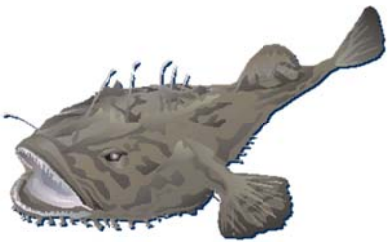

Final Report

2010 Monkfish Research Set Aside Program

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Northeast Regional Monkfish Tagging Program: Additional archival tagging and otolith analyses to assess monkfish movements and age

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A. EXECUTIVE SUMMARY

In the eastern US, monkfish (*Lophius americanus*) are managed as separate northern (Gulf of Maine and northern Georges Bank) and southern (southern Georges Bank and Mid-Atlantic Bight) stocks. However, the degree to which these stocks intermingle, or even whether or not they represent separate stocks, is unknown. Furthermore, the degree of connectivity between offshore and onshore populations remains little studied. Here we investigated patterns in monkfish movement and habitat usage using data storage (DST) tags. Along with our previous tagging efforts (2008 Monkfish RSA and NEC projects), we have tagged 329 monkfish with Starr Oddi centi (279) and Lotek (50) tags, and have recovered 15 tagged fish. Our results suggest little movement occurs between management area: all fish were recaptured in the same management area in which they were tagged. Furthermore, inspection of depth data and tidal signatures also suggests that no temporary movements occurred across management boundaries. Most fish were recaptured relatively close (<50 nmi) to where they were released. Some displayed sizeable changes in depth while at large, including three tagged offshore in Block Canyon that were captured later in the inshore fishery in Southern New England. Others displayed little change in depth, including one that wintered over in shallow water in Southern New England, perhaps migrating only alongshore. Off bottom movements were frequently observed and often accompanied by a change in depth, suggesting that selective tidal transport may aid migration of monkfish, as has been suggested previously. Other off bottom movements were not associated with a change in depth, and could be indicative of vertical migration for spawning. Fish migrations associated with rapid changes in depth (i.e., those tagged in Block Canyon and recaptured a month later in the inshore spring fisher in Southern New England)

exhibited very few off-bottom migrations. The suggestion of sex-specific differences in growth rates of monkfish is significant because gender differences in growth have not been apparent in standard age and growth studies. The growth data from the few tags recaptured thus far is highly variable, so our results must be viewed with caution. However, if we continue to find a pattern of slower growth in males in this size/age range, it will suggest that the aging method is not accurate or fails in older fish. This could have implications for the growth and natural mortality assumptions underlying the assessment model. The validation work using the chemically-marked recaptured fish and laboratory experiments is expected to shed further light on the aging method.

B. BACKGROUND AND OBJECTIVES

The monkfish (or goosefish, *Lophius americanus*) has been the highest valued finfish in the northeastern U.S. since the mid-1990s following the decline of traditional groundfish species (e.g., cod and yellowtail flounder) and the rapid development of the monkfish fishery (Richards et al., 2008). However, relatively little is known about key components of monkfish biology, thereby leaving it vulnerable to overfishing. For instance, a fundamental unknown, critical to population assessment of monkfish, is the degree of movement between monkfish management regions (the Northern and Southern Management Areas, or NMA and SMA). Monkfish are managed as if the two regions represent separate stocks, yet this may be a poor assumption. Another critical unknown is the degree of connectivity that exists between offshore and inshore portions of the fishery in the SMA.

Over the past several years, efforts to answer these monkfish population connectivity questions have been initiated using a number of tagging methods. With funding from the 2007 Monkfish RSA, we initiated a conventional tagging study to examine movement of monkfish within and between two monkfish management areas in the northeastern United States (Sherwood et al. 2009); this conventional tagging project was continued with additional funding from the 2009 Monkfish RSA (Sherwood et al. 2013). To date, a total of 6,162 monkfish have been tagged and released between the autumn of 2007 and summer of 2012 (1,385 in the NMA and 4,777 in the SMA) and recaptures have been monitored until the present. Mixing (straying) among management areas was found to be low and unidirectional; no monkfish tagged in the SMA were recaptured in the NMA (although reporting rates were low in the NMA), and we estimate that 13% of the monkfish tagged in the NMA moved to the SMA. However, conventional tagging only reveals where monkfish were tagged and caught, and thus does not reveal the entire scope of movement in between being tagged and recaptured. Conversely, DST

tags can be used to estimate real-time movement tracks while the fish are at large. Consequently, this method can reveal if fish migrate back and forth across management boundaries and also whether they move outside of fished (i.e., deeper) areas.

Data storage (or archival) tags have been used successfully in a variety of marine fish species, ranging from large pelagics such as bluefin tuna (e.g. Itoh et al. 2003), to smaller demersal fish such as cod (e.g. Godo and Michalsen 2000), salmon (e.g. Friedland et al. 2001), yellowtail flounder (Cadrin and Westwood 2004) and others. Effects of internal implantation of devices appear to be minimal (Cote et al. 1999; Lower et al. 2005; Righton et al. 2006, Richards et al. 2011), although the impact undoubtedly varies among species. Survival, growth rates and swimming performance of Atlantic cod (*Gadus morhua*) were unaffected by internally- or externally-attached DSTs (Righton et al. 2006; Cote et al. 1999); however, external attachment led to wounds and tissue necrosis at the attachment site (Righton et al. 2006).

Monkfish have been considered poor candidates for tagging because they have no scales and a large unprotected abdomen, which makes them susceptible to injury and infection resulting from capture and tagging. Because of this, there has been little tagging of monkfish in the northwest Atlantic to date. However, over 6,000 *Lophius americanus* have been tagged in the western Gulf of Maine and southern New England over the last 6 years with a return rate of about 3% (Sherwood et al. 2009, Sherwood et al. 2013). Thirteen externally DST-tagged monkfish were released over Georges Bank in 2003, one of which was recaptured after 192 days (Rountree et al. 2006). A congener (*Lophius piscatorius*) has been tagged successfully in the northeast Atlantic using conventional tags with return rates ranging from 4.5% to 14.4% (Laurenson et al. 2005; Landa et al. 2001; L.H. Ofstad, Faroese Fisheries Laboratory, personal communication). These results indicate that monkfish can survive the capture and tagging process and that tagging studies hold promise for elucidating monkfish movement patterns.

Richards et al. (2011) conducted laboratory assays to determine optimal tag location, surgical procedures, and tag retention and survival of DST tagged monkfish in the laboratory. The tags were dummy Star-Oddi DST centi-TD loggers (15 mm (diameter) x 46 mm (length), 19 g in air). The tags were inserted subcutaneously through a 2-cm incision lateral to the mid-dorsal aspect of the tail. The insertion sites healed cleanly and survival rates of tagged monkfish were equivalent to those of control (untagged) monkfish. Tag retention rates were 100% 4 months after tagging. In 2008, we initiated a DST study to examine the amount of monkfish exchange between the NFA and SFA. Five of the 187 DST tagged fish were recaptured, and recaptured fish suggested little to no migration among the NMA and SMA. One of the recaptured fish wintered over in relatively shallow water in the SMA, whereas another tagged in the NMA migrated to deeper water in winter in the Gulf of Maine.

While this initial DST tagging study has contributed additional information about movement patterns and exchange rates of monkfish caught very close to the management line that divides the NFA and SFA, it represents only a small region of the overall US fishery. Moreover, questions remain regarding the relative exchange between fish further south in the SFA and those caught in southern New England. In addition, it is currently unclear the degree to which monkfish caught in the offshore fishery in northeastern US migrate inshore, and if they do, where are they migrating to. All monkfish over 70 cm (~ 7 yr) from both areas are female, most likely because of shorter longevity of males (there is no evidence of sequential hermaphroditism in monkfish); conversely, recent aging results suggest that male monkfish have a different growth pattern than females and reach smaller asymptotic sizes (i.e., below 70 cm; Sherwood et al. 2011). We hypothesize that maturing females (L_{50}=46 cm, NEFSC 2002) from the southern region move out of the sampling/fishery region (<225 fa), perhaps into deeper

waters, before returning inshore to spawn. Some of these mature females may move northward into the Gulf of Maine and/or into Canadian waters. Monkfish have been caught from waters as deep as 900 m (500 fa) (NEFSC 2002), and their maximum depth distribution is not known. In experimental deepwater fishing, monkfish CPUE peaked at around 700 m (380 fa), and declined in waters deeper than 730 m (400 fa) (Balcom 1997). The maximum depth sampled in the study was 2,150 m (1175 fa).

Every aspect of the monkfish population assessment is impacted by underlying assumptions about stock structure and mixing among management areas, and potential bias due to false assumptions could have serious consequences. For example, if there is net movement from south to north that is unaccounted for, mortality will be overestimated in the southern management region and underestimated in the northern management region. Similarly, it may appear that monkfish stock status is satisfactory in the north, but not in the south, when in fact the reverse could be true. Understanding exchange between regions and possible movement into Canadian waters is critical to evaluating stock status.

Project Objectives

The objectives of the project were to investigate large-scale movements of monkfish (including deepwater excursions) and to compare inferences about movements and habitat use from archival tags and otolith microconstituents analysis (Campana 2005). We hypothesize net movement of monkfish from south to north, with a possible deepwater excursion by maturing females from the southern area. Furthermore, we aimed to examine the degree of connectivity between monkfish captured in the offshore fishery near the canyons and the spring fishery in southern New England in the SMA. Additional objectives of the archival tagging are to learn more about monkfish behavior, including off-bottom excursions (Hislop et al. 2000; Rountree

2006) that may be related to transport on ocean currents and/or spawning behavior; activity rhythms in relation to tidal cycles; and habitat (depth-temperature) associations. Our goal was to retrieve the entire fish along with the data storage tag (DST) to allow us to determine age, gender, and reproductive state as well as learn more about growth of monkfish.

C. METHODS

Archival tags were used in this study because we suspected that monkfish move outside the range of fishing and survey activity during part of their life history. The DSTs used in this study were Star-Oddi Centi data storage tags (S-DSTs) (Figure 1A) and externally-attached Lotek DSTs (L-DSTs) (Figure 1B). Collectively, we have released 279 S-DSTs ad 50 L-DSTs (Table 1). Both tags record time, pressure (depth) and temperature. The S-DSTs have an expected battery life of up to 5 years and a depth capability of at least 2000 m. The L-DSTs were made available by the University of Massachusetts School for Marine Science and Technology (SMAST). The L-DSTs were rated to 2,000 m but battery life was unknown because they were remainders from a previous project.

S-DST tags were inserted subcutaneously on the dorsal portion of the tail muscle directly posterior of the pectoral fin (Figure 2A) using methods developed by Richards et al. (2011). A small incision in the skin was created prior to inserting the tag, and this incision was then sewed shut with two to three Ethilon black 18" PS-1 cutting sutures from eSutures.com. Monkfish then received two conventional pink Hallprint t-bar tags located dorsally along the tail inserted to interlock between spine bones (Figure 1C). These tags contained GMRI's tagging phone number, a unique number to help identify the fish, GMRI's general tagging website address (www.gmri.org/tagging), and a note stating '$500 REWARD FOR RETURN OF WHOLE FISH.' Tags were inserted with an Avery Denison Mark 3 tagging gun.

During the first part of the study (n=149 fish), fish were injected intramuscularly with oxytetracycline (OTC, 75 mg/kg, Figure 2B) for growth validation studies. The first two recaptured monkfish had necrosis at the site of the injection (Figure 3). Subsequent releases used either no chemical marker (n=105), 50 mg/kg of OTC (n=20) in the intraperitoneal cavity, or 25 mg/kg of fluorexon (n=25). Fish were also measured (total length) prior to receiving DST tags, conventional tags, and an OTC injection. The length of the surgery procedure, fish condition, release time, and the release location (latitude and longitude) were noted for each tagged monkfish.

Fish to be tagged were caught in anchored gillnets (25-30 cm stretched mesh) after soak periods ranging 1-8 days (median 4.5 days). Candidates for tagging were fish that appeared healthy and lively with no serious injuries or skin abrasion. Candidate fish were transferred to holding tanks with running seawater for observation to further evaluate their condition. The tagging procedure was carried out in a tagging box immersed in circulating seawater to minimize trauma during the operation.

To date, We have released a total of 329 DST-tagged monkfish on 10 day-trips between January 2009 and December 2012 (Table 1, Figure 4) using funding from this grant, tags remaining from NEC Project Development Grant NA05NMF4721057, additional funding from the Monkfish Research Set-Aside program and Northeast Consortium (grants to Richards, Grabowski, Sherwood, and Bank), and Lotek tags donated by SMAST. Monkfish were tagged and released in 3 regions: southern New England (n=131; depths ranging 33-55 m), western Gulf of Maine (n=121; 27-48 m) and Block Canyon (n=77; 165-505 m) (Figure 4).

Recaptured monkfish were measured, weighed and dissected to determine gender, reproductive state and stomach contents. Samples collected included hard parts (vertebrae, sagittal otoliths and illicia (first dorsal spine or ‘fishing pole’)) for age and growth studies, and

tissue samples for genetics studies, isotopic analysis of diet, and histological studies of fish health and reproduction. Otoliths were archived for future studies of otolith microchemistry to compare with the movement patterns inferred from DST results for each fish.

To validate the age of monkfish tagged with OTC, excess tissue were removed manually from each of the structures (illicia, vertebra, and right sagittal otolith), embedded in epoxy (5:1 mixture; West Systems©) and allowed to harden in the dark in silicon molds. A sagittal section (0.3mm), centered on the focus of the vertebral centra, was cut using a double-bladed isomet saw (Buehler©) and mounted on glass slides. Sections were polished or sanded as required to enhance the annuli. Cross-sections of the otoliths and illicia were obtained using the same method. An Olympus BX51 microscope with a UV-light attachment was used to detect the presence of the OTC mark. Images of the sections were taken using the CoolSNAP Pro color digital camera. The number of annuli after the OTC mark was counted and compared to the time at large, providing a definitive timeline of annulus formation.

D. OUTREACH

We have launched a vigorous outreach program to alert US and Canadian fishermen and port authorities of our tagging activities. For instance, a postcard (Figure 5) was sent to all monkfish permit holders in the spring of 2008 to encourage participation from as many fishermen as possible. Additionally, posters have been hung along fishing wharfs throughout much of the monkfish's range in the U.S. and provided to port agents (Figure 6). An advertisement was published in Commercial Fisheries News in November 2008 (Figure 7). An announcement about the large reward was included on the back page of the final Cod Tagging Program mailing, which was sent to ~2500 fishermen in New England in 2009. An article was published by Janice Plante in Commercial Fisheries News in late January 2010 detailing our

ongoing tagging projects (Appendix 1; http://www.nefsc.noaa.gov/read/popdy/monkfish/Survey2009/Tagging%20Study/pdf%20files/Monkfish_Tagging_CFN%202_10.pdf). The article was featured on the inside cover, and covered 4 pages tackling several facets of our tagging program. We attempted to disseminate this article as broadly as possible throughout the fishing community. An announcement about the project was sent to the Monkfish Defense Fund and a press release was issued by the Northeast Fisheries Science Center in early 2010 (http://www.nefsc.noaa.gov/press_release/2010/SciSpot/SS1002/index.html). This project was also covered by Live Science: http://www.livescience.com/8942-data-tags-shine-light-mysterious-monkfish.html. Both NMFS (http://www.nefsc.noaa.gov/read/popdy/monkfish/Survey2009/taggingstudy.htm) and GMRI (http://www.gmri.org/mini/index.asp?ID=34) have created websites to disseminate information and results from this project. Finally, GMRI and SMAST have hosted participants' meetings in New Bedford, MA (2011 and 2012) detailing results of this project as well as those for all of our monkfish RSA funded research projects.

E. RESULTS AND CONCLUSIONS

As of July 2013, 15 tagged monkfish have been recaptured, indicating a recapture rate of 4.6%. Two were recaptured within 3 days of release on October 21, 2010, and another within 9 days of released on July 7, 2011, in the same area in which they were released, reducing the effective recapture rate to 4.0%. All tagged fish returns have come from gillnetters. Time at large ranged from 3 to 613 days, and 81% of these fish were female (size at release ranged from 54-85 cm, mean 87 cm). In this size range, expected sex ratios are heavily biased towards females

(Richards et al. 2008). All fish were recaptured in the same management region in which they were released (Figure 8). Twelve out of 15 recaptures have come from the SMA, where 63.2% of the tags have been released. Removing the 3 tagged monkfish that were at large for <9 days, 11 of 12 effective recaptures occurred in the SMA.

One overarching concern with any tagging study is whether tags are being found and reported. Given our high reward, extensive outreach, and collaborative participation by industry, we are fairly confident that any tagged fish that was found was reported. However, of greater concern for this study is whether or not the tags are being found. We had one S-DST recapture where the tag fell out of the fish onto the deck, and the fisherman was never able to relocate the tagged fish. To date, 10 of the returned fish had been tagged with Star Oddi DSTS (3.6% of released S-DSTs), and 5 of the returned fish were externally tagged with L-DSTs (10% of L-DST releases). This almost threefold difference stems from at least two possible explanations: First, that the first 149 fish received an OTC injection that likely caused a necrotic lesion at the site of injection, potentially reducing survival (Figure 3). And second, that the external DST tag is more visible (Figure 2A vs Figure 9A,B). Yet the attachment and anchor sites of the Lotek DSTs at large for over two months appeared irritated (Figure 10A, 10B). Incisions from internally-implanted tags generally were neatly healed (Figure 10C), but one tag had been shed. T-bar tags sometimes caused irritation at the insertion site (Figure 10D, 10E) and could become entirely fouled with algae (Figure 10F). To increase visibility and minimize methods that result in visible irritations, we are now using large pink disc tags instead of streamer tags with our internally tagged (S-DST) fish.

Although all fish were recaptured in the same management region in which they were released (Figure 8), fish release and recapture data coupled with temperature and depth logs suggested strong seasonal migrations in most but not all fish. Median distance between release

and recapture locations was only 41 nmi, which likely in part reflects the patch nature of the fishery. Furthermore, there were no migrations across management boundaries judging from release and recapture points or from examining differences in tidal signature. Of the fish that were at large during fall and spring migrations, one Gulf of Maine release moved into deep water (>270 m), possibly Wilkinson Basin, and then returned to ~ 40 m depth in the spring and was caught 23 nmi from its release point. The other (SNE release) remained in relatively shallow water (~40 m) and was recaptured 86 nmi southwest of its release location. Two fish tagged in spring near the continental slope in 170-290 m were recaptured a month later ~55 nmi to the north/northwest in 58 m. Overall, the results suggest that movements can be rapid and that monkfish in deep water do migrate onshore, but that some fish remain in shallower water throughout the winter. Evidence of long distance movements (e.g., > 100 nmi) is not evident from release and recapture locations; however, geo-location estimates may suggest otherwise. Long distance movements have been observed in previous tagging studies (Sherwood et al. 2009).

Behavior

Two monkfish released in Block Canyon in mid-April 2011 were recaptured 33 and 40 days after release in the inshore fishery, providing a view of the rapid inshore migration that occurs in spring (Figure 11). One of these fish (S-DST 5429, female, 64 cm at release), was released in ~170 m, where it remained for ~4 days before it began migrating to shallower depths. By the end of April, it was close to the depth at which it was caught. Unlike other tagged fish we have caught that have exhibited frequent off-bottom movements, it made only two off-bottom movements during this period. The second fish (DST 5448, male, 60 cm at release) was released at 280 m, where it remained until April 24, when it started to migrate to shallower depths (Figure

11). Between April 24 and 26, it migrated to ~210 m, where it remained until April 30. Between April 30 and May 1, it moved rapidly to ~120 m. On May 3, this monkfish appeared to migrate to slightly deeper depth (~130 m), suggesting that either it had passed over a small ledge or that it may have turned around for a brief period. On May 4, it began migrating to shallower depths again, and by May 7th it had reached the depth (50 m) where it was eventually captured. Overlaying the depth trajectories of these two monkfish suggests that they were following relatively similar trajectories, yet the female monkfish was 1 to 2 weeks in front of the male (Figure 12). A third tagged fish in Block Canyon was also recaptured in the inshore fishery (See Figure 8), but unfortunately we were unable to retrieve data from the Lotek tag. Our results collectively suggest that a sizeable portion of the spring fishery in Southern New England likely stems from monkfish migrating in from offshore locations such as Block Canyon.

Two fish released in the autumn were recaptured the subsequent summer after 241 and 248 days at large, providing a view of habitat use and behavior during fall, winter and spring (Figure 13). One of these fish, released in the western Gulf of Maine (S-DST 4119, gender unknown), exhibited high frequency off-bottom movements during the first 35 days after release. This was associated with increasing depth, which stabilized at about 150 m. After about 2 months at 150 m (mid-January), the fish again moved to deeper water (210-250 m) where it remained for 2 months before making a sudden jump to ~160 m following an off-bottom movement to 120 m. The fish moved steadily shallower during the next 2 months, then descended to 190 m and ascended to 30 m within about 2 weeks. The fish was captured about 3 weeks later in ~30 m of water. Temperature during the fall excursion to deeper water fluctuated between ~7-12°C, between ~7-9°C during the first residency period at ~150m, and remained fairly steady at ~8.5^{o}C during the winter residency at greater than 200 m. During the spring

migration, temperature dropped to as low as ~4.5^{o}C and then stabilized at around 6°C during the two weeks prior to recapture.

The female released in fall in southern New England (S-4078) and recaptured in summer showed much less off-bottom movement immediately after release, however several episodes lasting 5-10 hr were observed and were associated with a shift to slightly deeper water (~ 10 m deeper). From early December to early May, this fish remained in depths ranging ~45-50 m. Five excursions to the surface were observed in early March within a 5-day period, with no associated change in depth (spawning runs?). During early May, a series of off-bottom movements were recorded, two of which reached the surface. These excursions generally lasted about 3 hr and many were associated with a small change in depth; however, the fish remained at depths of about 30-40 m from May until its recapture in July south of Long Island, approximately 86 miles southwest of the release point. The water temperature at release was about 13°C, and increased to 14- 16°C about 2 weeks after release. The change in temperature was associated with an increase in depth of about 5 m. Thereafter, temperature declined steadily to a low of 3.6^{o}C in early March. Temperature began to increase in April, about a month before off-bottom movements began again and was about 8°C when the fish was recaptured.

We were able to isolate tidal signatures from recaptured monkfish (Figure 14). Monkfish recaptured in the SMA were typically found in waters with tidal amplitudes ranging between 1-2m's. Meanwhile, the one monkfish at large for >3 days in the NMA was in water with much higher tidal amplitudes (Figure 15). Examination of tidal amplitude data for DST 4119 further supports the notion that it remained within the NMA while at large, and likely entered a deep basin near to where it was tagged such as Wilkinson's Basin. Furthermore, tidal amplitude data for the fish recaptured in the SMA also support the notion that these fish are remaining in the SMA. Collectively, these fish provide an example of the types of behavioral information that

can be gleaned from the DST data. In future analyses we will compare models of tidal amplitude and frequency to tidal signals and depth data from the tags to estimate geo-location data for each fish and further examine if any connectivity exists between the two management areas.

Growth

Growth increments for 8 fish that were at large for 40-248 days were extrapolated to annual rates. Seasonal variation in growth rates was accounted for by calculating the proportion of time that recaptured fish were at large during each season. The expected proportion of annual growth during each season was estimated from seasonal size at age data for ages 5-7 (Figure 11A, from Richards et al. 2008) as 7% during winter, 82% during spring, 10% during summer and <1% during fall.

The adjusted annual growth estimates were highly variable. Two females grew at a rate of 5-8 cm per year (9-12% increase over their size at release), while two other females measured 1 cm shorter at recapture than release (Figure 11B, 11C). Males (n=2) grew only 2-3 cm per year (3-5% increase per year). The gender of two fish was unknown; one of these grew at a rate similar to the males (1 cm (2%) increase per year) and the other similar to the females that grew (6 cm (11%) increase per year).

Possible reasons for fish apparently shrinking include measurement error (mis-reading the scale or poor positioning on the measuring board), differences in body conformation before and after death, or actual shrinkage (Huusko et al. 2011). One female (64 cm at release) was at large for only 33 days (mid-April-mid-May), was returned in poor condition, and described as ‘very skinny’ when processed in the laboratory. The other (72 cm at release) was at large for 72 days during July-September and was in a ‘spent’ reproductive state at recapture. Given the slow

expected growth rates in summer-fall and the relatively short time at large, growth might have been too slow to disguise an error in release measurement.

Three fish recaptured within 9 days of release give further insights into the potential scale of errors in length estimates. All 3 fish measured larger when dead than they had at release 3-9 days earlier (0.5 cm, 1 cm and 3 cm). Discrepancies in estimated lengths may come about for several reasons. Monkfish often gape their mouths when in the tagging box and the mouth must be held closed in order to get an accurate measurement. In addition, the live fish often do not lie straight on the measuring board, but have a lateral twist (as if swimming) which must be straightened to get an accurate measurement. This can be surprisingly difficult, as these are strong, healthy animals that are not particularly relaxed under the conditions of tagging. Another factor is that muscle tone of dead fish is relaxed, which likely makes the fish measure somewhat longer when dead than alive.

Age Validation

The age validation work is part of the Master's thesis by Crista Bank of SMAST and is a component over our two remaining RSA projects from the 2011 and 2013 Monkfish RSA programs.

Tag Mechanical Issues

We have had calibration issues with several of the Star-Oddi DSTs recaptured. Several of the tags have been off when at sea level, though it is unclear if this is a meaningful measure of accuracy. Furthermore, one tag left on for six months after it was recaptured demonstrated significant drifting over time. Future depth testing is required to determine the degree to which tag bias is an issue. We currently have no data on temperature calibration. One of the DST tags

(S-5396) appears to be incapable of connecting with the tag box, and thus has yet to be downloaded. This tag was found on the deck of a fishing vessel, and thus may have been damaged when it fell out of the fish and struck the deck.

The Lotek tags released had been left over from an earlier project and were nearing the end of their battery life. Of the Five L-tags recovered, only 2 (L-12775 and L-12766) were downloadable. One of the defunct tags appeared damaged, perhaps due to being caught in the gillnet hauler mechanism.

Conclusions

More definitive conclusions will be possible after further tags are returned and analysis of tidal signature data/geo-location work is completed. It should be noted that this project is part of a larger tagging program, with two additional studies funded by the Monkfish RSA program in 2011 and 2013 still ongoing.

Our results suggest little movement between management areas. A previous conventional tagging study found <10% of fish tagged in the NMA were recaptured in the SMA and none migrating from the SMA to the NMA, whereas here all fish were recaptured in the same management area in which they were tagged. Furthermore, inspection of depth data and tidal signatures also suggests that no temporary movements occurred across management boundaries.

Most fish were recaptured relatively close (<50 nmi) to where they were released. Some displayed sizeable changes in depth while at large, including three that were tagged offshore in Block Canyon in April 2011 and recaptured later that spring or fall in the inshore in Southern New England. Others that were recaptured at similar depths to where they were released did exhibit substantial changes in depth, suggesting on and offshore migrations. Finally, others

displayed little change in depth while at large, including 1 that wintered over in shallow water, perhaps migrating only alongshore.

Off bottom movements were frequently observed and often accompanied by a change in depth, suggesting that selective tidal transport may aid migration of monkfish, as has been suggested previously. Other off bottom movements were not associated with a change in depth, and could be indicative of vertical migration for spawning. Fish migrations associated with rapid changes in depth (i.e., those tagged in Block Canyon and recaptured a month later in the inshore spring fisher in Southern New England) exhibited very few off-bottom migrations.

The suggestion of sex-specific differences in growth rates of monkfish is significant because gender differences in growth have not been apparent in standard age and growth studies. The growth data from the few tags recaptured thus far is highly variable, so our results must be viewed with caution. However, if we continue to find a pattern of slower growth in males in this size/age range, it will suggest that the aging method is not accurate or fails in older fish. This could have implications for the growth and natural mortality assumptions underlying the assessment model. The validation work using the chemically-marked recaptured fish and laboratory experiments is expected to shed further light on the aging method. Our report for a 2009 Monkfish RSA project (Sherwood et al. 2011) also indicated slower growth in males than females.

F. ACKNOWLEDGEMENTS

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G. REFERENCES

Armstrong, M.P., J.A. Musick, and J.A. Colvocoresses. 1992. Age, growth and reproduction of the goosefish *Lophius americanus* (Pisces:Lophiiformes). Fish. Bull. 90:217-230.

Arnold, G.P. and B.H. Holford. 1995. A computer simulation model for predicting rates and scales of movement of demersal fish on the European continental shelf. ICES J. mar. Sci. 52: 981-990.

Balcom. N. 1997. Exploration of Continental Slope Deep Water Fisheries. Final Report, Fishing Industry Grant No. NA56FKO109, National Marine Fisheries Service, Northeast Regional Office, State-Federal and Constituents Division.

Blanton, Brian O; Werner, Francisco E; Seim, Harvey E; Luettich, Richard A; Lynch, Daniel R; Smith, Keston W; Voulgaris, George; Bingham, Frederick M; Way, Francis. 2004. Barotropic tides in the South Atlantic Bight . Journal of Geophysical Research. C. Oceans, Vol. 109, no. C12.

Box, G.E.P. and G.M. Jenkins. 1976. Time Series Analysis: Forecasting and Control. Holden-Day, Oakland, CA.

Cadrin, S.X. and A.D. Westwood. 2004. The use of electronic tags to study fish movement: a case study with yellowtail flounder off New England. ICES CM 2004/K:81, 34 pp.

Campana, S.E. 2005. Otolith elemental composition as a natural marker of fish stocks. *In:* S. Cadrin, K. Friedland, and J. Waldman (editors). Stock Identification Methods. Elsevier Academic Press, Burlington, MA., p. 227-245.

Chikarmane, H.M., A.M. Kuzirian, R. Kozlowski, M. Kuzirian, and T. Lee. 2000. Population genetic structure of the Goosefish, *Lophius americanus*. Biol. Bull. 199: 227-228.

Cote, D., D.A. Scruton and L. Cole. 1999. Swimming performance and growth rates of juvenile Atlantic Cod intraperitoneally implanted with dummy acoustic transmitters. N. Amer. J. Fish. Management 19: 1137-1141.

Friedland, K.D., R.V. Walker, N.D. Davis, K.W. Myers, G.W. Boehlert, S.Urawa, Y. Ueno. 2001. Open-ocean orientation and return migration routes of chum salmon based on temperature data from data storage tags. Mar. Ecol. Prog. Ser. 216:235-252.

Godo, O.R. and K. Michalsen. 2000. Migratory behaviour of north-east Arctic cod, studied by use of data storage tags. Fisheries Research 48: 127-140.

Groeger, J.P., R. Rountree, U. Hogsbro Thygesen, D. Jones, D. Martins, Q. Xu and B. Rothschild. 2005. Geolocation of Cape Cod Bay cod using tidal information. ICES CM 2005/Z:10.

Hislop, J.R.G., J.C. Holst and D. Skagen. 2000. Near-surface captures of post-juvenile anglerfish in the North-east Atlantic-an unsolved mystery. J. Fish. Biol. 57:1083-1087.

Hunter, E., J. Aldridge, J. Metcalfe, G. Arnold. 2003. Geolocation of free-ranging fish on the European continental shelf as determined from environmental variables. Marine Biology 142: 601-609.

Itoh, T., S. Tsuji, and A. Nitta. 2003. Migration patterns of young Pacific bluefin tuna (*Thunnus orientalis*) determined with archival tags. Fish. Bull. 101: 514-534.

Johnson, A., A. Richards, D. Cullen, B. Nguluwe, and K. Lang. 2007. Biology of large monkfish *Lophius americanus.* ICES CM 2007 / K:11.

Landa, J., C. Farina, I. Bruno and U. Auton. 2001. Movement rates and validation trials of growth of white anglerfish (Lophius piscatorius) in the North-eastern Atlantic based on mark-recapture experiments. http://www.ices.dk/products/CMdocs/2001/O/O2201.pdf

Laurensen, C.H., I.R. Hudson, D.O.B. Jones, and I.G. Priede. 2004. Deep water observations of *Lophius piscatorius* in the north-eastern Atlantic Ocean by means of a remotely operated vehicle. J. Fish. Biol. 65: 947-960.

Laurensen, C.H., A. Johnson, and I.G. Priede. 2005. Movements and growth of monkfish *Lophius piscatorius* tagged at the Shetland Islands, northeastern Atlantic. Fisheries Research 71:185-195.

Lower, N., A. Moore, A.P. Scott, T. Ellis, J.D. James and I.C. Russell. 2005. A non-invasive method to assess the impact of electronic tag insertion on stress levels in fishes. J. Fish. Biol. 67:1202-1212.

Metcalfe, J.D. and G.P. Arnold. 1997. Tracking fish with electronic tags. Nature 387: 665-666.

NEFSC 1997. Report of the 23rd Northeast Regional Stock Assessment Workshop (23rd SAW): Public Review Workshop. [By Northeast Regional Stock Assessment Workshop No. 23.] March 1997.

NEFSC (Northeast Fisheries Science Center). 2002. Goosefish. *In:* 34th Northeast Regional Stock Assessment Workshop (34th SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments**.** Northeast Fisheries Science Center Reference Document 02-06. http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0206/index.htm

NEFSC (Northeast Fisheries Science Center). 2005. Goosefish. *In*: 40th Northeast Regional Stock Assessment Workshop (40th SAW) Assessment Report. Northeast Fisheries Science Center Reference Document 05-04. http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0504/

Richards, A. 2007. Development of Tagging Methods for Monkfish, *Lophius americanus.* Final Report to Northeast Consortium, Project NA05NMF4721057.

Richards, A., J. Moser, B. Dunnigan, and L.A. Alade. 2011. Archival tagging methods for monkfish. Transactions of the American Fisheries Society 140:582–586.

Richards, A., P. Nitschke, K. Sosebee and K. Lang. 2007. Population Biology of Monkfish *Lophius americanus.* ICES C.M. 2007 / K:04.

Righton, D., O.S. Kjesbu, and J. Metcalfe. 2006. A field and experimental evaluation of the effect of data storage tags on the growth of cod. J. Fish. Biol. 68:385-400.

Rikardsen, A.H. and E.B. Thorstad. 2006. External attachment of data storage tags increases probability of being recaptured in nets compared to internal tagging. J. Fish. Biol. 68:963-968.

Rountree, R.A., J.P. Goeger, and D. Martins. 2006. Extraction of daily activity pattern and vertical migration behavior from the benthic fish, *Lophius americanus*, based on depth analysis from data storage tags. ICES CM 2006/Q:01.

Sherwood, G.D., J.H. Grabowski, and S. Tallack. 2009. A tagging study to assess monkfish (*Lophius americanus*) movements and stock structure in the northeastern United States. 2007 Monkfish RSA program, Final Report, 28 pp.

Sherwood, G.D., J.H. Grabowski, and C. Bank. 2011. A weight-of-evidence approach for validating age and growth in US monkfish (*Lophius americanus*) stocks. 2009 Monkfish RSA Program, Final Report, 58 pp.

Sherwood, G.D., J.H. Grabowski, and C. Brown. 2013. Tagging to assess monkfish movement: Additional tagging to assess monkfish (Lophius americanus) movements and stock structure in the northeastern United States. 2009 Monkfish RSA Program, Final Report, 30 pp.

Welch, D.W. and J.P. Eveson. 1999. An assessment of light-based geoposition estimates from archival tags. Canadian Journal of Fisheries and Aquatic Sciences 36:1317-1327.

Westerberg, H., P. Eveson, D. Welch, L. Karlsson, and E. Ikonen.1999a. Data storage tag study of salmon (*Salmo salar*) migration in the Baltic: the performance of tags. ICES CM 1999/AA:07. 13 pp.

Westerberg, H., J. Sturlaugsson, E. Ikonen, L. Karlsson. 1999b. Data storage tag study of salmon (*Salmo salar*) migration in the Baltic: behaviour and the migration route as reconstructed from SST data. ICES CM 1999/AA:06.18 pp.

Wright, P.J., J. Panfili, A. Folkvord, H. Mosegaard, E.J. Meunier. 2002. Direct validation. In: Manual of Sclerochronology. IFREMER, Plouzane, France. 463 pp.

H. TABLES AND FIGURES

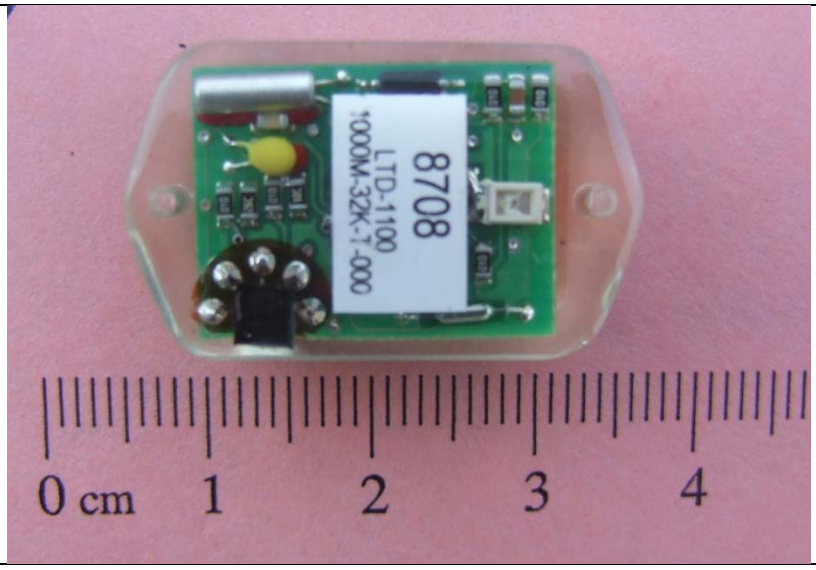
Table 1. DST Monkfish tagging efforts conducted in the Gulf of Maine, Southern New England, and in the offshore fishery near the outer edge of the continental shelf in the SMA.

Trip #	Date	Vessel	Captain	Management region	Tagging Location	Number DST tags released	Number Lotek tags released	Project
1	1/13/2009	Gertrude H	Ted Platz	SFA	So. New England	16	0	2008 RSA
2	7/23/2009	Gertrude H	Ted Platz	SFA	So. New England	26	0	2008 RSA
3	10/15/2009	C.W. Griswold	Tim Caldwell	MFA	W. Gulf of Maine	6	0	2008 RSA
4	10/26/2009	C.W. Griswold	Tim Caldwell	MFA	W. Gulf of Maine	43	0	2008 RSA
5	11/10/2009	Gertrude H	Ted Platz	SFA	So. New England	54	0	2008 NEC
6	10/24/2010	C.W. Griswold	Tim Caldwell	MFA	W. Gulf of Maine	42	0	2008 NEC
7	4/15/2011	Shamrock	Bill McCann	SFA	Offshore fishery	46	3	2010 RSA
7	4/16/2011	Shamrock	Bill McCann	SFA	Offshore fishery	16	12	2010 RSA
8	7/9/2011	Adventura	David Iglesias	SFA	So. New England	0	9	Additional
9	7/11/2011	Finest Kind \II	Rob Walz	SFA	So. New England	0	26	Additional
10	10/17/2012	C.W. Griswold	Tim Caldwell	MFA	W. Gulf of Maine	30	0	2010 RSA
					Total:	**279**	**50**	
					Grand Total:	**329**		

Table 2. Meta-data for recaptured DST-tagged monkfish.

RELEASE							RECAPTURE					
DST #	Gender	Date	Region	Mgmt Region	Total Length (cm)	Injection chemical and amount	Date	Region	Mgmt Region	Total Length (cm)	Days at Large	Growth Increment (cm)
4114	M	11/10/2009	SNE	South	58	OTC 75 mg/kg	6/11/2010	SNE	South	60.5	213	2.5
4078	F	11/10/2009	SNE	South	68	OTC 75 mg/kg	7/16/2010	SNE	South	75.5	248	7.5
4128	F	10/24/2010	WGOM	North	65	none	10/27/2010	WGOM	North	68	3	3
4127	F	10/24/2010	WGOM	North	74	none	10/27/2010	WGOM	North	74.5	3	0.5
5429	F	4/16/2011	SNE	South	64	none	5/19/2011	SNE	South	63	33	-1
5448	M	4/15/2011	SNE	South	60	none	5/25/2011	SNE	South	61	40	1
4119	unk	10/24/2010	WGOM	North	68	none	6/22/2011	WGOM	North	69	241	1
L12757	F	7/11/2011	SNE	South	77	FL 25 mg/kg	7/20/2011	SNE	South	78	9	1
L12775	F	7/11/2011	SNE	South	72	FL 25 mg/kg	9/21/2011	SNE	South	71	72	-1
L12773	F	4/16/2011	SNE	South	59	OTC 75 mg/kg	10/18/2011	SNE	South	63	185	4
L12766	unk	7/11/2011	SNE	South	54	FL 25 mg/kg	11/7/2011	SNE	South	57	119	3
L12756	unk	7/11/2011	SNE	South	60	FL 25 mg/kg	1/5/2012	SNE	South	N/A	178	N/A no fish
5396	unk	4/15/2011	SNE	South	85	none	2/29/2012	SNE	South	N/A	320	N/A no fish
4135	F	10/24/2010	WGOM	North	77	none	6/28/2012	WGOM	North	N/A	613	7.5
5444	F	10/17/2012	WGOM	North	62	FL 25 mg/kg	12/4/2012	WGOM	North	60	48	-2

A.



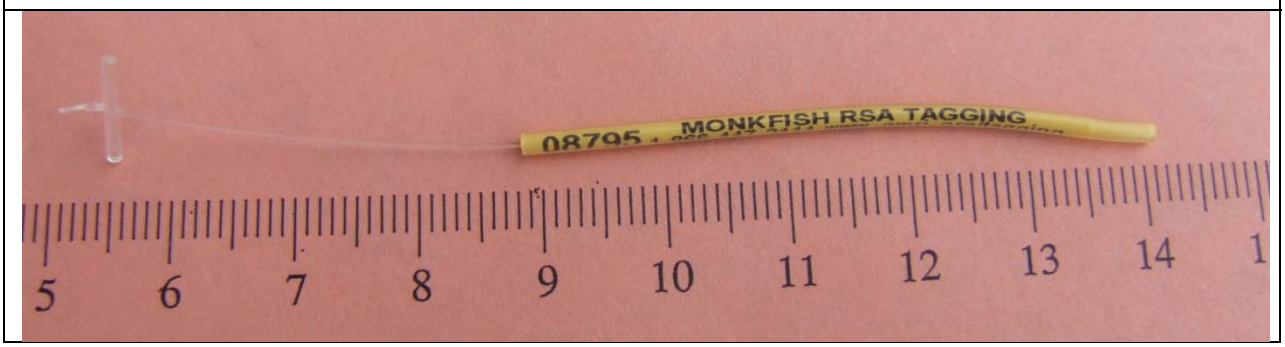


Figure 1. Tags used in this study. (A) Star-Oddi Centi data storage tag (for internal implantation), (B) Lotek data storage tag (for external attachment), (C) Floy t-bar tag for external mark. Scale is cm.

A.

B.

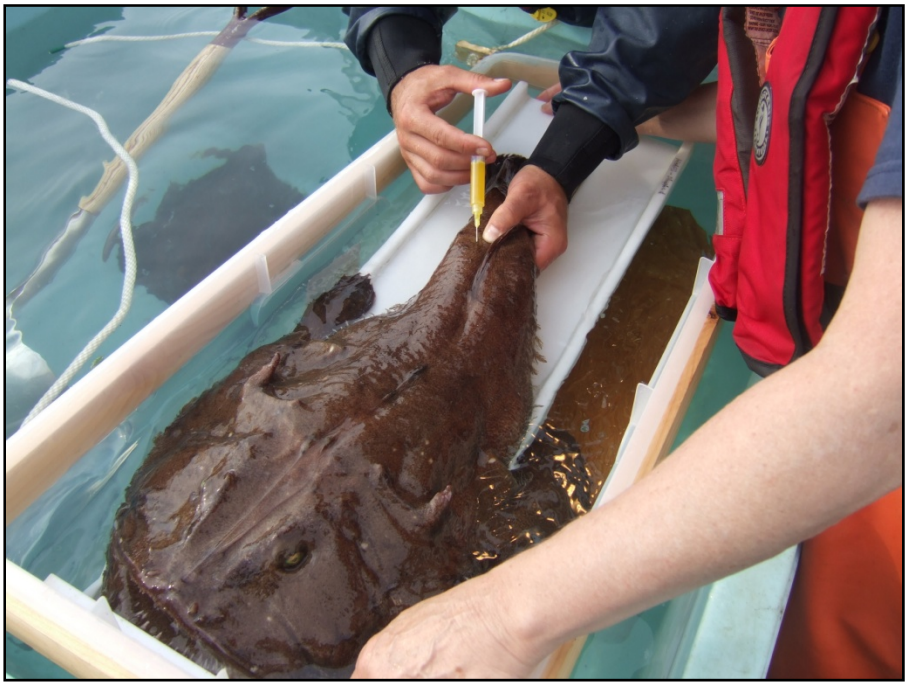


Figure 2. (A) Placement of DST and t-bar tags on monkfish ready for release. (B) Intramuscular injection with OTC.

Figure 3. Tissue damage and discoloration caused by OTC injection in fish at large for 248 days

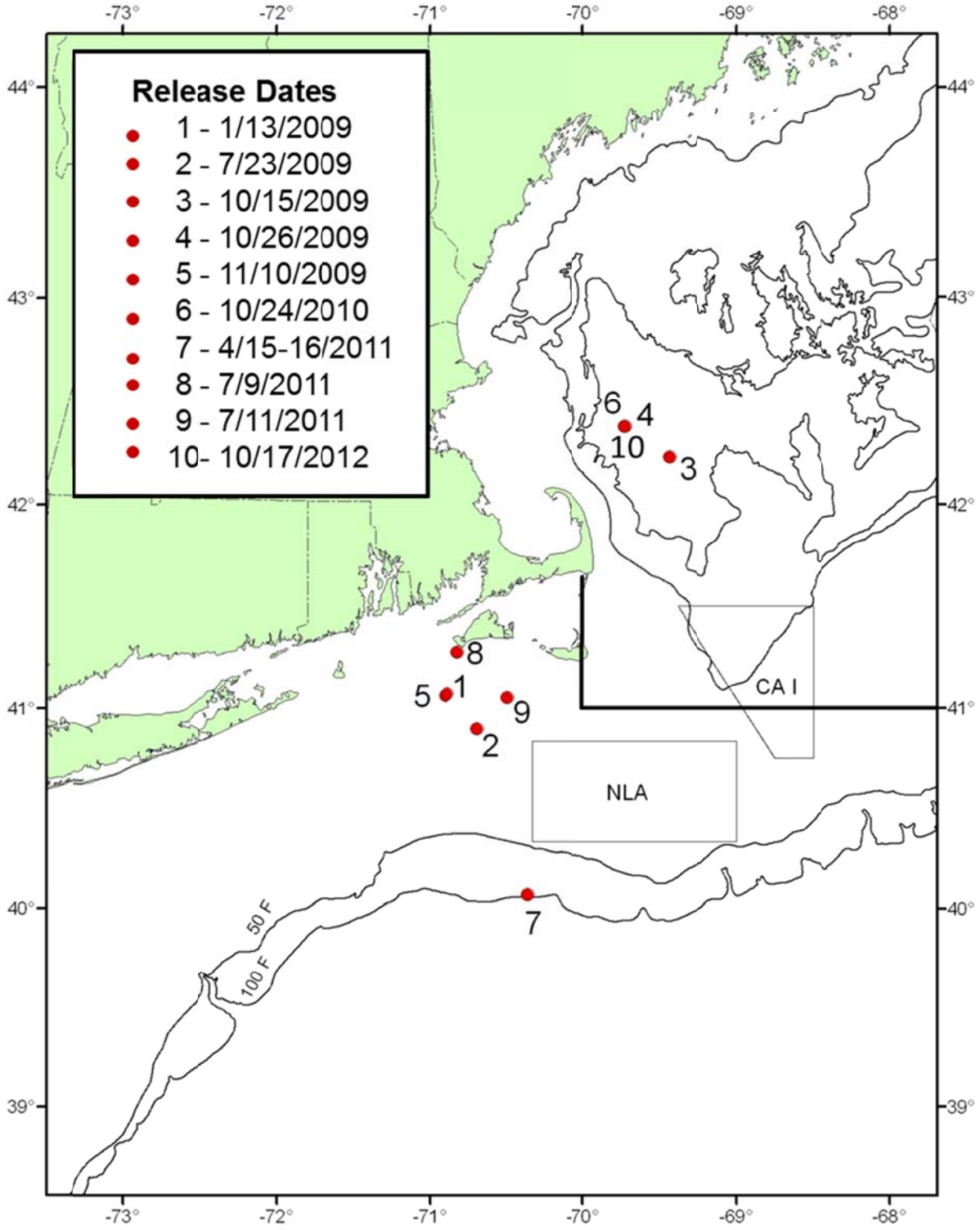


Figure 4. Release locations of DST-tagged monkfish during 2009-2011.

2 Monkfish Tagging Studies:

ONGOING STUDY

~3000 monkfish were tagged and released in fall of 2007 in Northern and Southern Fishery Management Areas to assess movement between the areas.

Please help us by reporting:
Tag Numbers ~ Capture Date ~
Capture Location ~ Fish Length

Reward:
-Monkfish tagging t-shirt (**yellow tags**)
-$100.00 (**High-Reward blue tags**)
-Entry into one of two $500 lotteries

COMING SOON (SUMMER 2008)

Electronic data logger tags will be implanted in 90 monkfish from the Gulf of Maine to Cape Hatteras to examine monkfish movement patterns. These fish will be marked externally with **2 pink tags**.

Please help us by RETURNING THE ENTIRE FISH and reporting:
Capture Location & Date

Reward:
-**$500.00** for **RETURN OF FISH** and data (**pink tags**)

Data Reporting:
Call toll-free: 1-866-447-2111
Email: tagging@gmri.org (subject:monkfish)

For More Information:
Visit: http://www.gmri.org/tagging

Administered By:
Gulf of Maine Research Institute
350 Commercial St.
Portland, ME 04101
207-772-2321

Gulf of Maine Research Institute
Science. Education. Community.

Figure 5. Image of front and back of postcard sent by mail to all monkfish permit holders. Note that this outreach effort overlapped with outreach for a 2007 RSA study to tag monkfish with conventional storage tags.

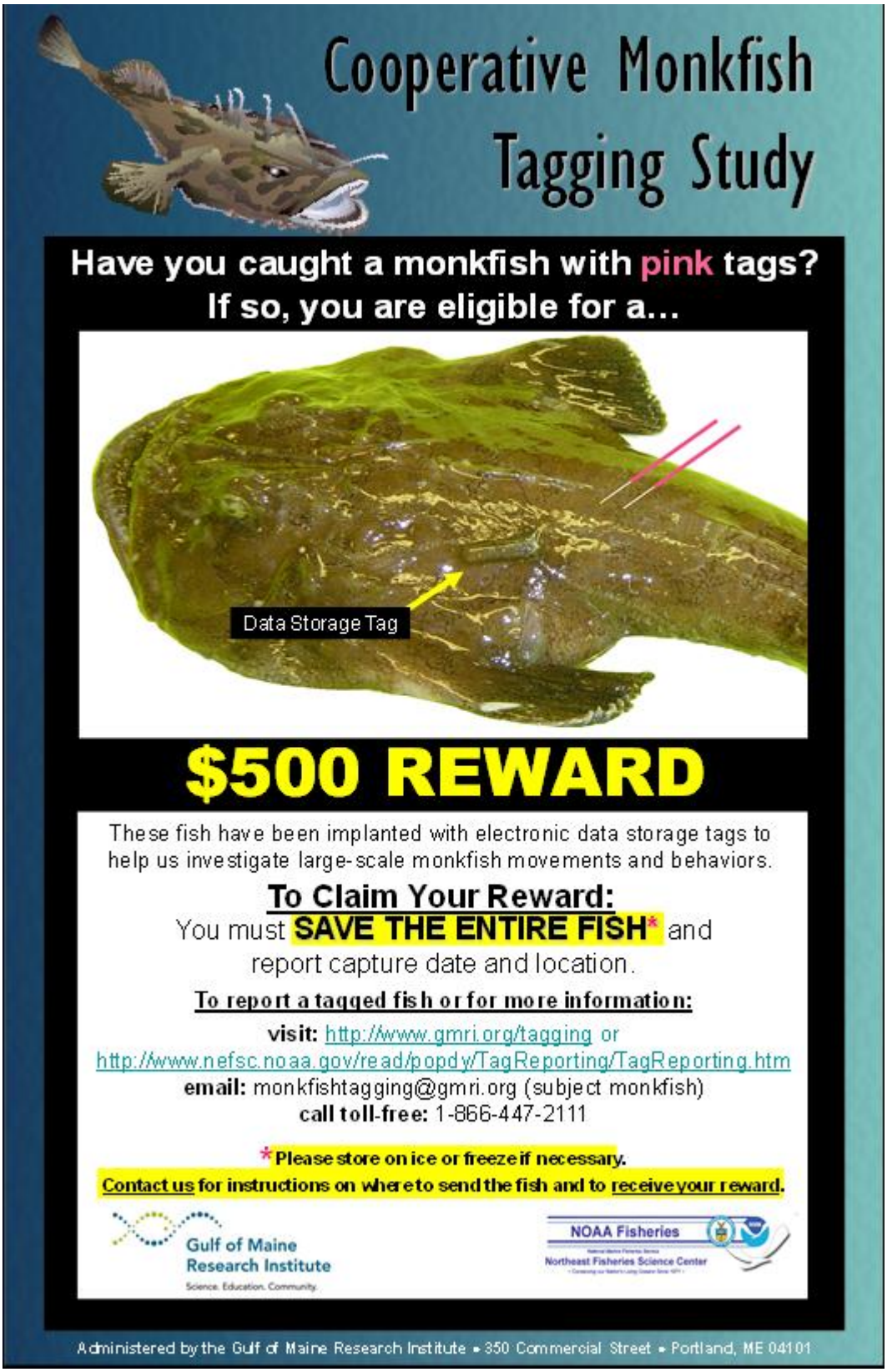


Figure 6. Laminated outreach poster posted at numerous fishing ports in the northeastern U.S.

Figure 7. Copy of add placed in Commercial Fisheries News.

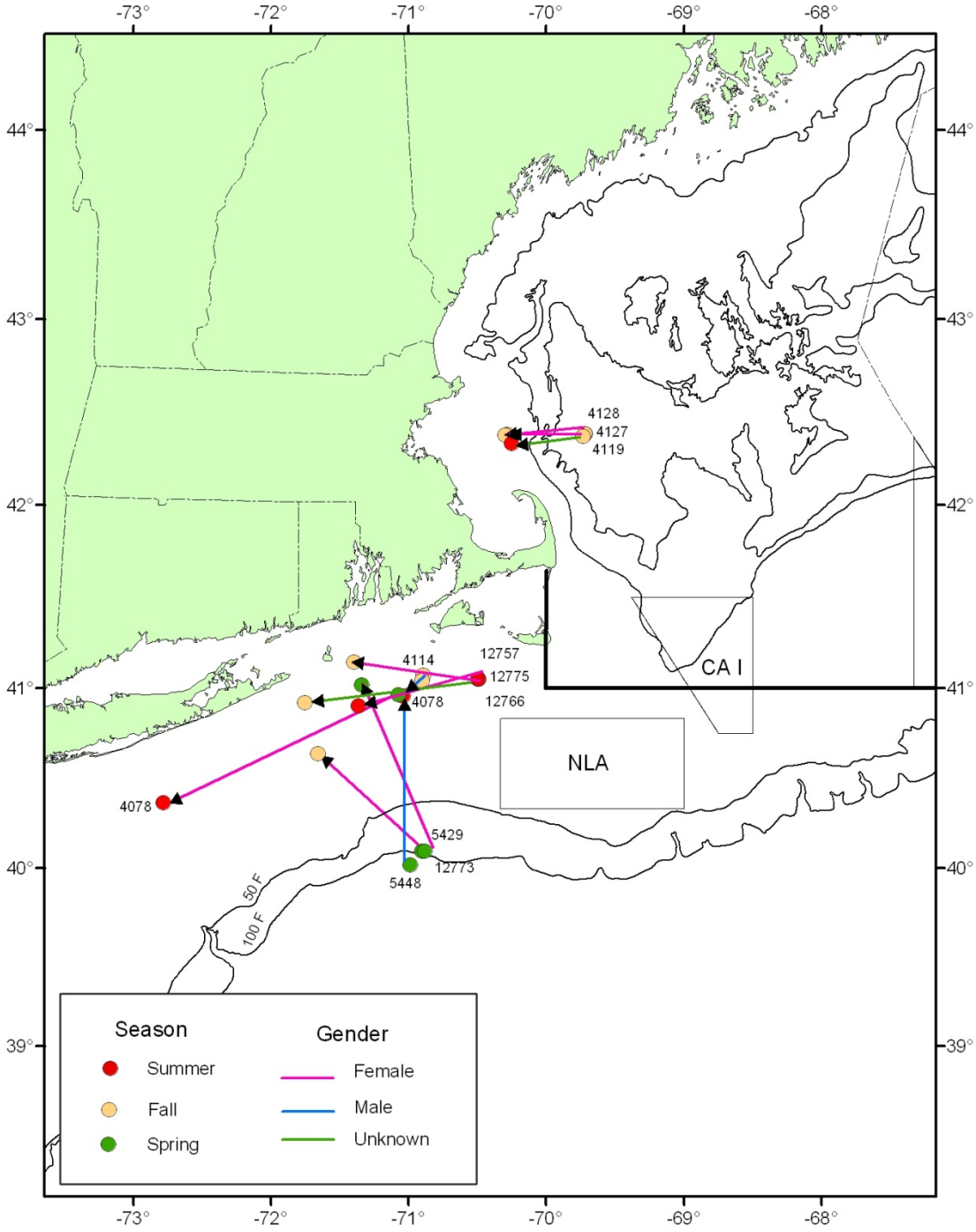


Figure 8. Map of recapture and release locations. Dot color indicates season of release or recapture, line color indicates gender of recaptured fish, numbers are DST tag numbers (numbers beginning with 12 are Lotek tags).

A.

B.

Figure 9. Monkfish tagged with external L-DST. (A) Dorsal surface with L-DST, (B) ventral surface showing anchor for L-DST.

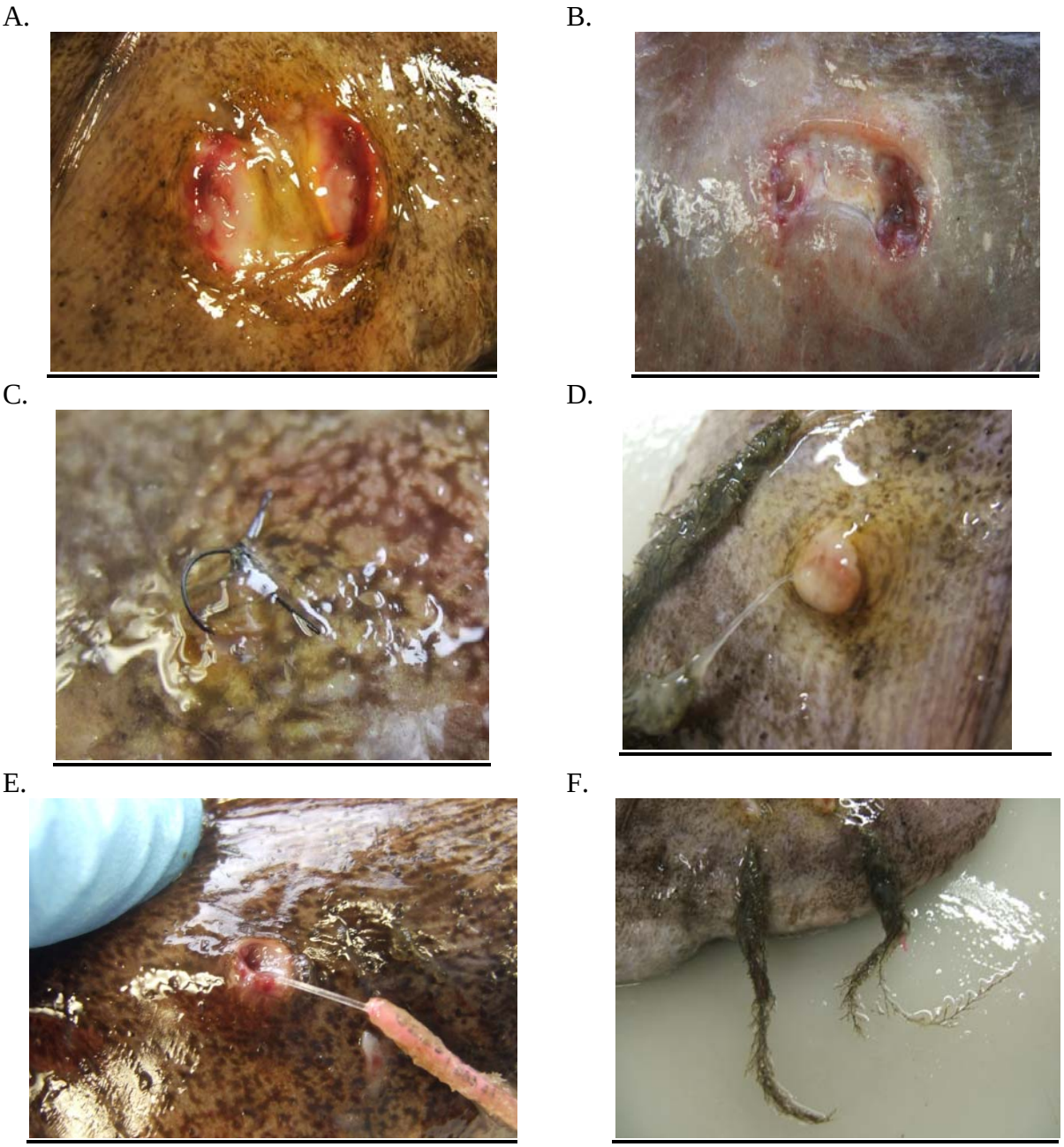
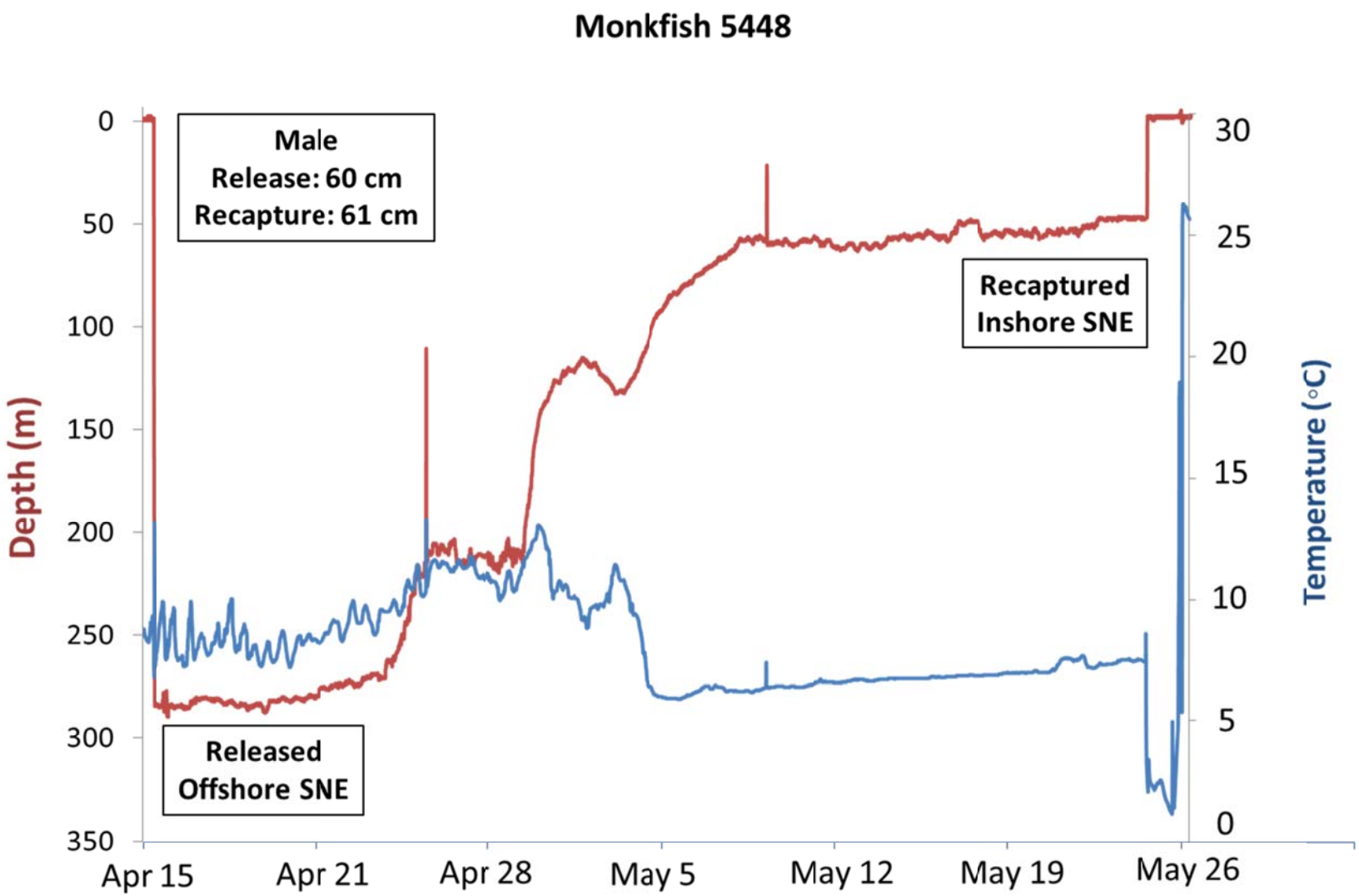


Figure 10. Attachment sites and tag fouling of recaptured monkfish. (A) Dorsal surface where L-DST was attached externally for 72 days (L-DST # 12775), (B) ventral surface showing anchor for same Lotek external DST (L-DST # 12775), (C) Dorsal surface showing healed incision site of monkfish tagged with internal S-DST at large for 213 days (S-DST # 4119), (D) insertion site for external t-bar anchor tag on fish at large for 185 days (L-DST # 12773), (E) insertion site for external t-bar anchor tag on fish at large for 88 days (L-DST # 12766), (F) t-bar tags fouled with algae on fish at large for 185 days (L-DST # 12773).


Monkfish 5448
Male
Release: 60 cm
Recapture: 61 cm
Recaptured
Inshore SNE
Released
Offshore SNE
Depth (m)
Temperature (°C)
0
50
100
150
200
250
300
350
30
25
20
15
10
5
0
Apr 15
Apr 21
Apr 28
May 5
May 12
May 19
May 26

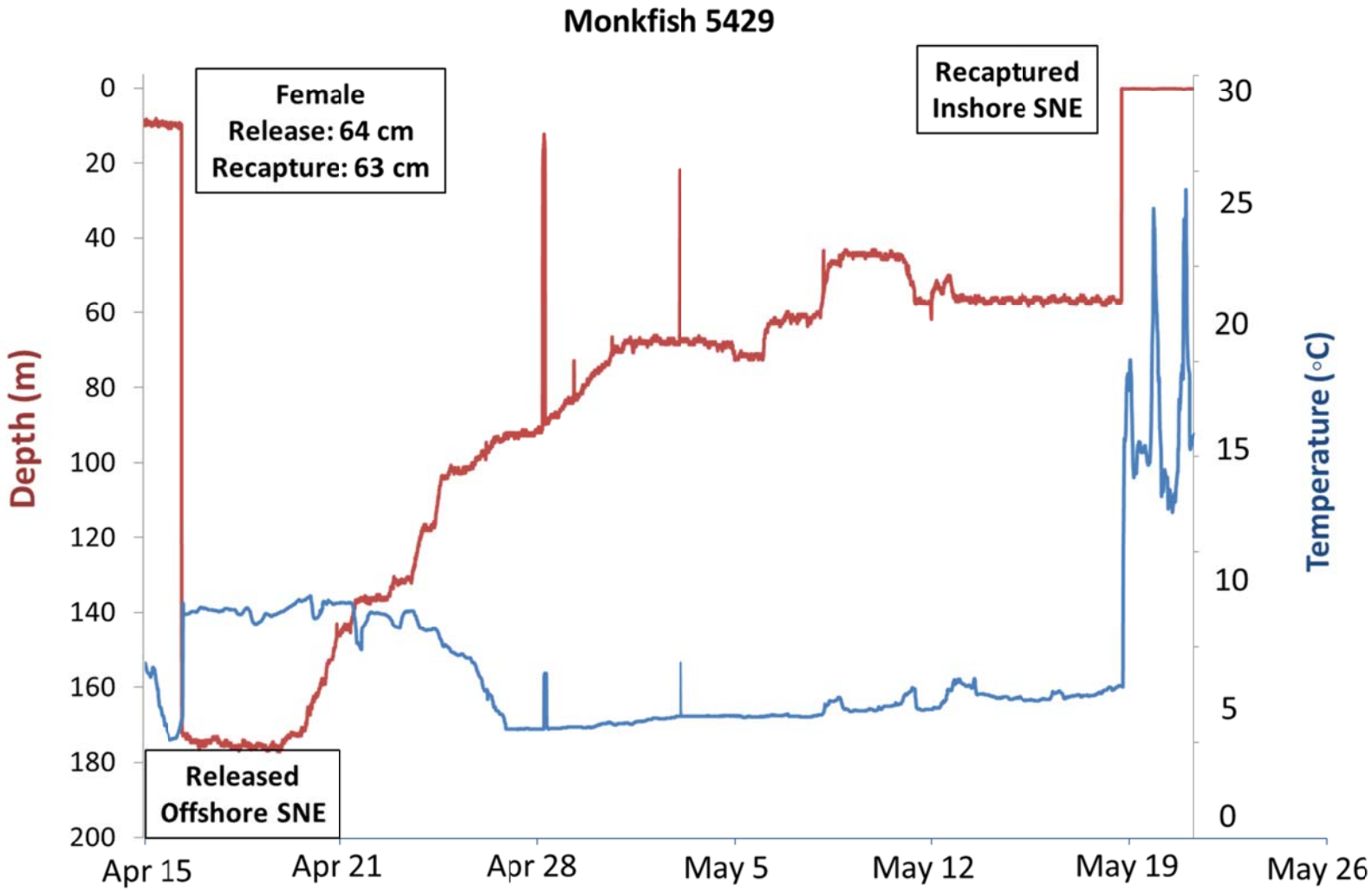


Figure 11. Temperature and depth profiles for two fish (5448 & 5429) tagged and released offshore on April 15/16 and recaptured within a month and a half further inshore in Southern New England. Temperature (C) blue, depth (m) red.

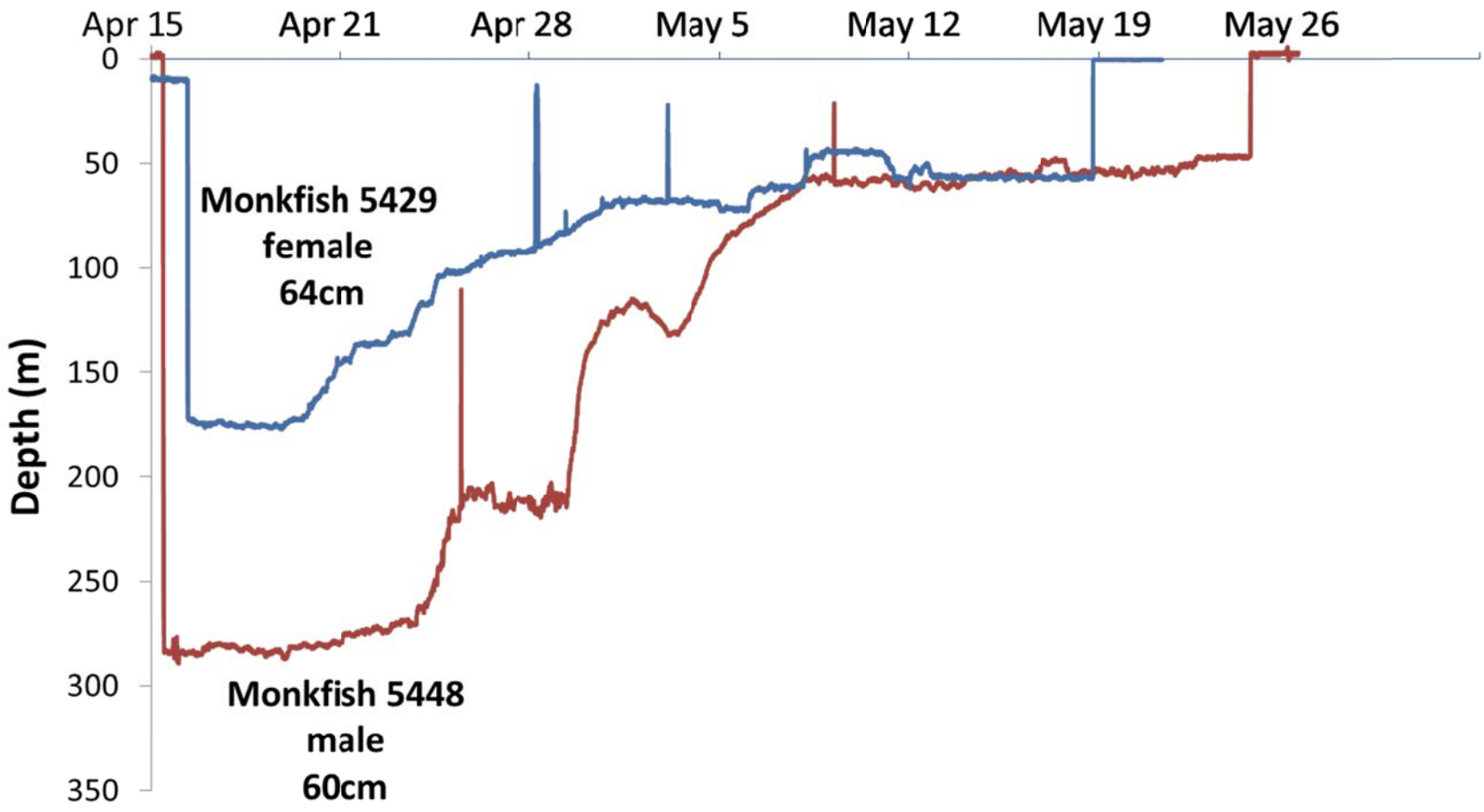
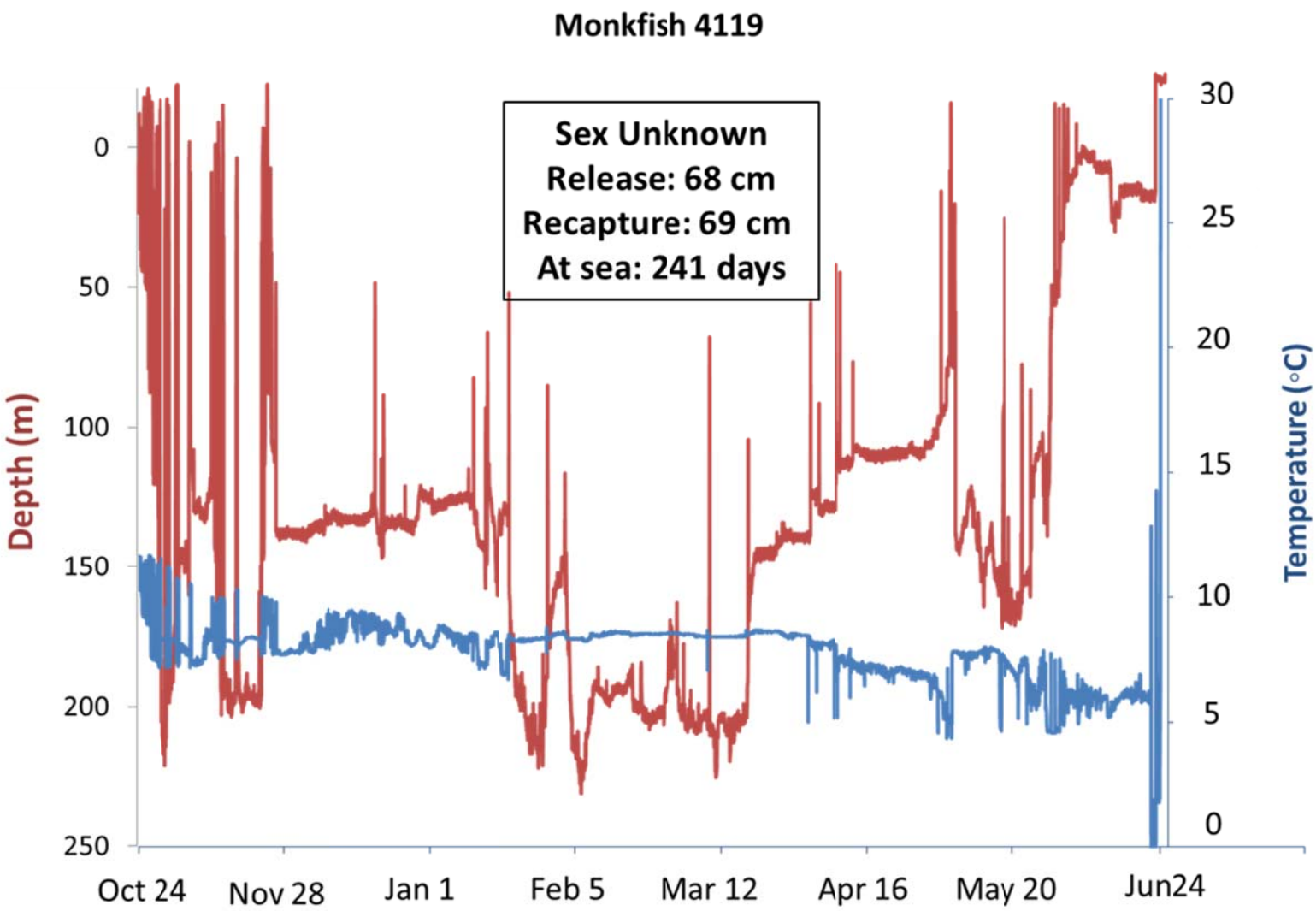


Figure 12. Comparison of monkfish 5448 and 5429 depth profiles. Both were tagged in mid april and recaptured in late May.


Monkfish 4119
Sex Unknown
Release: 68 cm
Recapture: 69 cm
At sea: 241 days
Depth (m)
0
50
100
150
200
250
Temperature (°C)
30
25
20
15
10
5
0
Oct 24
Nov 28
Jan 1
Feb 5
Mar 12
Apr 16
May 20
Jun24

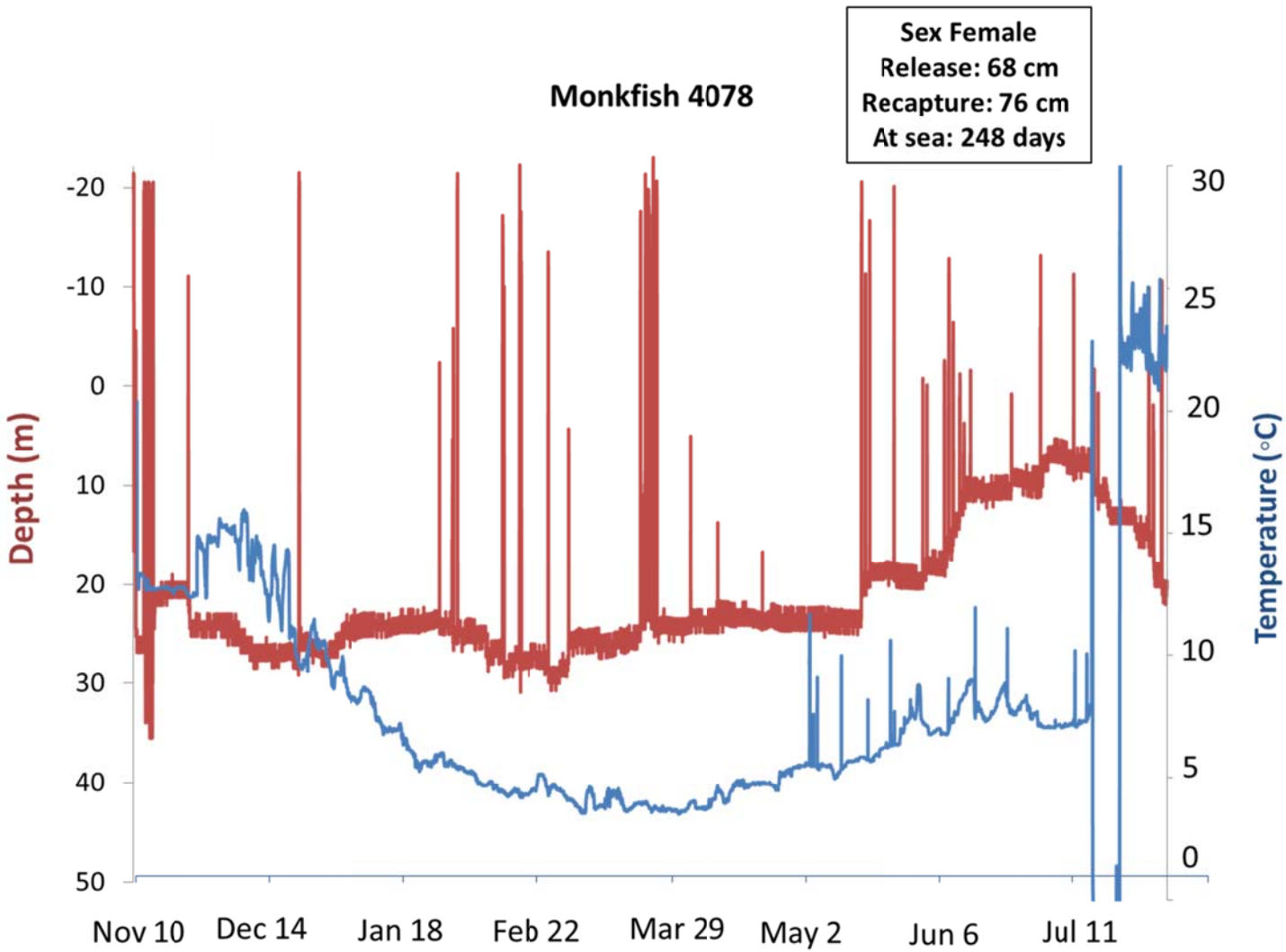
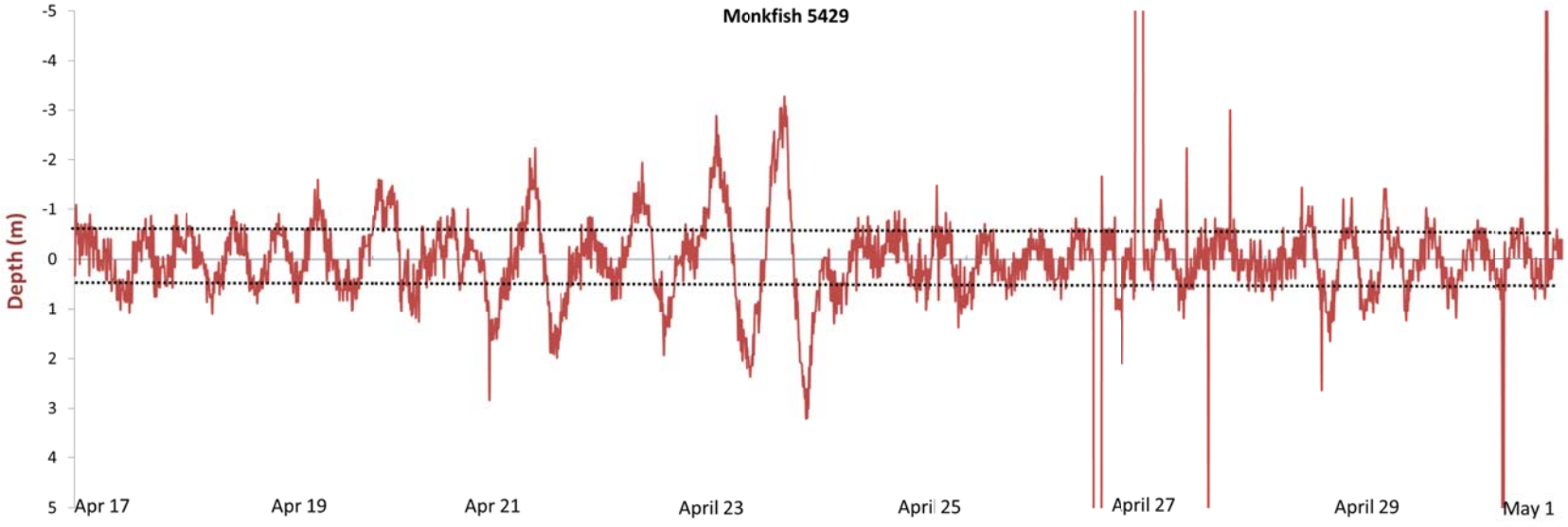


Figure 13.A Temperature and depth profiles for (A) fish 4119 tagged in the Gulf of Maine on October 24, 2010 and recaptured 241 days later inshore of where it was released, and (B) fish 4078 tagged in Southern New England on November 10, 2010, and recaptured 248 days later near where it was released. Temperature (C) blue, depth (m) red.


Monkfish 5429
Depth (m)
-5
-4
-3
-2
-1
0
1
2
3
4
5
Apr 17
Apr 19
Apr 21
April 23
April 25
April 27
April 29
May 1

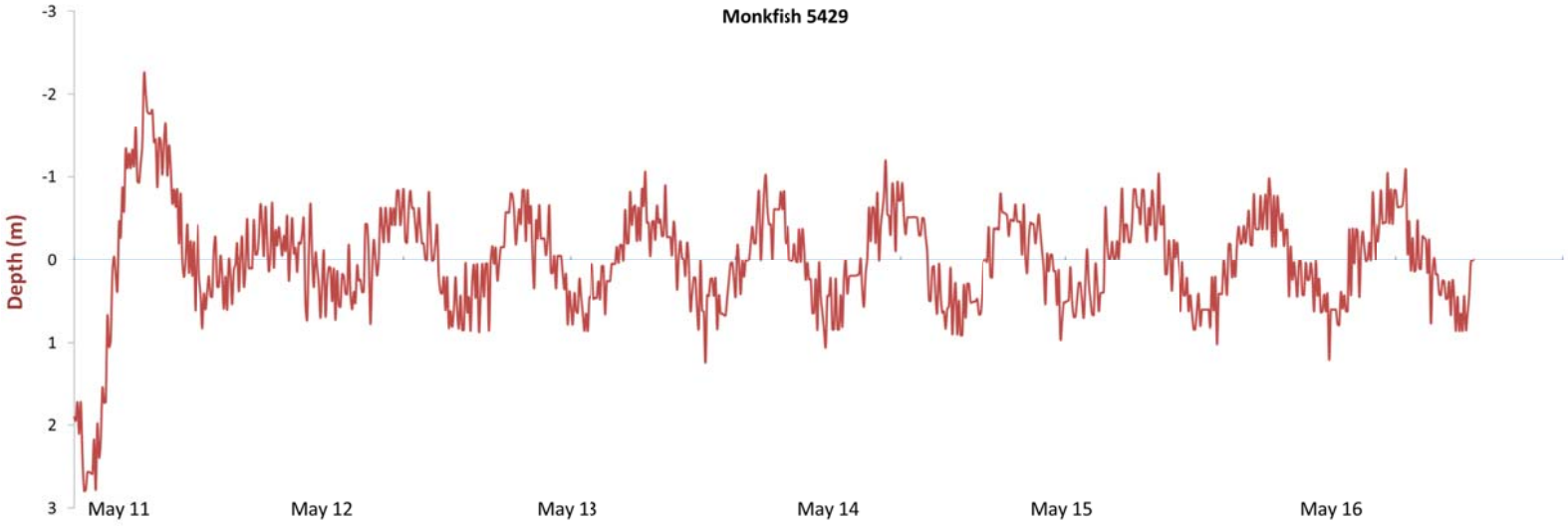

Monkfish 5429
Depth (m)
-3
-2
-1
0
1
2
3
May 11
May 12
May 13
May 14
May 15
May 16

Figure 14. Tidal signature extracted from DST data retrieved from Monkfish 5429, which was caught and recaptured in the SMA.

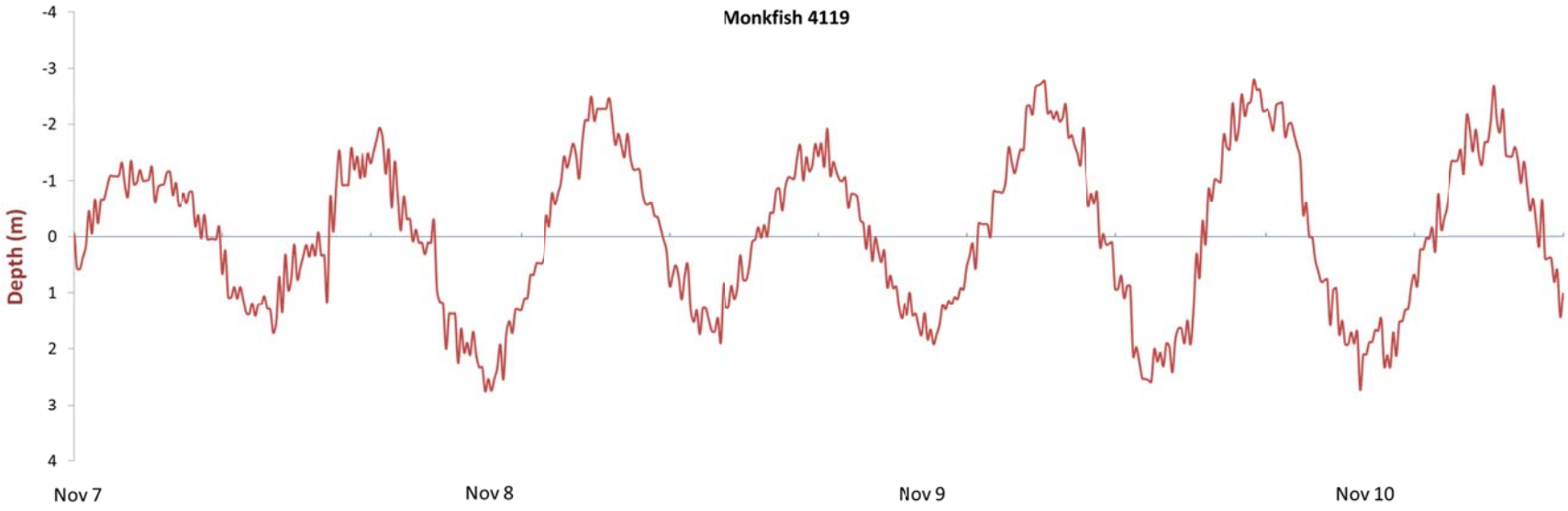
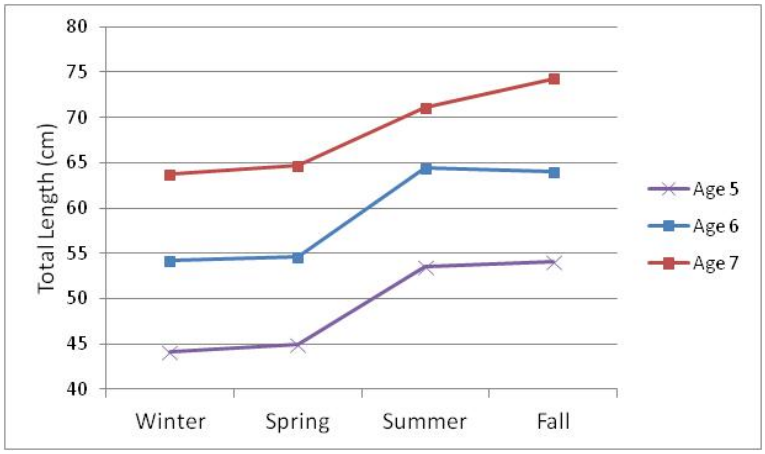
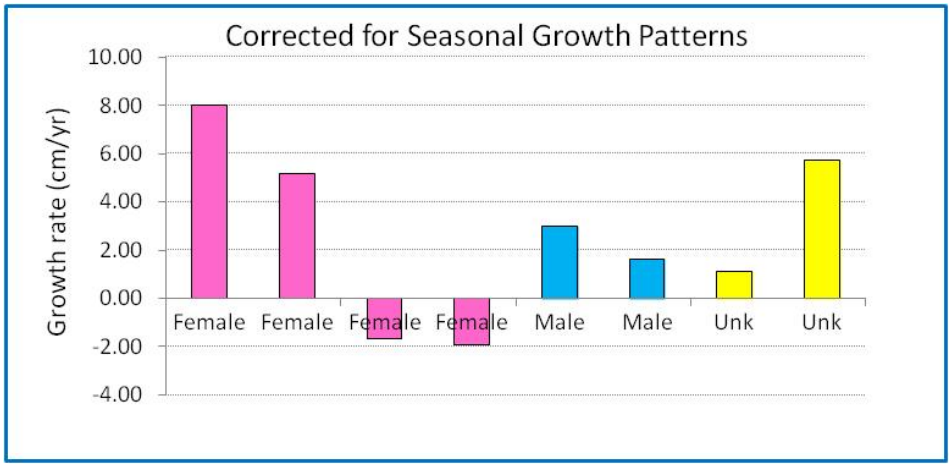


Figure 15. Tidal signature data extracted from DST data retrieved from Monkfish 4119, which was caught and recaptured in the GOM (NMA).





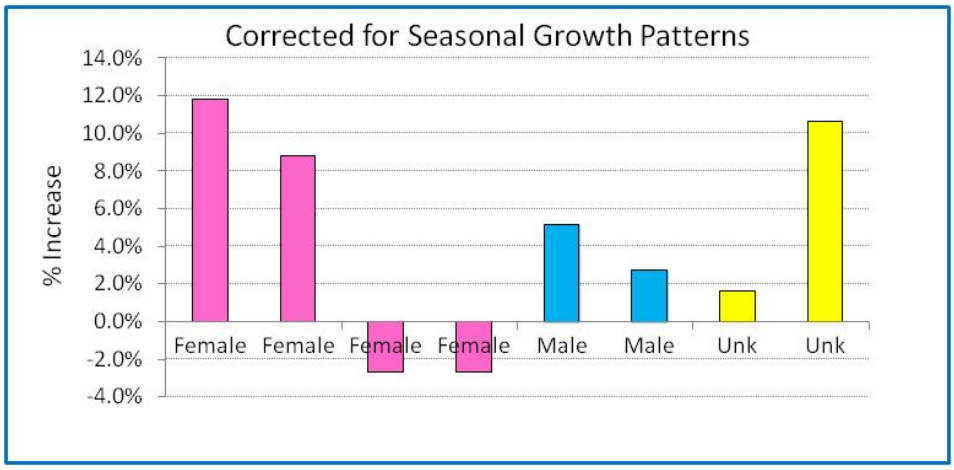


Figure 16. (A) Seasonal variation in growth based on survey length at age data (from Richards et al. 2008), (B) Annual growth increment of recaptured fish adjusted for seasonal growth rates while fish was at large, (C) Annual growth increment as percent of length at release. Unk = gender unknown.

Appendix 1. Article from Commercial Fisheries News, February 2010.

The Northeast's Fishing Newspaper for over 36 years

From the pages of: Commercial Fisheries News

February 2010 • Volume 37 Number 6 A Compass Publication

Pavel Ivanov photo

Monkfish tagging trip aboard gillnetter Gertrude H, with researcher Larry Alade.

Researchers, fishermen tag monkfish; probe north/south mixing rates

by Janice M. Plante

WOODS HOLE, MA – It takes a bit of skill to do surgery on a monkfish, especially at sea in the bitter cold.

But several researchers have mastered the art, making delicate incisions in the tail of each fish to surgically implant bullet-shaped data storage tags. They did it 150 times in 2009 aboard commercial fishing vessels and, as the new year opened, were prepping to head out to sea to do it again.

Newport, RI-based fisherman Ted Platz, the industry partner on three of the 2009 trips, said the teams now had the system down pat.

"We've figured out ways to get a lot of tags out in a short period of time," he said.

Aboard Platz's Gertrude H, researchers and fishermen worked together to tag 18 fish in January, 26 in July, and 54 in December, all in Southern New England, which is considered part of the "southern" area for monkfish management purposes.

Gillnetter Tim Caldwell was the industry partner for the project's Gulf of Maine trips, carrying researchers aboard his C. W. Griswold. Together, they tagged six fish in October and 46 in November.

Tagging teams were hoping to make a third northern-area trip with Caldwell in late January as *Commercial Fisheries News* was going to press.

Monkfish Tagging Program photo

Monkfish Tagging Program photo

Fishermen and researchers say that recovery of the information recorded by data storage tags (DST) is key to learning more about monkfish behavior. DSTs are surgically implanted at-sea, and the live monkfish are returned to the water. Above, NEFSC researcher Anne Richards and Curt Brown of GMRI are doing surgery on a monkfish during a tagging trip aboard the Gertrude H.

Researchers are able to complete the tag implant surgery and have the live monkfish back overboard in 5-7 minutes.

Finding a rhythm

By the third trip in December on Platz's boat, everyone knew their roles. Platz and a crewman worked to pull burly monkfish from the net, while two, two-person teams carried out surgeries simultaneously.

"The trick for us was hauling the net really, really slow," Platz said.

That took some getting used to. Commercial fishermen, after all, haul for a living, and slow is not the name of the game.

But slow hauling after a short, one-night soak produced live fish in prime condition – just the right candidates for tag implantation.

At first, the teams tried keeping monkfish in holding tanks on deck, lining up several fish in advance for tagging. But that didn't work because the fish became stressed.

"They got slimy with mucus when we put them together," said Platz, who worked with crewman Pavel Ivanov on the first tagging trip and Sergey Yuminov on the second two.

So, going against the grain, the gillnetters gave way to the slow-haul method, only supplying fish as needed, so that each of the sharp-toothed monks could have its own tank.

The teams soon fell into a rhythm. Industry partners handled the net, providing researchers with fish as needed, and researchers did the tag implantations. They injected each fish with oxytetracycline to mark its vertebrae, otoliths (ear bones), and dorsal spines for

aging studies that will be done after the fish are recaptured.

Altogether, it took between five and seven minutes to tag and inject each fish and gently put it back overboard.

Jon Grabowski of the Gulf of Maine Research Institute (GMRI) in Portland, ME, one of the tagging program's project leaders, said, "I watched those fish swim away. They looked very healthy."

Two tag types

The tagging work is part of a years-long collaboration between gillnetters and three of the region's most prominent research institutions – the Northeast Fisheries Science Center (NEFSC) in Woods Hole, GMRI, and the University of Massachusetts-Dartmouth's School for Marine Science and Technology (SMAST).

GMRI and fishermen have been tagging monkfish since 2007 with conventional T-bar tags – the ones that look like antennae sticking out of the fish. This work has been carried out through the Monkfish Research Set-Aside (RSA) Program, which is directly financed by industry. Fishermen collectively give up 500 monkfish days-at-sea per year to help fund research projects through the RSA program.

The T-bar tagging by itself has begun to provide important clues about monkfish movements, but this latest data storage tag (DST) work, also financed by the RSA program with additional support from the Northeast Consortium, goes even further.

"With the conventional T-bar tags, you know where the fish were released and where they were recaptured, but you have no idea where they have been in between," said Anne Richards of the science center, one of the project leaders for the DST work.

Many questions

With DSTs, commonly called archival tags, researchers can learn much more than the release-and-recapture points of a monkfish's travels. These remarkable tags additionally record time, temperature, and pressure, roughly every 10 minutes, for up to five years.

The pressure measurement is key because it can be used to estimate how deep a particular monkfish was swimming – all the way down to 1,500 meters, equivalent to 4,950 feet.

And that's what people really want to know: How deep do these monkfish go? How much time do they spend at depths beyond the reach of trawl surveys and commercial fishing activity? Do they travel from inshore to offshore and back again or visa versa? Do they move from south to north or the other way around? Where do the females go at certain times of the year when they seem to disappear? How deep do they go? Maybe they go *very* deep.

"These are big, overarching questions," said Grabowski. "We want to establish migratory patterns. We want to establish how much exchange there is between management areas. Is one area a source of monkfish and the other one a sink? Are there seasonal patterns of migration? Do they vary from the Gulf of Maine to Southern New England to the Mid-Atlantic Bight?"

Grabowski believes that finding answers to these questions is critically important to the commercial fishery.

"It's a very valuable fish species," he said. "It's important that we get it right."

Keep an eye out

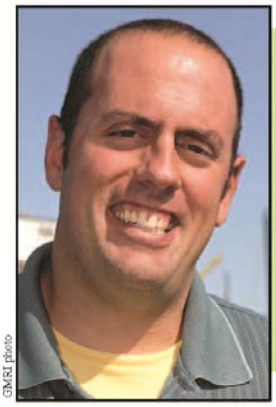
So many questions and so much hope for answers, all contained in tiny canisters sutured just under the surface of the tail-skin on 16"-to-20"-long monkfish.

The tags leave a noticeable bulge, an obvious clue that something is different about the fish.

"It looks like someone's thumb was sewn in," said Platz. "It's pretty hard to miss."

But fearing that busy fishermen might pass by what could be mistaken for a large growth, researchers also attached two, bright pink T-bar tags along the midridge area of the tail. And those pink antennae are practically impossible to overlook.

Furthermore, researchers are hoping that the high reward for returning a DST-



GMRI photo

I cannot emphasize enough how integrally involved the industry has been. They guide us to where the fish are. We use their vessels. We have been really fortunate to have so much support from industry.

—Jon Grabowski

Monkfish tagging: who, what, where, why at a glance

- **WHO**: Commercial fishermen and researchers from the Northeast Fisheries Science Center, the Gulf of Maine Research Institute (GMRI), and the University of Massachusetts-Dartmouth School for Marine Science and Technology (SMAST) are all involved in the collaborative tagging program.
- **WHAT**: Two types of tags are being used. Data storage tags, also called archival tags, look like bullets implanted just under the tail skin. T-bar tags stick out of the tail like colored antennae.
- **WHERE**: So far, tagging has taken place in the Gulf of Maine and Southern New England, and plans are in the works to expand tagging into the Mid-Atlantic and offshore areas. The Northeast Consortium and the industry-financed Monkfish Research Set-Aside Program have paid for the work with overhead and staff/research support from GMRI, SMAST, and the science center.
- **WHY**: The purpose of this enormous effort is to learn more about monkfish migration patterns, monkfish behavior, and the level of intermixing between the northern and southern management areas. Additional research, which is being conducted simultaneously on recaptured fish, is focusing on monkfish aging. **/cfn/**

tagged monkfish – $500 per fish – will entice fishermen to keep a keen eye on their catches.

DSTs expensive

Getting data storage tags back from recaptured *whole* monkfish is absolutely crucial to the success of the project, according to every researcher involved.

These tags do not transmit information to satellites like some ultra-high-end archival tags. Instead, they serve as time capsules, storing data for downloading onto a computer after the fish is recaptured.

The tags are wildly expensive, which has limited the number of DSTs the tagging teams can put in the water. Once this current round of tagging is complete, the teams will have implanted a total of 190 high-tech Star-Oddi DST centi-TD loggers at $360 a pop.

They also have on hand an additional 40 or so lower-quality DSTs, courtesy of SMAST, for external attachment. These 40 won't provide quite as much information and probably won't record as long as the Star-Oddi tags, but it's another tagging opportunity that everyone welcomes.

"We're using every opportunity we can to get as many tags out there as possible," said Richards.

And that includes more T-bar tagging.

Pavel Ivanov photo

Three monkfish tagging trips were made aboard Ted Platz's gillnetter Gertrude H. Pictured here during the January 2009 trip, from left, Platz and researchers Crista Bank of SMAST and Larry Alade of the NEFSC.

Practice makes perfect

Given that the archival tags are so valuable, researchers wanted to be sure they were right on the money with tag placement and fish survival rates.

So, before any of the at-sea tagging got underway, researchers spent a year honing their surgical skills in the lab with the help of a separate Northeast Consortium grant.

And now, with four trained "surgeons" and a fairly slick tagging system, the tagging teams are ready to keep going as long as they can buy more tags and receive funding for future projects.

"We can learn so much about monkfish behavior from these tags," said Richards.

She has plenty of questions of her own.

"Where do these fish spawn?" Richards wondered. "At the surface? At the edge of the continental shelf? Could they be riding currents to migrate? They're hydrodynamically designed. Their pectoral fins are like wings, and there have been sightings of monkfish at the surface. Are these fish going to Canada?"

While the information contained in those tiny canister-like DSTs probably won't answer all of those questions definitively, the stored data will provide important pieces of a very big puzzle.

T-bar tag results

Promising as it all is, the limiting factor with these remarkable data-rich archival tags is their cost; $360 apiece is a lot of money.

In contrast, conventional T-bar tags run less than a dollar each.

"The trade off is you can put out a lot of T-bar tags really cheap," said GMRI's Graham Sherwood.

In 2007 alone, GMRI and fishermen tagged 2,770 fish during the fall. It was the very first monkfish tagging study in the Northeast.

Of the 1,006 fish tagged in the north, 1.7% were recaptured, and of the 1,764 tagged in the south, 3.9% were recaptured. Only fish that were "at liberty" for more than 30 days after being released were counted as "recaptures" in the study, and most of the recaptures occurred

Monkfish Tagging Program photo

Gillnetter Tim Caldwell is the industry partner for the tagging project's Gulf of Maine trips, carrying researchers aboard his C. W. Griswold. Caldwell is pictured above during a 2007 trip when monkfish were tagged with conventional T-bar tags, work carried out through the Monkfish Research Set-Aside Program.

within 10 months of release.

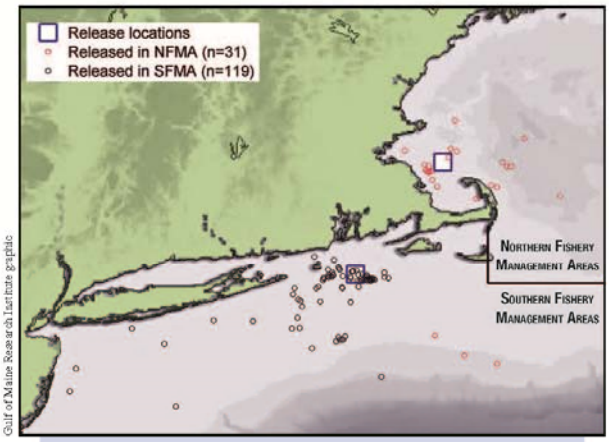
The results were intriguing. Contrary to popular thinking, 9.1% of the fish tagged in the northern area were estimated to have moved to the south (see chart, below). However, none of the fish tagged in the south had moved north.

Therefore, the study concluded that mixing rates were "low and unidirectional," and average movement was to the southwest.

But no one was putting undue weight on these results, especially since researchers strongly suspect that at least some monkfish move from south to north.

"The only data we have so far is from those 2007 fish," said Sherwood, who headed up the project. "It's a very preliminary snapshot of what's going on. No juveniles were tagged, and they may be the ones that are moving north. We need to tag in other seasons and in other areas. Plus, our return rate for the north was very low."

The study did show that monkfish have the potential to travel great distances. According to Sherwood, one monkfish tagged and released off Boston was recaptured off New Jersey.



Gulf of Maine Research Institute graphic

In addition to showing the line marking the northern and southern fishery management areas, the chart shows monkfish tag release/recapture locations. Note recaptured fish represented by red circles were tagged and released in the northern area. Black circles are for recaptured fish released in the southern area.

More in 2010

During 2010, GMRI hopes to get an additional 5,000 T-bar tags in the water, this time further south into the Mid-Atlantic and further offshore, as well as during the spring instead of the fall.

And, researchers also intend to train fishermen to do the tagging themselves. They'll meet with participating industry members to ensure they understand tagging methods and what's needed for data collection.

Yet even before any further training, researchers expressed full confidence that fishermen can take the lead on the at-sea T-bar work. Not only will this save valuable time and resources, but it will allow the tags to be more widely distributed.

Grabowski, a project leader for the 2010 T-bar work, said, "The fishermen involved in this are very interested in the science. They told us, 'You know, we can do these tags ourselves. You guys don't have to be on the boat.'"

All of the researchers involved in the tagging project expressed sincere appreciation for the partnerships they have developed with fishermen.

"I cannot emphasize enough how integrally involved the industry has been in all of this," Grabowski said. "They guide us to where the fish are. We use their vessels. We have been really fortunate to have so much support from industry. That kind of buy-in is invaluable."

From gillnetter Ted Platz's perspective, the work is worth the effort.

"It's what the fishery needs," he said. "We need to know about the mixing rates from north to south and how these fish move. I think there are a lot of misconceptions about the lives these monkfish lead. We need to do what it takes to get better science." ■

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Find a tagged monk? Save *whole* fish fresh, not frozen

WOODS HOLE, MA – Anyone lucky enough to haul up a monkfish outfitted with a valuable data storage tag (DST) can claim a $500 cash reward simply by saving the fish – the whole fish – and shipping it to researchers or arranging for a pick-up.

The bullet-shaped, canister-like tags are surgically implanted in the tail of the fish and form a significant bump under the skin. And, to further grab people's attention, two pink T-bar tags, which look like bright antennae, stick out around the midridge area of the tail.

Researchers are asking fishermen to save the *entire* fish, not just the tail, and, if at all possible, to keep the fish on ice in "fresh" condition. Freezing is a backup if necessary, but it's nowhere near as good as fresh.

"It's really important that we get the whole fish back," said Anne Richards of the Northeast Fisheries Science Center, one of the project leaders for the DST tagging work.

"It's way better to get a fresh fish than a frozen one, but frozen is better than rotten," she said.

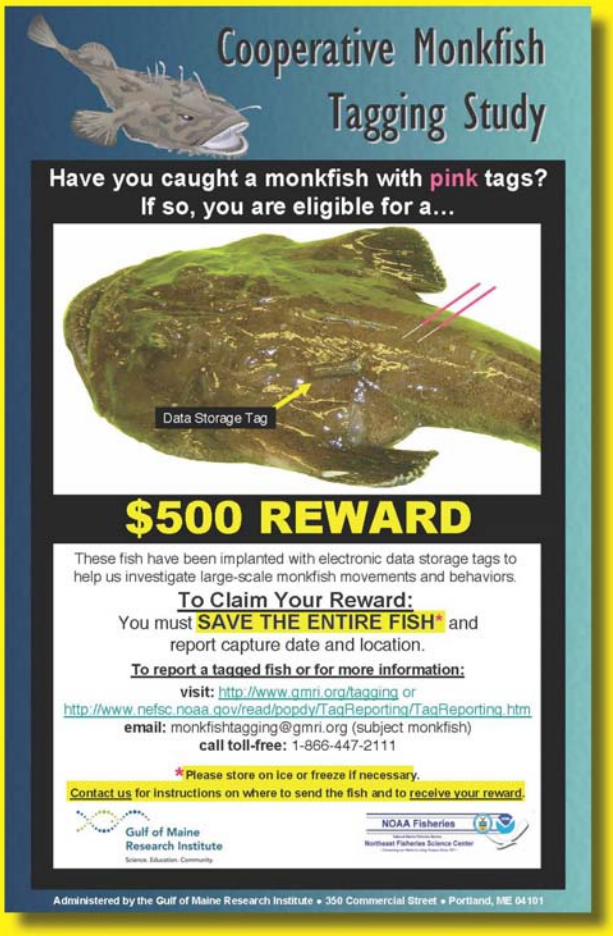
The whole fish is important because researchers at the science center, the Gulf of Maine Research Institute (GMRI), and the University of Massachusetts-Dartmouth School for Marine Science and Technology are carrying out a variety of different studies with numerous parts of the fish.

Among other things, researchers want to look at each fish's gender, reproductive state, length and weight at recapture, stomach content, vertebrae, dorsal spines, and otoliths.

"We're taking every kind of sample possible for genetic studies, feeding and aging studies, reproductive biology studies, and microchemical analyses to tell us where these fish have been," said Richards.

Researchers considered various options for tag placement but settled on the tail.

"That way, if the tag is missed on the boat and the tail goes into the market, it might be caught at the dealer or consumer level, or even during processing," Richards said.



What to do

Any fisherman who catches one of these DST-tagged monkfish should record the location of the recapture, save the fish on ice, and, as soon as possible, call the toll-free number to alert researchers to the important find. They'll tell you what to do from there.

The number is 1-866-447-2111.

The electronic tags are expensive to buy, costing $360 each. But each one can log up to five years worth of priceless data.

"That's why we're trying our best to get high return rates," said GMRI's Graham Sherwood, who's involved in the project.

For more information about tag returns and the tagging program in general, visit the GMRI web site at <www.gmri.org/tagging> or the science center web site at <www.nefsc.noaa.gov/read/popdy/TagReporting/TagReporting.htm>.

Janice M. Plante

Monkfish aging study may alter old thinking

NEW BEDFORD, MA – Like many other fish species, monkfish can be aged by reading the number of "rings" on certain bony body parts such as otoliths, vertebrae, and dorsal spines. It's like counting the circles on a slab of tree trunk. Three rings means the fish is three years old. Ten rings means it's 10 years old.

Or does it?

Scientists are beginning to question whether this long-accepted aging technique is completely suitable for monkfish, especially the older ones.

"We could be underestimating age. We're not sure if a ring is laid down every year when growth slows down," said Crista Bank, a technician at the University of Massachusetts-Dartmouth School for Marine Science and Technology (SMAST) who is also working on a master's thesis about the subject.

Yet knowing the age of monkfish is key to understanding their basic biology. So that's why researchers have embarked on a new series of studies to get to the root of the matter.

"We want to validate that the aging method is accurate, which will give us more confidence in our stock assessments," said Bank.

While the primary purpose of Bank's monkfish work at SMAST is to determine whether the current aging methodology is producing good results, she also is investigating whether one particular aging tool is preferable over another.

Is it better to count rings on otoliths – those tiny, calcified inner ear bones – or on vertebrae, which distinctly show rings without even being sliced? Or what about the first dorsal spine – the one with the "fishing lure" dangling from it? That's what some European scientists use to age monkfish.

In addition to surgically implanting data storage tags into monkfish, researchers also inject the fish with oxytetracycline. The antibiotic "marks" the fish for aging studies and may help reduce the chance of infection at the tag incision.

Monkfish Tagging Program photo

Graham Sherwood of the Gulf of Maine Research Institute (GMRI) has been deeply involved in the monkfish tagging program and its related studies. He emphasized the importance of all of the various aging work.

"There's a real difficulty in aging monkfish," he said. "We really need to know how long they live."

There's a real difficulty in aging monkfish, and we really need to know how long they live.
—Graham Sherwood

Oxytetracycline

Some of the aging work is being carried out during monkfish tagging trips.

Researchers, working aboard commercial fishing vessels, have been surgically implanting data storage tags into monkfish tails and then injecting the fish with oxytetracycline.

The tagging project is designed to produce more information about monkfish migration patterns and north/south mixing rates, but the oxytetracycline injections are part of the aging studies.

The oxytetracycline "marks" the fish. It works by leaving a light glow or stain on the specific ring that was being laid down at the time the fish was caught, tagged, and injected.

Then, when the fish is recaptured, researchers will be able look for the marked ring with ultraviolet light, which will help them determine how much growth occurred between tagging and recapture, assuming the fish isn't recaptured before it has time to grow.

Crista Bank also is keeping live monkfish in holding tanks at SMAST.

"Growth in the lab won't be like actual growth in the wild, but we should be able to see seasonal growth patterns," she said. "This also will help us confirm whether the oxytetracycline method is working."

Bank participated in all but one of the 2009 tagging trips and is one of four researchers who have mastered the surgical procedure used to implant the high-tech electronic data storage tags into monktails. She also has taught other researchers to do oxytetracycline injections so the work can continue even when she's not onboard.

Oxytetracycline is an antibiotic. Anne Richards of the Northeast Fisheries Science Center, one of the project leaders in the monkfish tagging program, said using the antibiotic for aging studies might have an ancillary benefit following tag surgery.

"It should help with healing by reducing the chance of infection at the tag site," she said.

Microchemical work

In another phase of the aging work, researchers plan to save otoliths from recaptured monkfish for future microchemical analyses that may help them better interpret growth rings.

The people involved hope to age fish chemically by looking at the ups and downs of certain microchemical components in the otoliths, such as with the element strontium. Researchers may be able to track seasonal variations in temperature, for example, by looking at differences in strontium concentrations.

It's complicated and highly technical work for sure, but it has the potential to provide amazing results.

Graham Sherwood said GMRI researchers ran a single otolith through the process at Memorial University in St. John's, Newfoundland.

"We thought it was an eight-year-old monkfish," he said. "But after the analysis, it looked like it might have been more like 13 years old."

Thanks to industry

The aging studies will be years in the making and won't produce any immediate results, but fishermen are supportive of the effort, knowing that better aging information will lead to better stock assessments, which then will lead to better management.

With this in mind, industry has been working hand-in-hand with researchers, taking them to sea when needed and supplying them with fish.

Bank, who was readying to meet a fisherman at the dock one Friday night in mid-January to pick up yet another live monkfish for her laboratory holding tanks, expressed deep appreciation for industry's support.

"Without them, we couldn't do any of this," she said. "We rely on their help."

Janice M. Plante

Monkfish Tagging Program photo

Crista Bank, an SMAST technician, is working on a study of current monkfish aging methodology.

Pavel Ivanov photo

Above, NEFSC's Larry Alade with the T-bar tags. GMRI hopes to get an additional 5,000 T-bar tags in monkfish in 2010. Researchers intend to train fishermen to do the tagging, training them on tagging methods and what's needed for data collection.

Types of Tags

Fishermen are asked to save the entire fish, if they land a monkfish that has been implanted with a data storage tag, see below. The canister-like tags create a visual bump under the skin in the tail of the fish. The fish have also been marked with two pink T-bar tags, which stick out around the midridge area of the tail.

Monkfish Tagging Program photo