Nemasket River and Ipswich River field cages. All fish from each system were sacrificed to collect blood samples for plasma cortisol, glucose, and chloride. Each cage was processed separately. One person removed fish from the cage; within 8 min of being netted, each fish was bled by piercing the caudal vein with a heparinized syringe. Samples were processed and stored as described above. Plasma cortisol was measured by direct enzyme immunoassay (Carey and McCormick 1998), which has been validated for use in alosids (Shrimpton et al. 2001). Glucose was measured by the hexokinase (enzyme number 2.7.1.1; IUBMB 1992) and glucose-6-phosphate dehydrogenase (1.1.1.49) enzymatic method using external standards (Stein 1963). Plasma chloride was analyzed by the silver titration method using a Buchler-Cotlove digital chloridometer and external standards. Two fish (one tagged and one untagged) in the Ipswich River field cages were not processed for blood plasma in the laboratory because of limited blood volume. For the Nemasket River and Ipswich River cage data, plasma cortisol, glucose, and

chloride were compared between tagged and untagged fish by means of a two-factor analysis of variance (ANOVA) in Statistical Analysis System (SAS) software (GLM procedure; SAS Institute 2003). Tag presence or absence and cage location (Nemasket River versus Ipswich River) were used as main effects. Post hoc power analysis was used to determine statistical power for each two-factor ANOVA (G*Power version 3.0.8; Buchner et al. 1997). Initial cortisol, glucose, and chloride ion concentrations were compared with values for tagged and untagged fish at each location by use of four individual *t*-tests (TTEST procedure in SAS; SAS Institute 2003). Sequential Bonferroni corrections were made to maintain an overall α of 0.05 (Holm 1979). Data were checked for conformity with analysis assumptions (i.e., normality and homogeneity of variance). Cortisol data were \log_e transformed to meet the ANOVA assumption of normality; glucose and chloride data did not require transformation.

Evaluation of postrelease movement.—To assess general behavior of tagged fish, 14 Ipswich River alewives (mean total length = 275 mm; SE = 3.2 mm; sex unknown) caught while volitionally moving upriver were tagged at the Ipswich Mills fishway (rkm 6; Figure 1B) on April 26–28, 2006. We used the tagging protocol described above with Lotek Model NTC-6–1 NanoTags. Upriver migrants were captured by a box trap (61-cm height, 61-cm width, 122-cm length) at the top of the Ipswich Mills fishway. Within 24 h of capture, fish were removed, measured, tagged, and released. Fish were handled for less than 30 s in each tagging event. Movements of the tagged, naturally migrating upriver fish were quantified by nine stationary receivers (Lotek Model SRX 400), each equipped with a single four-element Yagi antenna. The receivers were deployed between rkm 6 and 30 from April 26 to June 1, 2006 (Figure 1B). The first receiver was at the tagging site. We measured the number of fish that moved upstream and the time spent upstream of the release site. The purpose of this behavioral test was to link our protocol and evaluation to existing studies in which only the behavioral response to tagging was measured. Although we could not document immediate fallback because fish were released at the first receiver, we could quantify the number of fish that moved upstream.

Results

Tagging Protocol

The average time taken to insert a tag was 24.5 s (SE = 2.1 s). The optimal gastric tag position was just above the pyloric sphincter at a depth of about 80 mm for a 270–300-mm fish (Figure 2C, D).

Evaluation of Tagging Protocol

In the hatchery, 100% of the alewives survived the tagging procedure (10 min; $N = 35$). On both dates, all fish survived to 1 h posttagging and exhibited normal behavior (i.e., were oriented upright and swimming; Figure 3A). One fish's stomach was ruptured on April 2, 2006, but none of the fish had regurgitated their tags by 2 h posttagging on either date (Figure 3B). All fish survived to 14 d posttagging ($N = 10$). In field cages, no fish died within 24 h in either the Nemasket River or the Ipswich River and there was no difference in survival between tagged and untagged fish (Figure 3C). There was no tagger effect, as evaluated by posttagging mortality at 14 d (Figure 3D).

Physiological Stress Response

Alewives that were captured, handled, and held for 24 h in field cages had higher plasma cortisol and glucose and lower plasma chloride than initially caught fish ($P \leq 0.05$; Figure 4). No differences in cortisol (Figure 4A), glucose (Figure 4B), or chloride (Figure 4C) at 24 h were detected between tagged and untagged fish at either the Nemasket River or Ipswich River location (tag effect; Table 2). Alewives that were transported (Ipswich River) and those that were not transported (Nemasket River) had similar glucose and chloride levels, but cortisol was marginally higher in transported fish (\log_e -transformed mean = 6.66; SE = 0.19; mean = 780.55 ng/mL) than in nontransported fish (\log_e -transformed mean = 6.25; SE = 0.11; mean = 518.01 ng/mL; location effect: $P = 0.06$; Table 2). Power for all tests exceeded 0.71 (Table 2).

Posttagging Behavior

Of the 14 fish that were tagged during their upstream migration, 12 (86%) continued to migrate upstream to the next receiver after tagging (Figure 5A). The 12 upstream-migrating fish stayed upstream in the river for an average of 114 h (SE = 27 h; Figure 5B).

Discussion

Our study is unique in comparison with previous studies because we are the first to systematically evaluate the tagging response of alosids. Of all anadromous fish tagging studies, relatively few have examined alosid species. Of the radio- and acoustic tagging studies that used alosids (Dodson et al. 1972; Bell and Kynard 1985; Barry and Kynard 1986; Chappellear and Cooke 1994; Beasley and Hightower 2000; Moser et al. 2000; Hightower and Sparks 2003; Acolas et al. 2004; Bailey et al. 2004; Sprankle 2005; Olney et al. 2006), most have worked with American shad and have examined passage around dams with a

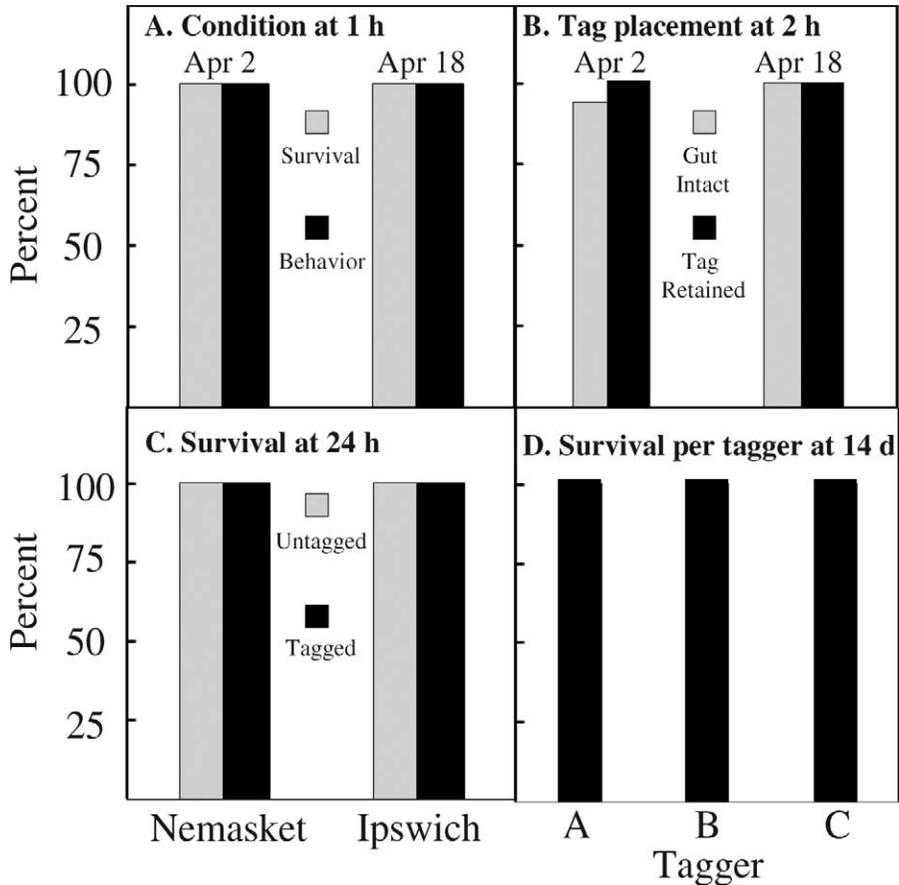


FIGURE 3.—Results of tagging protocol development and testing in anadromous alewives from Massachusetts rivers, 2006: (A) percent survival and normal behaviors (upright orientation and swimming) at 1 h posttagging in fish held at Sandwich Fish Hatchery; (B) percentage of tagged fish in which the gut was intact (not ruptured) and percentage of tags that were retained (correctly placed in the gut; not regurgitated) at 2 h posttagging; (C) percent survival of untagged (U) and tagged (T) Nemasket River-origin fish held for 24 h in field cages at the Nemasket and Ipswich rivers ($N = 20$ fish/location; 10 tagged and 10 untagged fish); and (D) percent survival at 14 d posttagging for fish tagged by taggers A–C and held at Sandwich Fish Hatchery.

secondary focus on spawning habitat and behavior. In telemetry, selection of tag size and type is critical because the presence of the transmitter can produce negative behavioral or physiological side effects that can impact the legitimacy of the study (Bridger and Booth 2003). Tagging studies of alosids have used radio tags (6 of 11 studies) and acoustic tags (5 of 11 studies) on adult fish (mean mass = 0.8 kg), and the weight of the tag has never exceeded 2% of the fish's body weight (Table 1). In these alosid studies, all tags (radio and acoustic) were attached via gastric insertion, generally without anesthetic (10 of 11 studies, the exception being Acolas et al. 2004; Table 1). Antennas, when present (3 of 11 studies), ranged from 75 to 300 mm (mean = 217 mm; Table 1). In the studies that reported it, handling time was less than 4 min (Table

1). About half of the prior studies held fish for a 5–40-min recovery period (5 of 11 studies) and ensured upright swimming after tagging (Table 1). Some studies (4 of 11) explicitly reported tag mortality (range = 1–14%; Table 1). Two studies reported tag rejection (5% in both cases; Table 1). One study that included allis shad was published in French and was not included in our summary (Gueneau 1986).

Most alosid tag studies used posttagging movements as a way of examining tag effects. Ten of 11 alosid tagging studies described fallback; the extent of fallback ranged from 9% to 100% of tagged fish (mean = 48%; Table 1). We defined fallback as downstream movement of tagged fish for a period of hours to days after release. Some researchers designated a 24-h limit for fallback, after which fish are assumed to be affected

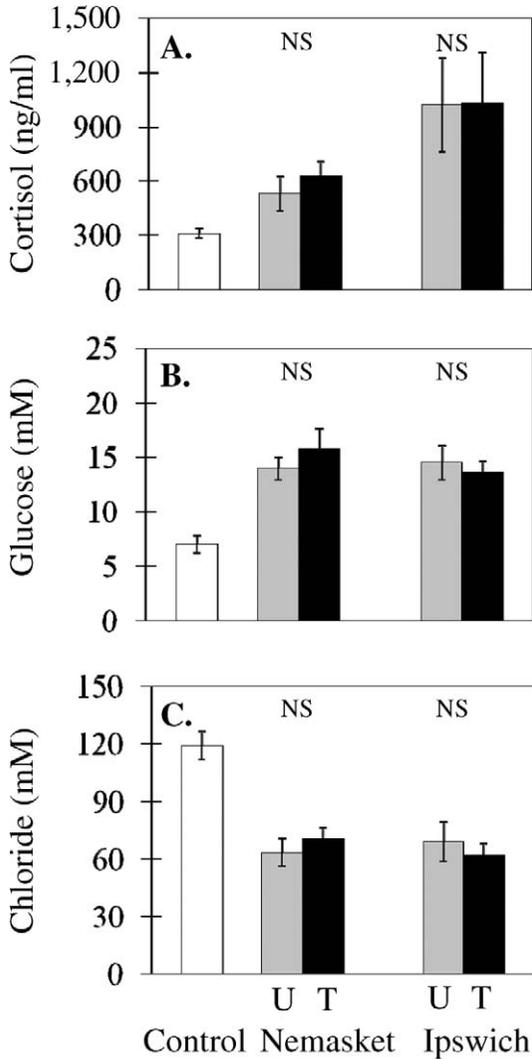


FIGURE 4.—Plasma levels of (A) cortisol, (B) glucose, and (C) chloride in initially sampled (control), untagged (U), and tagged (T) alewives of Nemasket River origin that were held in field cages at the Nemasket and Ipswich rivers, Massachusetts ($N = 20$ fish/location; 10 tagged and 10 untagged fish). Initial samples were collected before any tagging or handling activity occurred; tagged and untagged fish were sampled at 24 h posttagging. Tagged and untagged fish did not differ in any physiological parameter (two-way analysis of variance: NS = not significant, $P > 0.05$). Comparisons between the initial sample and each of the four conditions (tag presence or absence, Nemasket or Ipswich River location; not shown) were significant, indicating an effect of handling in all treatments.

by the tags and are removed from the data analysis (Chappelear and Cooke 1994). The fish that fall back may eventually recover and resume their upstream migration or may abandon upstream movement

completely. The NR percentage was reported in 10 of 11 studies (mean = 63%; Table 1). In our study, we were not able to assess fallback because we did not have a downstream receiver below the release site. However, we were able to assess how many alewives went upstream (86%; Figure 5A) and how long they stayed upstream (mean = 114 h; SE = 27 h; Figure 5B). The high percentage of upstream movements demonstrates that most of our fish did not fall back indefinitely and provides further evidence that our tagging protocol had low impacts on river herring.

The physiological effect of tag presence has not been previously evaluated for alosids. Cortisol increase is part of a fish's primary response to stress, and the magnitude of cortisol response can indicate the severity of the stressor (Barton and Iwama 1991; Jepsen et al. 2001). Secondary responses to stress involve changes in blood and tissue chemistry and are often indicated by elevated plasma glucose and decreased plasma chloride (Close et al. 2003). Cortisol levels in gizzard shad *Dorosoma cepedianum* increased after a 2-h confinement and transportation experiment, indicating clupeid sensitivity to handling and transport stressors (Davis and Parker 1986). In our study, caged river herring had higher plasma cortisol and glucose and lower plasma chloride than fish that were sampled directly from the entrance to the fish ladder (Figure 4). Our experimental design prevented us from distinguishing whether initial handling or captivity was responsible for the observed physiological stress response. Indeed, this question will be difficult to answer with regard to migrating fish, which are inherently difficult to recapture and which may be stressed under any holding conditions. The absolute levels of plasma cortisol are higher than those of salmonids but consistent with levels resulting from handling stress in juvenile American shad (Shrimpton et al. 2001). Plasma cortisol was higher for alewives held in Ipswich River cages than for alewives held in the river of origin (Nemasket River), which suggests that the added transport to the Ipswich River increased the level of stress, although this was not manifested in higher plasma glucose or lower plasma chloride. Our physiological results show that after 24 h, cortisol, glucose, and chloride levels in tagged fish did not differ from levels in untagged fish. These results indicate that the tagging protocol did not cause any added stress relative to the initial handling and transport experienced by untagged fish.

Recommendations

We tested and evaluated a protocol for gastric radio-tagging of anadromous river herring and found that tagged and untagged fish responded similarly. Specif-

TABLE 2.—Two-factor analysis of variance results for the effects of tagging (radio tag presence or absence) and field cage location (Nemasket or Ipswich River, Massachusetts) on plasma concentrations of cortisol, glucose, and chloride ($N = 38$) in Nemasket River-origin adult alewives held for 24 h posttagging. Power is statistical power calculated using G*Power software. Plasma concentrations did not differ between tagged and untagged fish at either location.

Source of variation	Cortisol				Glucose				Chloride			
	<i>F</i>	<i>df</i>	<i>P</i>	Power	<i>F</i>	<i>df</i>	<i>P</i>	Power	<i>F</i>	<i>df</i>	<i>P</i>	Power
Overall	1.51	37	0.23	0.93	0.48	37	0.70	0.71	0.31	37	0.82	0.82
Tag	0.73	1	0.40		0.12	1	0.73		0.00	1	0.98	
Location	3.78	1	0.06		0.35	1	0.56		0.05	1	0.83	
Tag \times location	0.01	1	0.91		0.94	1	0.34		0.87	1	0.36	

ically, tagged fish did not suffer higher mortality or a higher stress response than untagged fish. Several insights and recommendations emerged from our evaluation. First, it was essential that a detailed protocol be distributed to all members involved in tagging. Each member needed to be familiar with the steps and to be involved in practice trials. This lowered the level of confusion that is inherent to large-scale collaborations at the time of field tagging. Second, our successful tagging operation was well organized in the pretagging phase, and substantial planning was undertaken to minimize the duration of fish disturbance. Third, handling of the fish in a quick, gentle, and efficient manner was critical. We believe that practice was essential to maximize the success of tagging. This included getting a feel for how far the tag needed to go into the fish's gut and making sure that the tag was properly loaded into the insertion tool (i.e., taut and straight). Dissecting a subsample of fish after tagging to examine tag placement in the stomach was very useful in developing a technique that worked with these sensitive fish. We found that a slight resistance could be felt when the tag hit the pyloric sphincter, indicating that the tag was correctly placed. If the tag was inserted past the pyloric sphincter, the stomach could rupture. In this study, one stomach was ruptured, but the rupture was not detected until dissection of the fish. Putting a marker on the insertion tool at about 80 mm for a 270–300-mm fish may be a useful guide to prevent stomach rupture. To minimize scale loss, it was important for the handler to keep the fish straight without gripping the fish too tightly. Lastly, it was important for tagging teams to practice together and come to a consensus on the best tagging procedures.

Our study is the first to systematically evaluate tag placement and tagging response in alosids and to compare tagged and untagged anadromous alewives. Most tagging studies of alosids have not systematically evaluated and reported fish response to tagging. Only one study has involved the tagging of river herring (blueback herring; Chappellear and Cooke 1994), and no studies have conducted systematic evaluations of

river herring response to tagging. Most studies provide anecdotal information on tag effects, as is appropriate for research with more-complex objectives.

To restore and conserve these economically, socially, and ecologically important species, we need to more fully understand the factors that determine their distribution and abundance. Telemetry is a key tool in obtaining this understanding. However, if the act of tagging severely alters the movements and behaviors of the fish, the information that researchers gain may be of little importance. Consequently, to assess the reliability of scientific findings, we need to evaluate and quantify the fish response to telemetry tagging. Our results, which are the first to describe the tagging response of anadromous alewives, contribute to this effort.

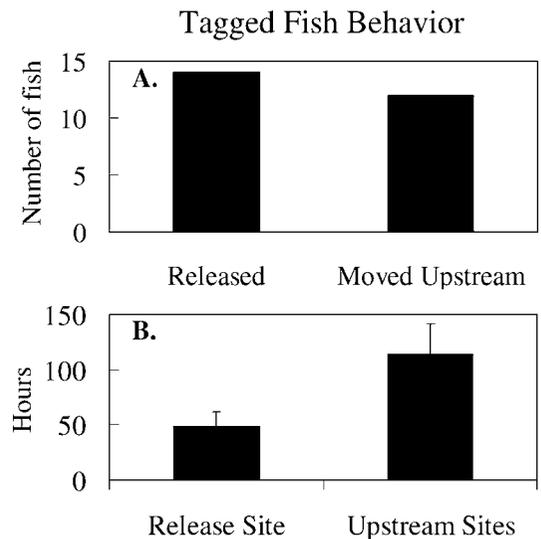


FIGURE 5.—Posttagging movement and behavior in adult alewives that were captured and radio-tagged at the Ipswich Mills fishway during their volitional upstream migration in the Ipswich River, Massachusetts, 2006: (A) number of fish released and number of fish detected at any of the nine upstream receivers (i.e., fish not affected by tags) and (B) mean number of hours spent at the release site receiver and at upstream receiver sites.

Acknowledgments

This project was administered through the Massachusetts Cooperative Fish and Wildlife Research Unit, which includes the University of Massachusetts, U.S. Geological Survey, Massachusetts Division of Marine Fisheries, Massachusetts Division of Fisheries and Wildlife, and Wildlife Management Institute. Use of brand names does not confer endorsement by the U.S. Government. Funding was provided by the Massachusetts Division of Marine Fisheries. We thank Michelle Monette, Amy Moeckel, and Darren Lerner for help with blood plasma collection and analysis. We thank Mike Carey, Cara Campbell, Ken Sprankle, and two anonymous reviewers for comments that improved the manuscript.

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