Final Report

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Tagging to Assess Monkfish Movement: Additional tagging to assess monkfish (*Lophius americanus*) movements and stock structure in the northeastern United States

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A. EXECUTIVE SUMMARY[1]

A conventional tagging study was conducted to examine movement and mixing rates of monkfish (*Lophius americanus*) within and between two monkfish management areas in the northeastern United States (the Northern and Southern Management Areas, or NMA and SMA, respectively). A total of 6,162 monkfish were 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 were monitored over this time period. This study represents the first tagging study for monkfish in the U.S. northeast and more than triples in effort (i.e., tag releases) the next largest tagging study for *Lophius sp*. The following is a summary of the main findings:

1) The overall reporting rate for filtered recaptures (i.e., days at liberty > 30 days) was 2.7% and this rate was higher in the NMA (2.9%) than in the SMA (2.7%).

2) Tag shedding rate (based on double tagging of all monkfish released), was found to be 18.8% which compares well to shedding rates for other species (e.g., cod).

3) Movements after 30 days at liberty ranged from 1 to 748 km; mean displacement was similar in both areas: 50.2 ± 82.7 km in the NMA versus 51.3 ± 83.2 km in the SMA.

4) Based on recaptures of NMA tagged monkfish in the SMA and reporting rates of tagged monkfish in the SMA, we estimate that 13% of monkfish tagged in the NMA moved to the SMA. Although movement from the SMA to the NMA was not observed, we did observe seasonal patterns of movement within the SMA such that movements to the northeast were common in the spring and movements to the southwest were dominant in the fall. Our tagging efforts may not capture movement of smaller monkfish to the NMA from the SMA which may act to balance what appears to be a one way exchange.

5) Growth rate was estimated for a subset of monkfish for which reliable length data existed at the time of recapture (n = 46) to be 10.9 ± 8.9 cm yr^{-1} (mean ± std) which compares well with tagging-based estimates of growth for *Lophius piscatorius*. **There was a highly significant trend for lower growth in larger monkfish** ($r^2 = 0.19$, $p < 0.01$) which, if coupled to further

[1] This study is a continuation of a conventional tagging program that began in 2007 with funding from the 2007 Monkfish Research Set Aside Program. In this report, which follows the same format as the 2007 report, results and figures are updated with new tagging data.

data and evidence, could call into question the validity of current aging results and the assumption of linear growth in monkfish.

B. BACKGROUND AND OBJECTIVES

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 haddock) and the rapid development of the monkfish fishery (Richards et al., 2008). However, monkfish biology is relatively poorly understood, primarily because few are caught in Northeast Fisheries Science Center (NEFSC) resource surveys (Richards et al., 2008). On a broad scale, monkfish are distributed in the northwest Atlantic from the Grand Banks and northern Gulf of St. Lawrence to Cape Hatteras, North Carolina (Caruso, 2002). No genetic differentiation exists between samples caught in North Carolina and the Gulf of Maine (Chikarmane et al., 2000). Despite this, perceived differences in biology (growth patterns and recruitment), as well as differences in how monkfish are fished north and south of Georges Bank, led to the establishment of two management areas in 1999 (Richards et al., 2008); the Northern Management Area (NMA, Gulf of Maine and northern Georges Bank) and the Southern Management Area (SMA, southern Georges Bank and Mid-Atlantic Bight). A fundamental unknown, critical to population assessment and management of monkfish, is the degree of movement of these fish between management areas in the northeast United States (north and south of Georges Bank).

Monkfish are not intuitively considered to be a migratory species. Their body form (strongly depressed) does not indicate high movement capacity and their feeding strategy (sit-and-wait, or ambush predators) suggests a highly sedentary lifestyle. Despite this expectation, a recent conventional tagging study (using anchor tags and relying on fishery recaptures) conducted on monkfish (*Lophius piscatorius*) in the Shetland Islands revealed a surprising ability for long-range movements (Laurenson et al., 2005). Most (33%) of the 80 reported monkfish were recaptured within 25 km of the release location (a total of 1,768 monkfish were released). However, one monkfish swam as far as the Faroe Islands and another made it all the way to the southern coast of Iceland for a total straight line displacement of 876 km. In all, 7 of the 80 recaptures were 100 km or more from the initial release sites suggesting that monkfish can indeed move large distances. No such tagging study has ever been conducted for monkfish in the northeast United States and it is unclear to what extent monkfish may move between the Southern and Northern Management Areas.

Such movement and mixing may already be predicted from existing biological data. For instance, the distribution of monkfish caught in the NEFSC bottom trawl survey shows a clear shift in abundance (numbers per tow) throughout the year with monkfish more abundant in the SMA in February and March. Monkfish reach high levels of abundance in both areas in April. By May, monkfish are most abundant in the NMA and inshore sites in the SMA. The summer months are characterized by low levels of abundance in both management areas. Monkfish abundances then increase in the survey in the SMA in September, both areas in October and then primarily in the NMA in November. These changes in abundance patterns may reflect real shifts in distribution. They may also, however, reflect changes in catchability within each area. For instance, during periods of assumed low abundance, monkfish may settle into habitats inaccessible to trawl gear (previous diet studies have shown that there is a trophic advantage to being in more complex habitats for large monkfish; Sherwood and Grabowksi, 2008), or they may move out of the survey area altogether (e.g., deep slope waters; Richards et al., 2008).

In addition to seasonal shifts in abundance, there are other biological indices that may be suggestive of movement between the two areas including differing patterns in sex ratios and differences in larval surveys. In the SMA, sex ratios (F:M) shift from ~50:50 in fish less than 40 cm to approximately 20:80 in fish ~60 cm in length (Richards et al., 2008). Ageing studies indicate that the change in sex ratios is not due to a cessation of growth in males (NEFSC 2002, 2005), although Sherwood et al. (2011) found evidence for sex-based differences in growth. A different pattern in sex-ratio-at-length is seen in the NMA, where F:M sex ratios gradually increase in fish greater than about 45 cm (~4 yr) (Richards et al., 2008). All monkfish over 70 cm (~7 yr) from both areas are female, possibly because of higher male mortality (there is no evidence of sequential hermaphroditism in monkfish) or sexual size dimorphism. This difference in sex ratios may also be explained by movement of females into the NMA from the SMA. Alternatively, these females may move into deeper waters or different habitats. In terms of larval patterns, icthyoplankton surveys conducted by NMFS-Marine Resources Monitoring, Assessment and Prediction (MARMAP) from 1977-1987 broadly suggest that monkfish spawning is highly aggregated in the Mid-Atlantic bight, and that fewer larvae exist on Georges Bank and in the Gulf of Maine (Steimle et al., 1999). Able and Chambers (2003) reviewed NMFS sea scallop (*Placopecten magellanicus*) assessment surveys and determined that demersal YOY (20-120 mm TL) monkfish were relatively rare in the Gulf of Maine and the eastern edges

of Georges Bank. In contrast, NEFSC trawl surveys have captured greater abundances of larger (100-200 mm TL) juvenile monkfish in the northern management region in both the spring and fall of eight of the nine previous years (NEFSC, 2002). These studies collectively suggest that juvenile monkfish may be migrating northward, and that monkfish inhabiting areas along the Mid-Atlantic Bight may be an important source of more northern monkfish populations within the Gulf of Maine.

Given the intensity of monkfish fishing pressure in the NE U.S., information on large-scale migratory patterns of monkfish could be critical to sustaining this important fishery. The objective of this conventional tagging study is therefore to provide up-to-date information on monkfish movement behaviors in eastern U.S. waters with particular emphasis on demonstrating potential movements between the Northern and Southern Management Areas (NMA and SMA, respectively).

C. METHODS

C.1. Tagging

Tagging for this project occurred between September of 2007 and August of 2012 at eight capture and release sites (five in the SMA and three in the NMA; see Table 1). A total of 6,162 monkfish (4,777 in SMA and 1,385 in NMA) were captured by gillnet (8" and 12" mesh, ranging in soak time from 2 to 5 days), measured (to nearest cm), tagged with conventional T-bar tags (Hallprint Pty Ltd.), and released immediately. The processing time between removing monkfish from gillnets and releasing them back into the water was approximately 5 minutes. The tag insertion protocol was modified from a previous tagging study conducted in the Shetland Islands on *Lophius piscatorius* (Laurenson et al. 2005). Tag location on the fish was dorsal just anterior to the 2nd dorsal fin with tags inserted on an angle of approximately 30-45° (Figure 2). Ten percent of the monkfish were double-tagged with high reward tags (one blue and one yellow); the rest were double tagged with yellow tags. Tags were individually numbered and printed with return and reward information (Figure 2).

C.2. Outreach

A variety of outreach strategies were utilized throughout the course of the project to encourage a high recapture reporting rate. Laminated posters (Figure 2) summarizing the project and detailing tag reporting procedures were posted at fishing ports throughout New England and further south to New York and New Jersey (Newburyport, Scituate, Gloucester, Chatham, Harwich, Fairhaven, New Bedford, Tiverton, Newport, and Point Judith). A project website was created (http://www.gmri.org/mini/index.asp?ID=15&p=46) to provide more detailed information on project rationale and methods, while also presenting information about tag reporting. Additionally, a postcard (Figure 3) was sent to all monkfish permit holders approximately 3 months after tagging was initiated to encourage participation from as many fishermen as possible.

A reward system was also implemented to further encourage tag reporting. Those who recaptured and reported fish with regular yellow tags received a monkfish RSA tagging T-shirt (Figure 4). Those who recaptured fish with high-reward blue tags were sent a check for $100. A letter thanking reporters for their information along with a map of tag recaptures to date were sent along with the reward (Appendix I).

C.3. Data Analysis

Length distributions of released monkfish were compared among areas qualitatively by producing histograms (length-frequency distributions) and by student's t-test. Length distributions of recaptured monkfish were also compared to releases within areas to explore possible length bias in recaptured monkfish (student's t-test). Recapture rates, as total number and percentages were tabulated and calculated by area for the entire data set (unfiltered) and for monkfish recaptured after 30 days at liberty (filtered data set) to allow for mixing after the initial capture and tagging event. The 30-day cutoff is commonly used as a minimum period of time when looking at mixing and growth from mark-recapture data (e.g., Tallack 2009) and examination of monkfish displacement versus days at liberty (Figure 7) suggests that monkfish had ample time to move large distances within this time frame. Tag shedding rates were calculated by dividing the number of monkfish returned with only one tag by the total number of returns (this was done with unfiltered data by area and for both areas combined). Mixing (straying) rate among areas was calculated by 1) first dividing the number of stray tags returned

from an adjacent area (i.e., not the area of origin) by the area and tag color-specific reporting rate for the area in which the stray fish were captured, and 2) then dividing this number by the total number of monkfish tagged in the area from which stray fish originated. Area-specific reporting rates were based on release and recaptures within the same area (i.e., do not include stray fish). Mixing rates were calculated using unfiltered data. Differences in mean displacement among areas were explored by student's t-test (filtered data). Mean bearing for straight line displacements was also calculated separately for each area (filtered data). Finally, monkfish growth (cm year^{-1}) was calculated for a subset of monkfish for which valid length data was available at recapture (see section D.4. for filtering criteria) and compared among areas (student's t-test) and as a function of length at release (linear regression).

D. RESULTS AND DISCUSSION

D.1. Length distributions of tagged monkfish

A total of 6,162 monkfish were tagged between the fall of 2007 and the summer of 2012. 4,777 monkfish were tagged in the SMA and 1,385 in the NMA. Length-frequency distributions for monkfish tagged in the Northern and Southern Management Areas are shown in Figure 5. Mean length was significantly larger in the NMA than in the SMA (67.2 ± 11.3 cm versus 60.7 ± 9.1 cm; student's t-test, $p < 0.0001$). This finding is consistent with higher proportions of females in the NMA (Richards et al., 2008). In addition, there was a much higher proportion of larger monkfish (> 80 cm) in the NMA. A previous study examining diet, habitat and energetic relationships (Sherwood and Grabowski, 2008) found that large monkfish (> 80 cm) gain an energetic and trophic advantage from living in complex (rocky/ledgy) habitats of which there is more in the NMA than in the SMA. Mean length of recaptured monkfish (length at release) was not significantly different (student's t-test, $p > 0.05$) than mean length for all releases in both areas indicating that there was no bias in the size of fish likely to be recaptured and no apparent size-selective mortality associated with tagging. This lack of a relationship between length at release and recapture rate is consistent with the findings of Laurenson et al. (2005) and is not typical for other species (Fowler and Stobo, 1999).

D.2. Recapture and reporting rates

Table 2 is a summary of recapture data by management area for non-filtered and filtered (days at liberty > 30 days) data. The following is a discussion of the filtered data only (i.e., for tagged monkfish that were recaptured after 30 days at liberty). Of the 1,385 monkfish tagged and released in the NMA, a total of 32 were recaptured and reported in the NMA (2.3%). Eight of the fish released in the NMA were recaptured in the SMA (0.58%). In the SMA, a total of 129 of the 4,777 monkfish tagged were recaptured and reported (2.7%). None of the fish tagged in the SMA were recaptured and reported in the NMA, although the majority of monkfish tagged in the spring in the SMA moved in a northeasterly direction. The lower overall reporting rate for tags in the NMA versus the SMA may reflect movement out of the area, differences in fishing effort, or differences in motivation to report recaptured monkfish. The overall reporting rate for the project was 2.7% (169 of 6,162 monkfish). This is slightly lower than the recapture rate (4.5%, or 80 of 1,768 monkfish) reported by Laurenson et al. (2005) for *Lophius piscatorius*, the only other tagging study conducted on monkfish. The lower rate for the present study is likely due to the fact that we excluded recaptures less than 30 days at liberty and Laurenson et al. (2005) did not. Had we included all recaptures, our overall reporting rate would have been higher at 4.8%.

Since all monkfish were double tagged, it was possible to estimate tag shedding rates. This was done for all tag recaptures (i.e., without filtering). Of the 233 recaptured fish for which we could confirm from the harvester whether the fish had one or two tags, 44 had one tag. This gave us an overall tag shedding rate (both areas combined) of 18.8%. This is slightly higher than, yet comparable to shedding rates reported for T-bar tags in cod (~15%, Tallack 2009).

D.3. Monkfish movements and mixing

The purpose of this project was to examine whether monkfish move between the Southern and Northern Management Areas. Despite movement north and east within the SMA we found no evidence of movement from the SMA into the NMA, while there was some movement from the NMA into the SMA. A total of 9 monkfish tagged in the NMA were recaptured in the SMA (Figure 1). If 9 NMA tagged monkfish were recaptured and reported in the SMA, and if reporting rate is 5.0% for tags in the SMA (using unfiltered data, see above), then we estimate that 180 tagged monkfish moved from the NMA to the SMA. Therefore, it is estimated that 13%

of the 1,385 monkfish tagged in the NMA moved across the management boundary into the SMA, whereas 0% underwent the opposite movement.

The average displacement was very similar for monkfish released in the NMA compared to the SMA (50.2 ± 82.7 km versus 51.3 ± 83.2 km). The maximum displacement for a monkfish released in the NMA was 503 km (from Stellwagen Bank to off New Jersey), while the maximum distance traveled for a monkfish released in the SMA was 748 km (from Cox's Ledge south of Rhode Island to off of Ocracoke, N.C. These maximum displacements are similar to those reported by Laurenson et al. (2005) for *Lophius piscatorius* tagged at the Shetland Islands (one was recaptured near the southern coast of Iceland, over 800 km). There was no significant relationship between days at liberty and displacement in either area (Figure 7). Monkfish movement in the SMA appears to be seasonal (Figure 8). Fish tagged in the fall and recaptured within 180 days tended to move to the southwest (average orientation of 224.8 degrees ± 14.1), this supported both our previous findings from this study and fishermen's knowledge. Previously, we had lacked tagging results from the spring. Thanks to industry tagging efforts we were able to get thousands of tags out in the SMA in the spring of 2010. From the recapture data from these tags it appears that fish in the SMA, especially fish tagged off of Long Island and the Block Canyon, tend to head to the north and east (average heading of 57.1 ± 93.2), again supporting the observations of our fishing partners. Orientation data for fish tagged in the NMA and recaptured between 30 and 180 days did not indicate any clear trend in movement direction for either the spring or the fall. This could have been due to smaller sample sizes.

Figure 9 shows the relationship between monkfish size (cm) and displacement in kilometers for filtered data (i.e., for monkfish at liberty longer than 30 days). While displacement was not significantly greater for larger monkfish overall or within each management area, the largest migrations were all undertaken by large monkfish. With one exception, all migrations over 200 km were undertaken by monkfish over 60 cm. Large monkfish may move larger distances to spawn or perhaps to seek out optimal feeding environments; a previous study by Sherwood and Grabowski (2008) found that large monkfish in the SMA require complex habitats to realize full trophic potential.

D.4. Monkfish growth

Of the 297 total reported monkfish, lengths at recapture were available for 89 individuals. The mean ± 1 SD DAL for these recaptures was 155 ± 163 days. Of the 89 recaptures with length data, 48 individuals were at large for 90 days or more. It was these monkfish that were subsequently used to examine growth while at large and how this varies with size. We only considered individuals at large for more than 90 days to ensure adequate time for growth to manifest. Growth (G) was calculated as growth increment (cm) divided by days at large × 365. Thus, units for growth were cm · yr^{-1}. Growth increment was simply length at recapture (nearest cm) minus length at release (nearest cm). Two of the data points were considered suspect likely due to gross measurement error (at recapture) and were subsequently objectively excluded using Peirce's criterion for the removal of outliers (Peirce 1852). All of the remaining values fell well within Peirce's criterion (for inclusion) and only two were slightly negative. The 46 usable data points are tabulated in Table 3.

The relationship between growth rate (G) and monkfish length (L) is shown in Figure 10. For all data combined, the relationship is given as: $G = 32.8(6.8) - 0.35(0.11) \cdot L$ ($r^2 = 0.19$, $n = 46$, $P < 0.01$). The relationship between growth and length was significant for the SFMA data ($G = 42.4(10.0) - 0.51(0.16) \cdot L$; $r^2 = 0.24$, $n = 33$, $P < 0.01$) but not for the NFMA data ($G = 21.1(6.7) - 0.17(0.10) \cdot L$; $r^2 = 0.20$, $n = 13$, $P = 0.12$) likely due to smaller sample size in the NFMA. Mean growth rate for all monkfish was 10.9 ± 8.9 cm · yr^{-1} (10.2 ± 5.2 cm · yr^{-1} for the NFMA, and 11.2 ± 10.0 cm · yr^{-1} for the SFMA); the slight difference in mean growth among areas was not significant ($p > 0.05$, student's t-test). Our results for mean growth, not taking into account size variability, agree quite well with the only other study examining monkfish (*L. piscatorius*) growth with tagging (9.4 cm · yr^{-1}, Laurenson et al. 2005). Overall, our results strongly support declining growth rate with increasing size in monkfish which calls into question the linear growth pattern assumed by the assessment (Richards et al. 2008). A manuscript in preparation by the authors (Sherwood et al. *in prep*) uses the empirical relationship between size and growth (shown here) to model monkfish growth over time. Results of this modeling exercise, which accounts for error in the length versus growth relationship, reveals a curvilinear growth pattern from which Von Bertalanffy growth parameters can be derived with error (these results are shown in Table 4).

E. CONCLUSIONS

This tagging study is the largest of its kind for *Lophius* sp. (6,162 tag releases, versus the next largest study of 1,768 tags; Laurenson et al., 2005) and has provided important new insights into movement behavior, stock structure and growth of monkfish in the northeastern United States. Two separate management areas for NE U.S. monkfish were established in 1999 based on perceived differences in biology (primarily growth and recruitment; Richards et al., 2008). In line with more recent findings to suggest that monkfish constitute one population from the mid-Atlantic Bight to the Gulf of Maine, including information on abundance patterns and sex ratios (Richards et al., 2008) and larval (Steimle et al., 1999) and juvenile surveys (Able and Chambers, 2003), we found a relatively high level of movement (13%) of larger monkfish from the north to the south (but curiously not in the other direction). This suggests that perhaps younger monkfish may undertake the opposite movement to the north (to close the loop?). Further studies may examine movement of younger/smaller monkfish, although capturing and tagging such individuals is a more challenging undertaking. Other notable findings are as follows:

- Based on double tagging, overall tag shedding rates were found to be 18.8% which is comparable to shedding rates reported for other species (e.g., cod ~15%, Tallack 2009) and indicate that monkfish are well suited to conventional tagging studies.
- While no significant relationship between monkfish length and displacement was found; it was overwhelmingly large monkfish (greater than 60 cm) that moved over 200 km.
- In addition to providing new information on monkfish movement behaviors, this study has revealed some interesting patterns in growth. Monkfish growth is currently thought to be linear over the entire size range (Richards et al., 2008). **This tagging study found a highly significant relationship between growth and length in monkfish which calls into question the linear growth pattern currently used in management.**

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Table 1. Summary of tagging locations (centers of general tagging areas), and numbers tagged.

Management Area	Site	Latitude	Longitude	Fish Tagged
NMA	Scituate	42 10.820	70 32.299	352
NMA	Stellwagen	42 20.326	70 17.719	669
NMA	Gloucester	42 40.514	70 32.2	269
SMA	Newport	41 04.387	71 06.072	1997
SMA	Pt. Judith	41 06.514	71 20.437	891
SMA	Long Island	40 42.950	72 25.681	444
SMA	Long Island	40 33.573	72 44.35	501
SMA	Block Canyon	40 01.35	70 59.95	1037

Table 2. Summary of recaptures by management area for non-filtered and filtered (days at liberty > 30 days) data.

		Total recaptures		NMA recaptures		SMA recaptures	
Release Area	Releases	Recaptures	Percent	Recaptures	Percent	Number	Percent
NMA	1385	58	4.19%	49	3.54%	9	0.65%
SMA	4777	239	5.00%	0	0.00%	239	5.00%
Total	6162	297	4.82%	49	0.80%	248	4.02%
Filtered for days at liberty > 30							
NMA	1385	40	2.89%	32	2.31%	8	0.58%
SMA	4777	129	2.70%	0	0.00%	129	2.70%
Total	6162	169	2.74%	32	0.52%	137	2.22%

Table 3. Length at release, length at recapture and growth rate for monkfish from both management areas. Data is filtered showing only individuals at large for longer than 90 days.

Management Area	Length at Release (cm)	Days at Large	Length at Recapture (cm)	Growth Rate (cm·yr^{-1})
NFMA	47.5	118	53.0	17.0
NFMA	68.5	129	74.0	15.6
NFMA	73.0	143	79.0	15.3
NFMA	84.0	212	91.0	12.1
NFMA	66.5	215	74.0	12.7
NFMA	64.0	217	66.0	3.4
NFMA	57.5	342	71.0	14.4
NFMA	74.5	354	80.0	5.7
NFMA	59.0	381	71.0	11.5
NFMA	56	407	67.0	9.9
NFMA	74.0	459	80.0	4.8
NFMA	39.5	492	53.0	10.0
NFMA	91.0	865	91.0	0.0
SFMA	71.8	93	75.0	12.7
SFMA	59.7	95	64.0	16.6
SFMA	57.0	109	61.0	13.4
SFMA	70.0	110	71.0	3.3
SFMA	72.0	117	70.0	-6.2
SFMA	58.0	130	64.0	16.8
SFMA	69.0	141	71.0	5.2
SFMA	64.5	147	70.0	13.7
SFMA	73.0	147	80.0	17.4
SFMA	80.6	156	84.0	7.8
SFMA	60.3	162	63.5	7.2
SFMA	54.5	166	58.0	7.7
SFMA	48.3	167	66.0	38.8
SFMA	73.0	173	79.0	12.7
SFMA	63.5	185	66.0	4.9
SFMA	62.0	193	76.0	26.5
SFMA	60.5	196	61.0	0.9
SFMA	70.0	197	71.0	1.9
SFMA	73.5	199	74.0	0.9
SFMA	68.0	206	71.0	5.3
SFMA	72.5	253	79.0	9.4
SFMA	45.7	292	64.8	23.8
SFMA	59.0	293	65.0	7.5
SFMA	62.9	315	61.0	-2.2
SFMA	58.4	332	61.0	2.8
SFMA	52.7	332	66.0	14.6
SFMA	55.2	345	61.0	6.1
SFMA	47.0	348	62.0	15.7
SFMA	50.2	359	59.0	9.0
SFMA	45.72	378	76.0	29.2
SFMA	54.5	380	58.5	3.8
SFMA	50.8	401	85.7	31.8
SFMA	47.0	671	63.5	9.0

Table 4. Von Bertalanffy growth function parameter estimates for monkfish from the SMA, NMA and both areas combined. Data is from a Monte Carlo simulation generating 100 estimates of length-at-age for ages 1-10 (from Sherwood et al. *in prep*).

Case	L_∞	SE	*k*	SE	*t0*	SE	r^2	*N*
Both areas	116.5	4.6	0.21	0.02	-0.02	0.15	0.6	100
SMA	108.3	3.9	0.25	0.03	-0.04	0.17	0.49	100
NMA[a]	166.9	20.0	0.11	0.02	-0.04	0.21	0.55	100

[a]VBGF parameters for NMA are based on non-significant G_{adj} vs L_0 relationship.

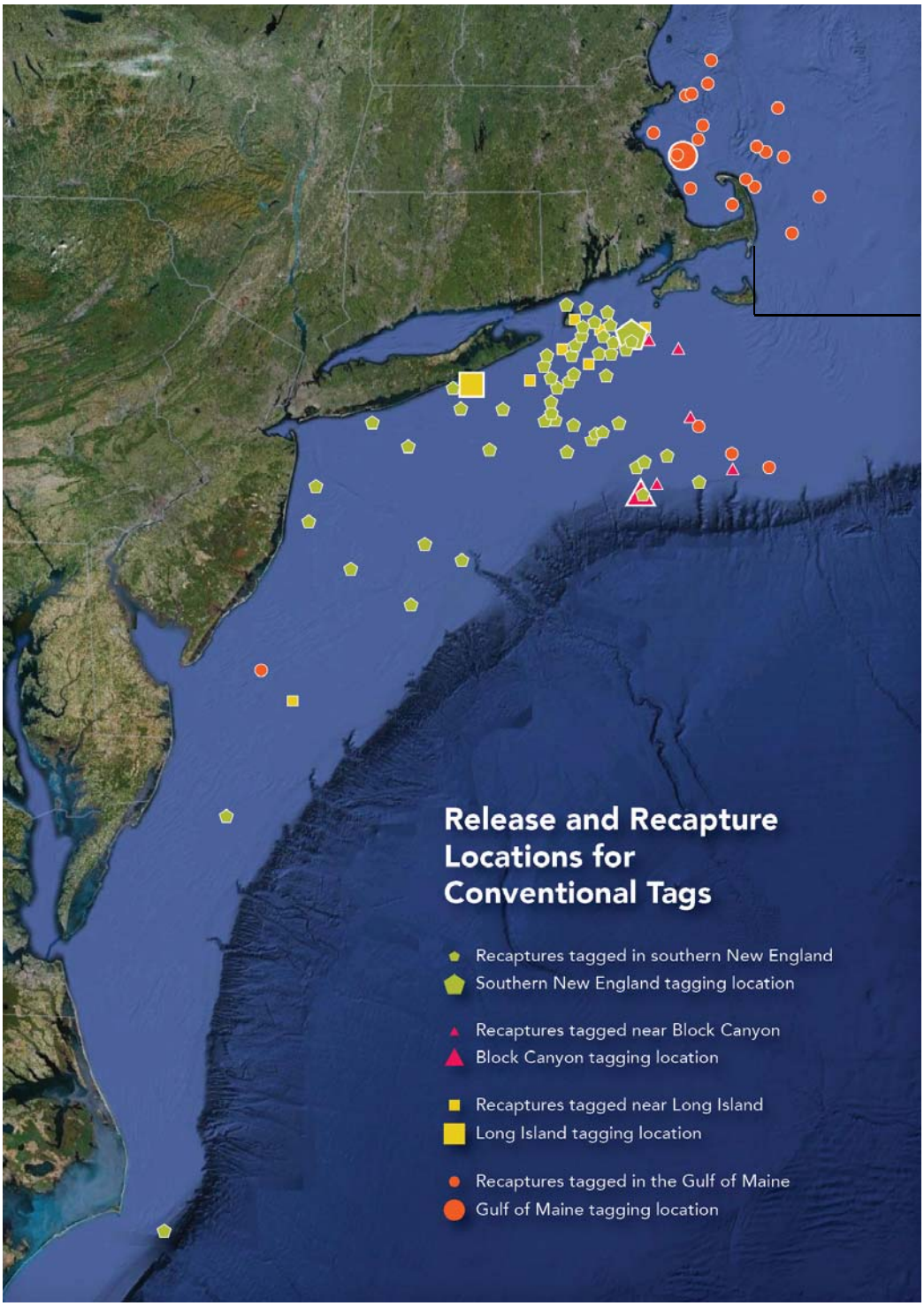

Figure 1. Map showing locations of release sites and locations of recaptured fish. The chart shows five (two points overlap) of the fish tagged in the NMA recaptured in the SMA. Another three NMA-tagged fish were recaptured in the SMA but did not have exact coordinates and are therefore not included in this chart.

Figure 2. Laminated outreach poster posted at numerous fishing ports.

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 3. 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 2008 RSA study to tag monkfish with data storage tags.

Figure 4. Back of T-shirt mailed to all participants mailing in yellow (regular) tags. Front has no image and reads “2007 Monkfish RSA Tagging Study” in white text over the left breast.

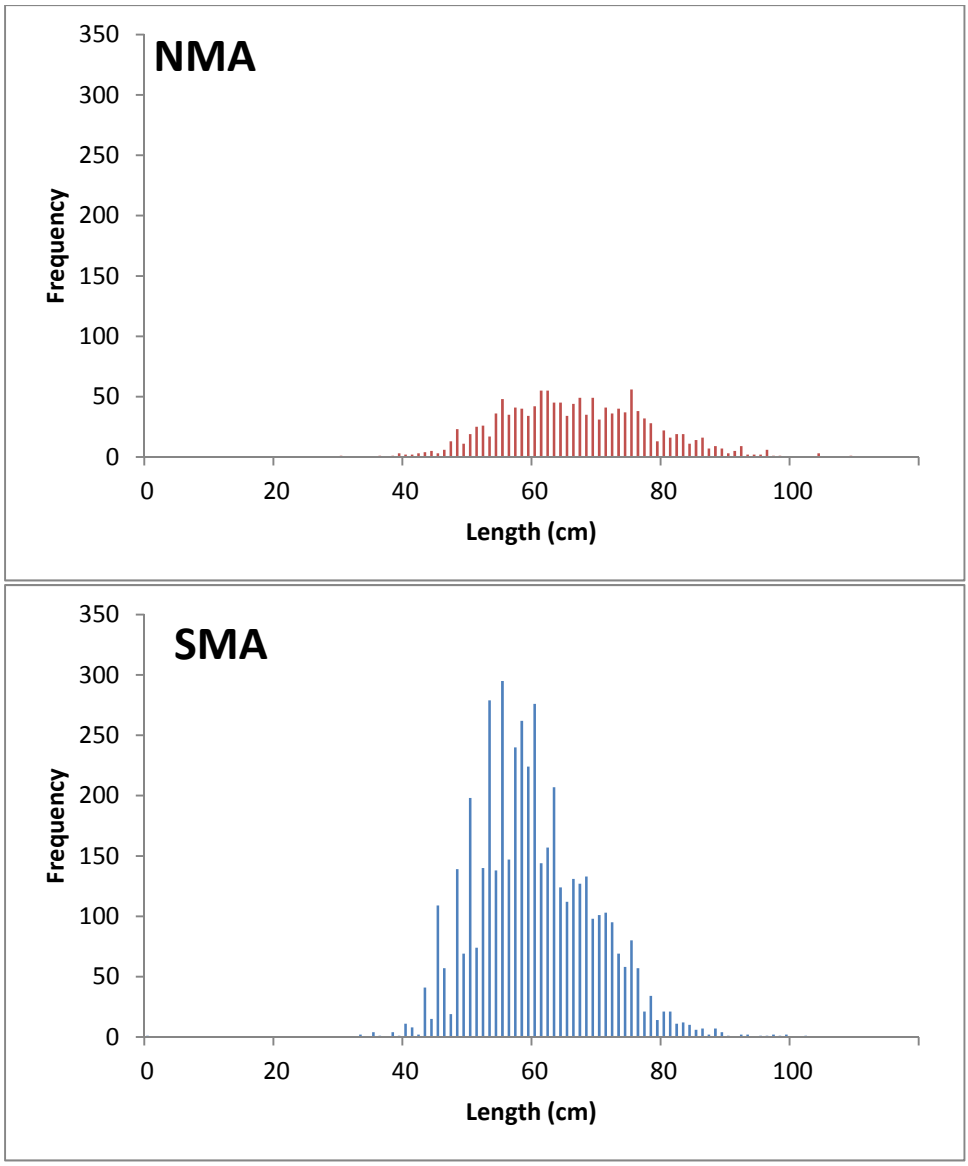

Figure 5. Length-frequency distributions for all monkfish tagged and released in the Northern and Southern Management Areas. Length frequency distributions of recaptured monkfish (length at release) are similar.

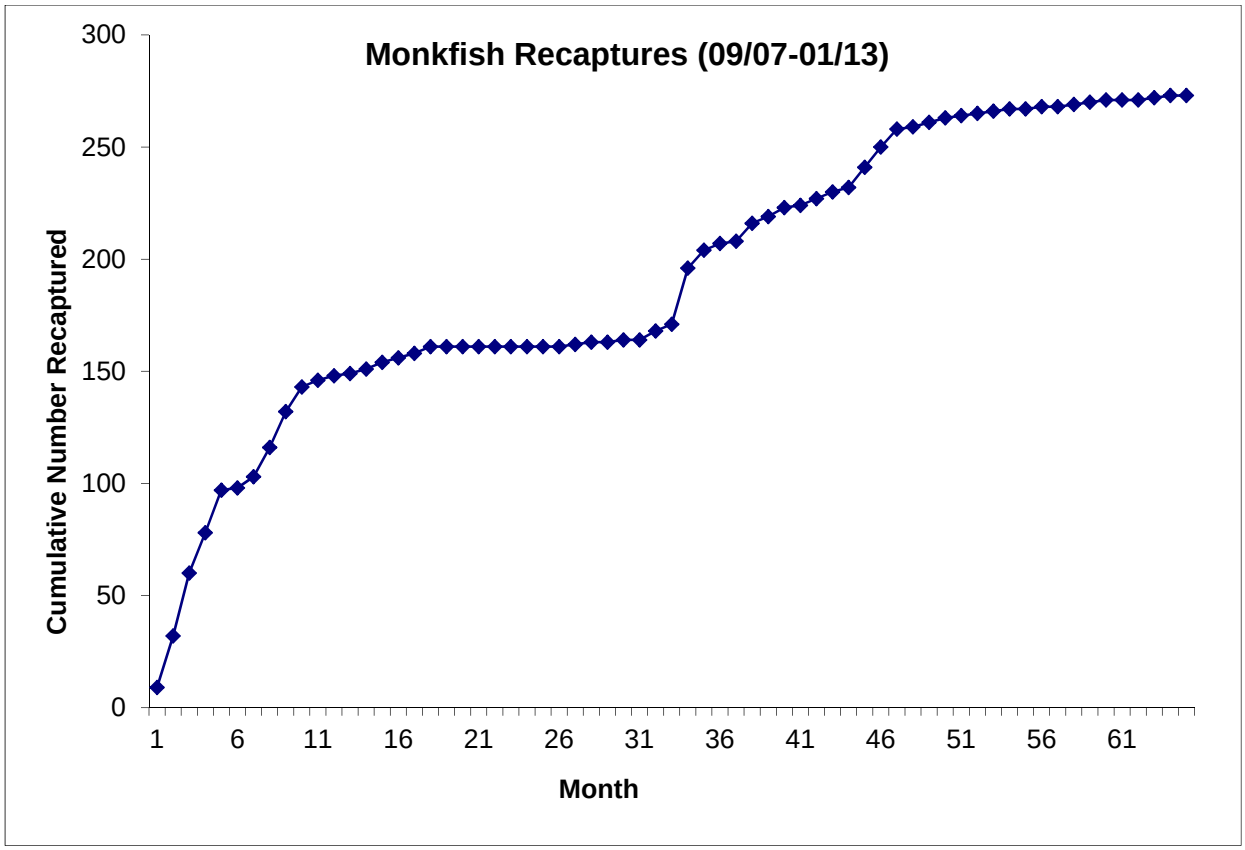

Figure 6. Cumulative recaptures of monkfish in the Northern and Southern Management Areas. First rise is due to releases from 2007 project and the 2nd increase is due to releases for 2009 project.

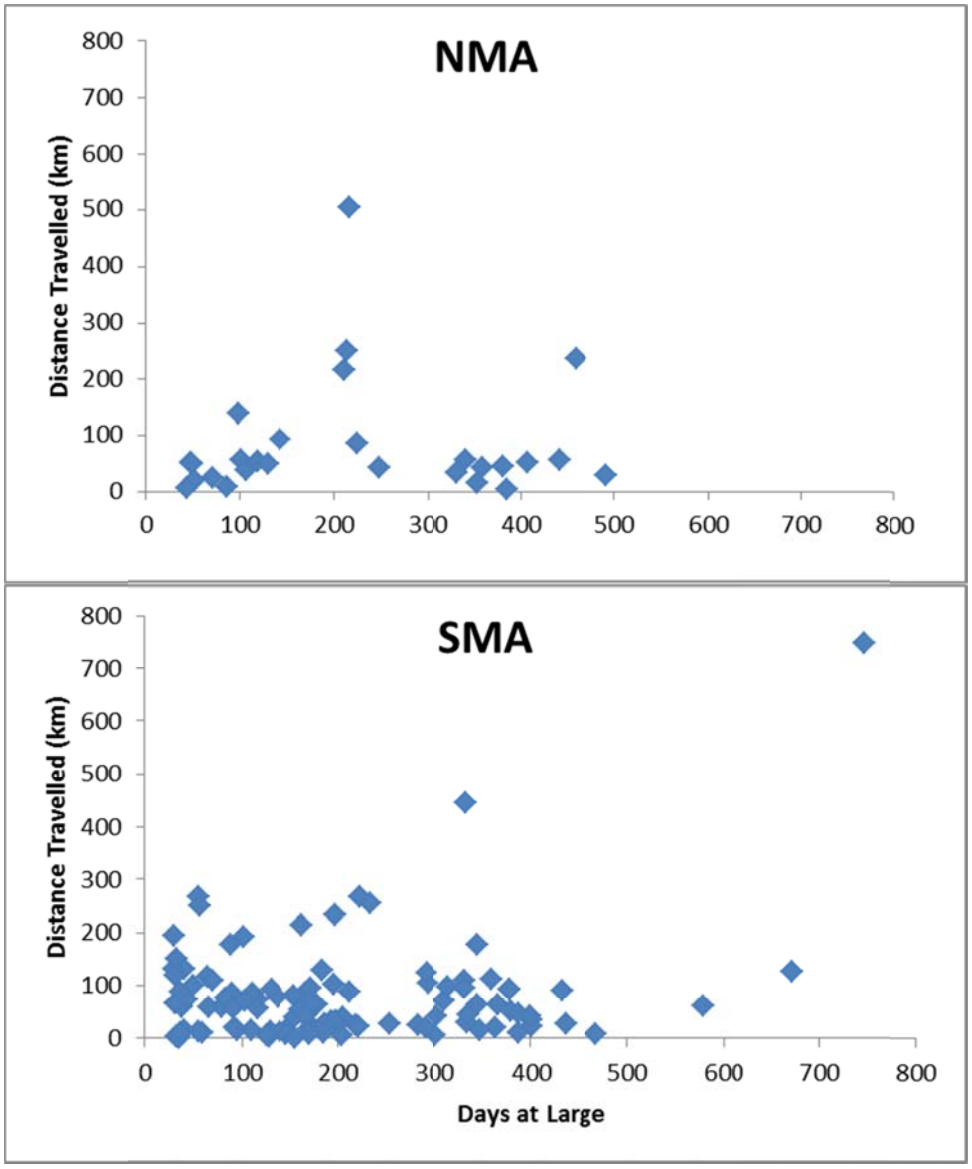

Figure 7. Total straight line displacement between release and recapture sites versus days at liberty by release area.

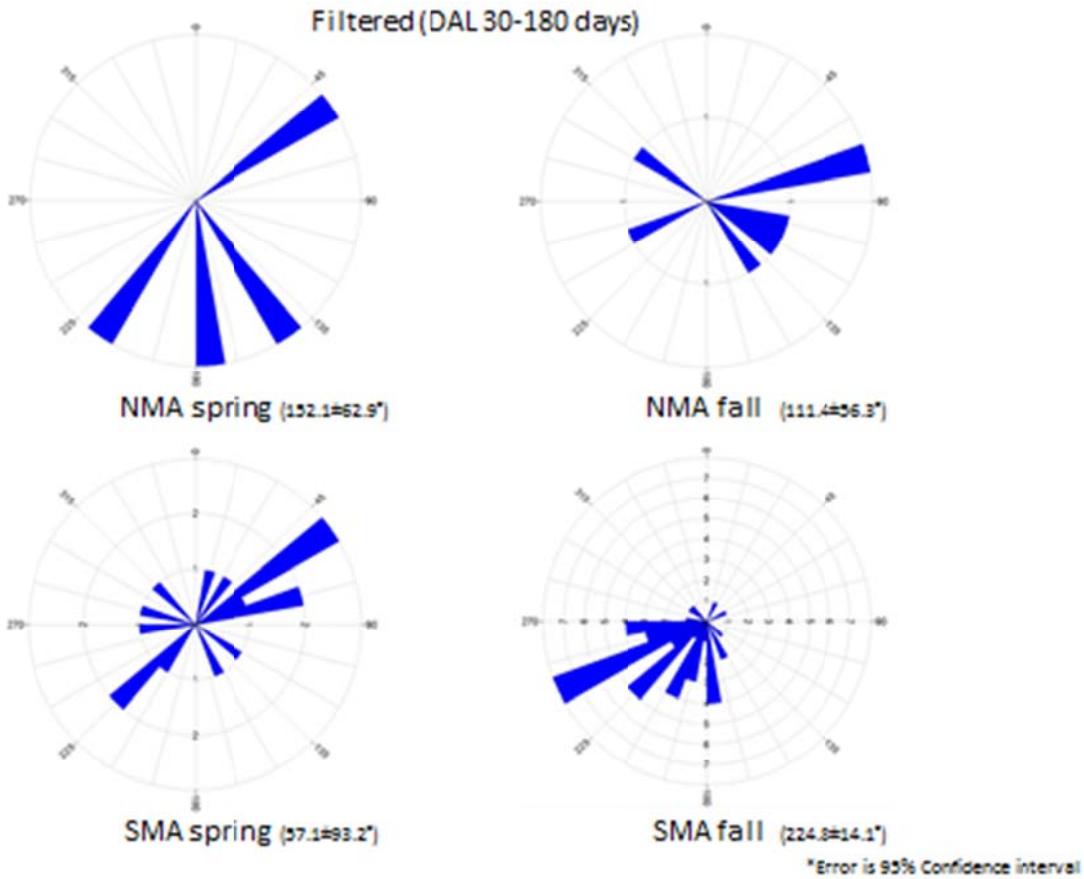

Figure 8. Rose diagram showing bearing for monkfish movements in the Northern and Southern Management Areas for fish tagged in the spring or fall, at large for at least 30 days and then recaptured within 180 days in order to determine seasonal movement patterns.

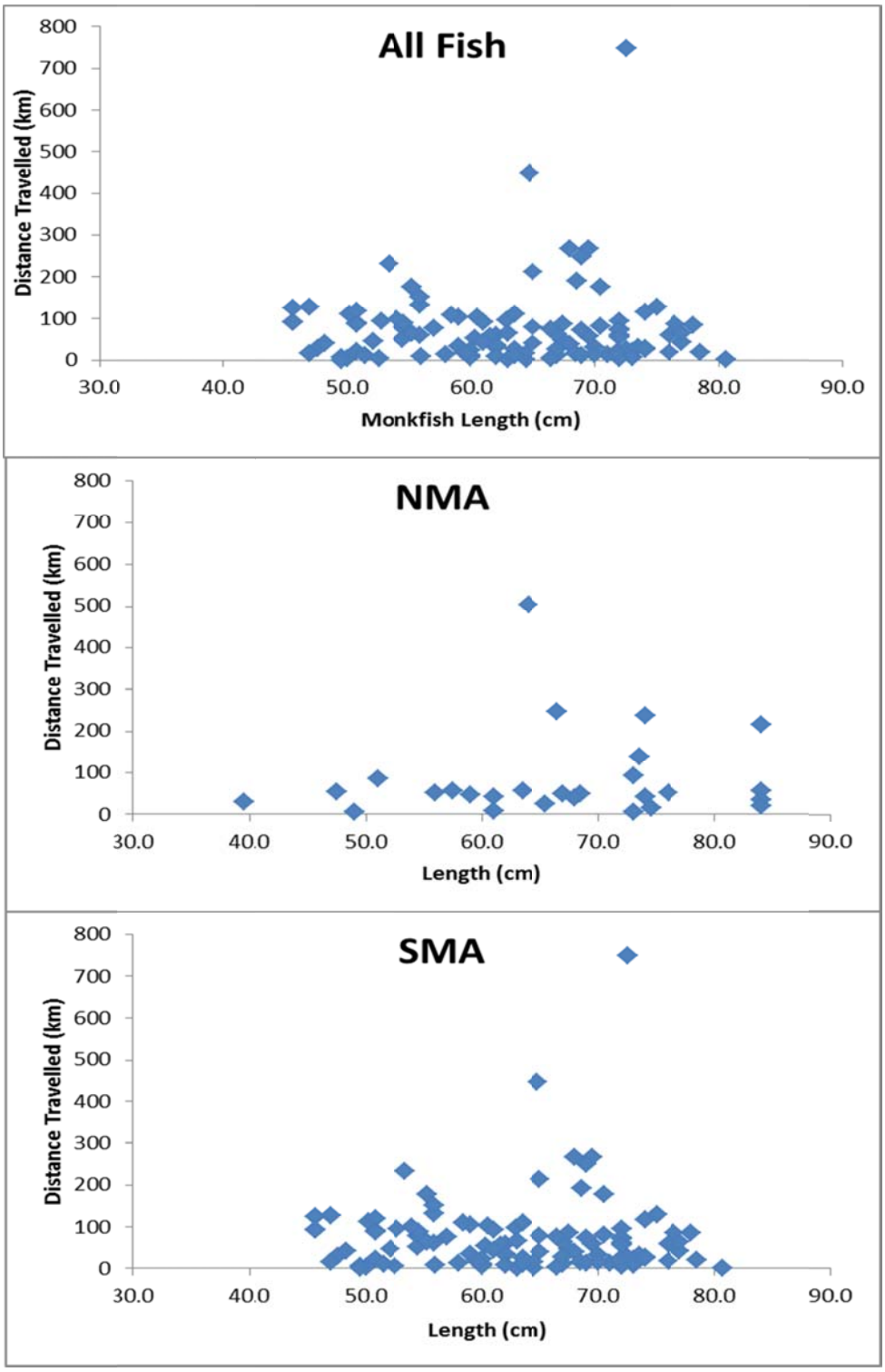

Figure 9. Displacement (km) versus length for monkfish tagged and released in the NMA and SMA.

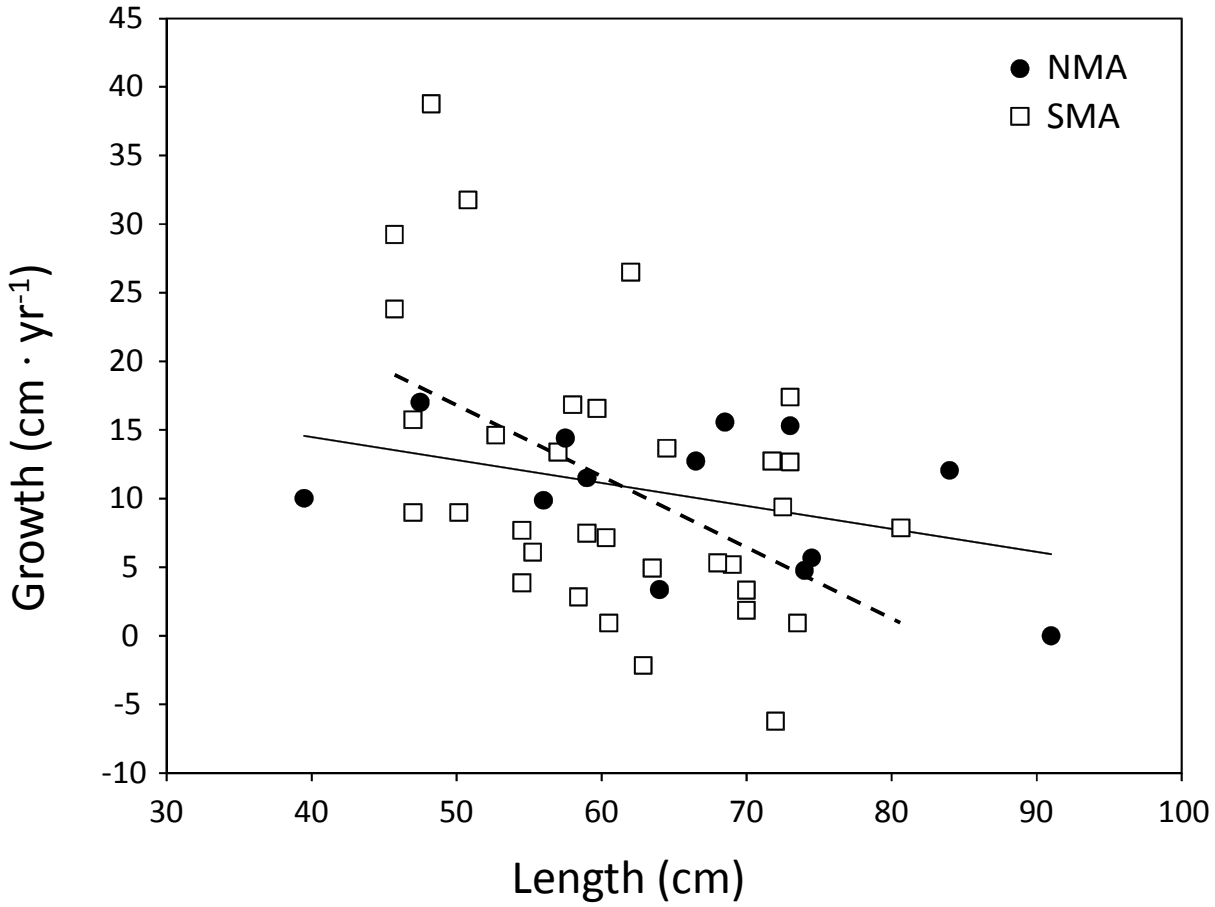

Figure 10. Growth rate versus length for monkfish from Northern and Southern Management Areas.

APPENDIX I
Example of letter mailed out to fishermen who reported tags

John Doe
34 Doe Ave.
John, RI 00000

June 28, 2013

Dear John,

Thank you for reporting data about the tagged monkfish you caught. This monkfish was tagged as part of a study assessing monkfish movement between Northern and Southern Fishery Management Areas. Almost 3000 fish were tagged and released between August 2007 and January 2008. Additionally, nearly 2000 fish have been tagged by industry members north and south of Cape Cod in 2010 and 2011. Some of these fish were tagged with data storage tags which enable us to monitor more fine scale movements of these fish.

In appreciation of your efforts, we have enclosed your reward. Yellow tags are rewarded with a Monkfish Research Set Aside Tagging Study T-shirt and high-reward blue tags are worth $100.00 each. We will continue to offer rewards for each additional tagged monkfish you report. We have also provided you with a map showing release sites, along with recapture locations to date. Also, keep an eye out for monkfish with pink tags. These fish are tagged with data storage tags and are worth $500 if returned to the Gulf of Maine Research Institute whole (frozen is ok).

Your continued assistance is an essential component of this study. Please continue to provide the following information about tagged monkfish: **tag number(s), capture date, capture location,** and **fish length**. Data can be reported in 3 ways:

- Call the tagging hotline toll-free: 1-866-447-2111
- Email: tagging@gmri.org (subject: monkfish)
- Fill in the enclosed datasheets and send them to:
  Monkfish RSA Tagging Study, c/o GMRI, 350 Commercial St., Portland, ME 04101

For more information please visit http://www.gmri.org/mini/index.asp?ID=15. We truly appreciate your participation and look forward to receiving additional monkfish recapture information from you.

Sincerely,

Curt Brown
Research Technician

***Note: Blue tags *must* be returned for verification.**