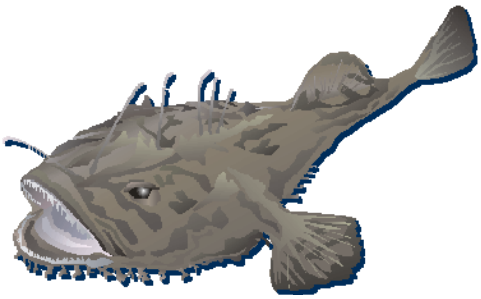

Final Report

2007 Monkfish Research Set Aside Program

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A tagging study to assess monkfish (*Lophius americanus*) movements and stock structure in the northeastern United States

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A. EXECUTIVE SUMMARY

A conventional tagging study was conducted to examine movement and mixing rates of monkfish (*Lophius americanus*), respectively, within and between two monkfish management areas in the northeastern United States (the Northern and Southern Management Areas, or NMA and SMA). A total of 2770 monkfish were tagged and released in the autumn of 2007 and winter of 2008 (1006 in the NMA and 17764 in the SMA) and recaptures were monitored over the following 21 months. This study represents the first tagging study for monkfish in the U.S. northeast and almost doubles 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 3.2% and this rate was higher in the SMA (3.9%) than in the NMA (1.7%).

2) Tag shedding rate (based on double tagging of all monkfish released), was found to be 18.6% which compares well to shedding rates for other species (e.g., cod).

3) Movements after 30 days at liberty were mostly in the southwest direction and ranged from 1 to 503 km; mean displacement was higher in the NMA than in the SMA: 110.4 ± 129.9 km versus 54.7 ± 58.5 km, and positively correlated with monkfish size in the SMA.

4) 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 9.1% of the monkfish tagged in the NMA moved to the SMA.

5) Growth rate was estimated for a subset of monkfish for which reliable length data existed at the time of recapture (n = 23) to be 10.6 ± 4.7 cm year^{-1} (mean ± std) which compares well with tagging-based estimates of growth for *Lophius piscatorius*. There was a trend (insignificant) for lower growth in larger monkfish which, if coupled to further 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 1768 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 (NE U.S.) 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). 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, most likely because of higher male mortality (there is no evidence of sequential hermaphroditism in monkfish). This difference in sex ratios may 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). This study represents a starting point, and will hopefully evolve into a longer-term tagging program over many years. To this end, a follow-up conventional tagging study has been funded through the 2009 Research Set Aside (RSA). Another study to deploy data storage tags, to primarily examine depth movements and estimate movement tracks, is also underway (funded by the 2008 RSA).

C. METHODS

C.1. Tagging

Tagging for this project occurred between September of 2007 and January of 2008 at four general capture and release sites (two in the SMA and two in the NMA; see Figure 1 and Table 1). A total of 2770 monkfish (1764 in SMA and 1006 in NMA) were captured over 18 separate trips 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 (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 completed 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 $100.00. 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 (SPSS Version 16.0). 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 and tag color 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, *in press*) 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 filtered data. Differences in mean displacement among areas were explored by student's t-test (filtered data) and seasonal trends in displacement were visualized by plotting displacement versus days at liberty (and by fitting LOESS best fit lines, SPSS Version 16.0). Mean bearing for straight line displacements was also calculated separately for each area (filtered data). The relationship between displacement and monkfish length was explored by linear regression (SPSS Version 16.0) for all data combined and by area with 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. Catch per unit effort and length distributions of tagged monkfish

A total of 2770 monkfish were tagged over 5 months in the fall and winter of 2007. 1764 monkfish were tagged in the SMA and 1006 in the NMA with roughly the same amount of effort (10 days fishing in the NMA and 8 days in the SMA). Given that fishing technique was similar in both areas, catch per unit effort (CPUE) was therefore about two times higher in the SMA compared to the NMA (220 monkfish per day in the south versus 100 per day in the north). Length-frequency distributions for monkfish tagged in the Northern and Southern Management Areas are shown in Figure 5. Mean length was significantly (albeit marginally) larger in the NMA than in the SMA (69.5 ± 10.6 cm versus 67.6 ± 7.1 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

Figure 6 shows cumulative recaptures of monkfish over the course of this study. Following an earlier slow down in tag reports (at about 5 months), tag numbers increased again from 7-10 months and generally tapered off after the 10th month of the study. The resurgence at 7-10 months was likely due to an increase in effort associated with the opening of the season in the SMA (May). Table 2 is a summary of recapture data by management area and tag color 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 1006 monkfish tagged and released in the NMA, a total of 17 were recaptured and reported in the NMA (1.7%). 11 of these 17 reported monkfish had regular (yellow) tags and 6 had high reward (blue) tags; associated reporting rates were therefore 1.2% for yellow tags and 6.0% for blue tags. In the SMA, a total of 68 of the 1764 monkfish tagged were recaptured and reported (3.9%). Fifty-nine of these had yellow tags and 9 had blue tags. Reporting rate for yellow tags in the SMA was therefore 3.7% and for blue, 5.3%. 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; however reporting rates for blue tags were similar in both areas. The overall reporting rate for the project was 3.2% (89 of 2770 monkfish). This is slightly lower than the recapture rate (4.5%, or 80 of 1768 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 5.8%.

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). For monkfish tagged in the NMA, 32 of the 36 reported monkfish retained both tags. In the SMA, 99 of 125 reported monkfish still had both tags. Therefore tag shedding rates were 11.1% in the NMA and 20.8% in the SMA; this

difference was not significant (Chi-Square, p = 0.18). Overall tag shedding rate (both areas combined) was 18.6%. This is slightly higher than, yet comparable to shedding rates reported for T-bar tags in cod (~15%, Tallack, *in press*).

D.3. Monkfish movements and mixing

The purpose of this project was to examine whether monkfish move between the Southern and Northern Management Areas. For monkfish tagged in the fall, 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 4 monkfish tagged in the NMA were recaptured in the SMA (Figure 1); 2 of these were high reward (blue) tags and 2 were regular (yellow) tags. For the yellow tags, if 2 were recaptured and reported in the SMA, and if reporting rate is 3.7% for yellow tags in the SMA (using filtered data, see above), then we estimate that 54 yellow-tagged monkfish moved from the NMA to the SMA. The corresponding number for blue-tagged monkfish is 38 (2 divided by the 5.3% reporting rate for blue tags in the SMA) for a total of 92 monkfish which may have moved from the NMA to the SMA. Therefore, it is estimated that 9.1% (92) of the 1006 monkfish tagged in the NMA moved across the management boundary into the SMA, whereas 0% underwent the opposite movement. We present the latter number (i.e., 0% movement) with a fair amount of caution given that reporting rates in the NMA were very low (2.1% for both color tags and filtered data) and the chance of not observing movement of SMA tagged monkfish into the NMA is correspondingly high. On the other hand, movements within the SMA for which tag reporting rates were almost two times higher (3.9%) were convincingly in the south-west direction (see below) and not towards the NMA.

While the overall mixing rate was found to be less than 10% among management areas, the potential for long-range movement in monkfish was found to be quite high. Average straight line displacement between release and recapture points was 65.8 ± 80.2 km (mean ± std). Average displacement was two times higher for monkfish released in the NMA compared to the SMA (110.4 ± 129.9 km versus 54.7 ± 58.5 km). This difference was not significant (student's t-test, p = 0.11). 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 267 km. 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). There were indications of seasonal trends in movement, however, particularly for monkfish released in the NMA. For these fish, peak displacement occurred around May and June of 2008, about 200 days following release. This may represent a time of mobility for these fish, or alternatively may just reflect higher fishing effort in the south starting in May (the beginning of the fishing season). Displacement for monkfish released in the SMA was highest in the first 200 days and thereafter, for the next year, was very low (< 50 km). Overall, monkfish tended to move south from their release sites in both areas (Figure 8). Mean bearing for monkfish released in the NMA was 165°, or almost directly due south (although smaller range movements were to the east). Similarly, mean bearing for monkfish released in the SMA was 227° or southwest.

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). Displacement was significantly higher for larger monkfish (both areas combined) as indicated by the following equation: log displacement = 0.42 (0.54) + 0.02 (0.01) × Length; $R^2 = 0.06$, $p < 0.05$ (numbers in parentheses are standard error of estimate). When examined within areas, displacement was positively related to length in only the SMA: log displacement = -0.30 (0.67) + 0.03 (0.01) × length; $R^2 = 0.11$, $p < 0.01$. 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 160 reported monkfish, lengths at recapture were available for 54 individuals. 31 of these data points were excluded as outliers (< 3 cm year^{-1} or > 20 cm year^{-1}; after Laurenson et al., 2005). Days at liberty for the remaining monkfish (n = 23) ranged from 41 to 459 days with the average being 181 days (Table 3). Growth for all individuals was 10.6 ± 4.7 cm year^{-1} (mean ± std). This is slightly higher than growth rate for *Lophius piscatorius* (9.4 cm year^{-1}) estimated in the same way (Laurenson et al., 2005). Although not significant (student's t-test, $p < 0.05$), mean growth rate was slightly higher in the NMA than the SMA (11.9 ± 4.8 versus 9.7 ± 4.7 cm year^{-1}, respectively). There was also a trend for lower growth rate with increasing size in monkfish for both areas (Figure 10). However, this relationship was not significant (linear regression), but

likely would have been with larger sample sizes. Lower growth rate is expected with increasing size in fish (as they approach asymptotic size). Recent assessments for monkfish indicate no asymptote (i.e., linear growth; Richards et al., 2008). Length increases between 9 and 10 cm from 3 all the way through 9 years of age, or from about 25 cm to 80+ cm (Richards et al., 2008). Results here (albeit insignificant) suggest that growth should in fact asymptote in monkfish given that growth appears to slow down with increasing size. Therefore this finding raises some concerns with the validity of previous monkfish age results using vertebrae (which are the basis of current growth estimates; Northeast Data Poor Stocks Working Group, 2007). This uncertainty is the motivation for a recently funded study (2009 Monkfish RSA) to re-examine monkfish age and growth results (Sherwood et al., 2009).

E. CONCLUSIONS

This tagging study is the largest of its kind for *Lophius* sp. (2770 tag releases, versus the next largest study of 1768 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). Despite 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 only a limited amount of exchange between the two areas. No movement from the SMA to the NMA was observed, though recaptures in the NMA were generally low. Movement from the NMA to the SMA was confined to only a few individuals making up just under 10% of the total number of releases (after being corrected for reporting rates in the SMA). **We therefore conclude that exchange between the two management areas is low with the following caveat: our data represents tag releases in the fall and early winter (and most recaptures were made within the ensuing 10 months**, **Figure 6), and recaptures were more frequent in the SMA**. Monkfish may undergo net southward movements during this period and it is currently unknown if a reversal would have been observed if monkfish had been released in the spring or summer (monkfish were released only in the fall/early winter due to logistical constraints associated with carrying out research set-aside science). Despite the fact

that monkfish did not appear to mix substantially between the two management areas, this study did confirm that monkfish do possess the potential to undertake long migrations (more than 500 km). A follow-up study has been approved to continue this conventional tagging work and to target releases for the spring of 2010 (Grabowski and Sherwood, 2009). In the meantime, an ongoing study using data storage tags should provide further insight into this question of mixing and migrations (Grabowski and Sherwood, 2008). Other notable findings are as follows:

- Based on double tagging, overall tag shedding rates were found to be 18.6% which is comparable to shedding rates reported for other species (e.g., cod ~15%, Tallack, *in press*) and indicate that monkfish are well suited to conventional tagging studies.
- A positive relationship between monkfish length and displacement was found; large monkfish move greater distances than smaller monkfish.
- In addition to providing new information on monkfish movement behaviors, this study has revealed some interesting trends in growth (albeit with a limited data set). Monkfish growth is currently thought to be linear over the entire size range (Richards et al., 2008). **This study found a trend (not significant, likely due to small sample sizes) for decreasing growth with increasing size which, if coupled to further evidence, could call into question the validity of current aging techniques**. A study has recently been approved to address this question by re-examining monkfish age structures to confirm whether linear growth does indeed exist (Sherwood et al., 2009).

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G. REFERENCES

Able, K. W., and Chambers, R.C. 2003. Essential fish habitat for young-of-year goosefish (*Lophius americanus*). Final Report to CMER.

Caruso, J.H. 2002. Goosefish or monkfishes: family Lophiidae. In Bigelow and Schroeder's Fishes of the Gulf of Maine, 3rd edn, pp. 264-270. Ed. by B. Collette, and G. Klein-MacPhee. Smithsonian Institution Press, Washington, D.C. 748 pp.

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

Fowler, G.M., and Stobo, W.T. 1999. Effects of release parameters on recovery rates of tagged groundfish species. Canadian Journal of Fisheries and Aquatic Sciences 56: 1732-1751.

Grabowski, J.H., and Sherwood, G.D. 2008. Movements, Growth, and Habitat Use of Monkfish, *Lophius americanus*, based on Archival Tagging and Otolith Elemental Analyses. 2008 Monkfish Research Set Aside Program, ongoing research.

Grabowski, J.H., and Sherwood, G.D. 2009. Tagging to assess monkfish movement: additional tagging to assess monkfish movements and stock structure in the northeastern United States. 2009 Monkfish Research Set Aside Program, ongoing research.

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

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, pp. 181-346. US Department of Commerce, Northeast Fisheries Science Center Reference Document 02-06. 346 pp.

Northeast Data Poor Stock Working Group. 2007. Monkfish Assessment Report for 2007. US Department of Commerce, Northeast Fisheries Science Center Reference Document 07-21. 232 pp.

Richards, R.A., Nitschke, P.C., and Sosebee, K.A. 2008. Population biology of monkfish *Lophius americanus*. ICES Journal of Marine Science 65: 1291-1305.

Sherwood, G.D., and Grabowksi, J.H. 2008. Critical diet and habitat shifts in New England monkfish (*Lophius americanus*): insights from stable isotopes and relation to biological condition. Final Report to 2006 Monkfish Research Set Aside Program. 31 pp.

Sherwood, G.D., Grabowski, J.H., and Bank, C. 2009. A weight-of-evidence approach for validating age and growth in monkfish. 2009 Monkfish RSA Program, ongoing reseach.

Steimle, F.W., Morse, W.W., and Johnson, D.L. 1999. Essential fish habitat source document: Goosefish, *Lophius americanus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-127, 31 pp.

Tallack, S.M.L. (in press). Regional growth estimates of Atlantic cod, *Gadus morhua*: applications of the maximum likelihood GROTAG model to mark-recapture data in the Gulf of Maine region. Fisheries Research.

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

		Coordinates			
Management Area	Site	Longitude	Latitude	Date	# Tagged
NMA	Scituate	-70 32.299	42 10.820	9/4/2007	37
NMA	Scituate	-70 32.299	42 10.820	9/10/2007	70
NMA	Scituate	-70 32.299	42 10.820	9/16/2007	89
NMA	Scituate	-70 32.299	42 10.820	9/21/2007	76
NMA	Scituate	-70 32.299	42 10.820	9/27/2007	64
NMA	WGMCA	-70 17.719	42 20.326	10/11/2007	69
NMA	WGMCA	-70 17.719	42 20.326	10/17/2007	147
NMA	WGMCA	-70 17.719	42 20.326	10/22/2007	117
NMA	WGMCA	-70 17.719	42 20.326	10/31/2007	140
NMA	WGMCA	-70 17.719	42 20.326	11/5/2007	196
SMA	Newport	-71 06.072	41 04.387	10/16/2007	189
SMA	Newport	-71 06.072	41 04.387	10/18/2007	241
SMA	Newport	-71 06.072	41 04.387	10/31/2007	187
SMA	Newport	-71 06.072	41 04.387	11/12/2007	547
SMA	Newport	-71 06.072	41 04.387	12/9/2007	196
SMA	Newport	-71 06.072	41 04.387	1/7/2008	107
SMA	Point Judith	-71 20.437	41 06.514	11/30/2007	143
SMA	Point Judith	-71 20.437	41 06.514	1/10/2008	151

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

			Total recaptures		NMA recaptures		SMA recaptures	
Release Area	Tag color	Releases	Number	Percent	Number	Percent	Number	Percent
No filtering								
NMA	yellow	906	27	3.0	25	2.8	2	0.2
NMA	blue	100	9	9.0	7	7.0	2	2.0
NMA	Total	1006	36	3.6	32	3.2	4	0.4
SMA	yellow	1595	106	6.6	0	0	106	6.6
SMA	blue	169	19	11.2	0	0	19	11.2
SMA	Total	1764	125	7.1	0	0	125	7.1
All	yellow	2501	133	5.3	25	1.0	108	4.3
All	blue	269	28	10.4	7	2.6	21	7.8
All	Total	2770	161	5.8	32	1.2	129	4.7
Filtered for days at liberty > 30								
NMA	yellow	906	13	1.4	11	1.2	2	0.2
NMA	blue	100	8	8.0	6	6.0	2	2.0
NMA	Total	1006	21	2.1	17	1.7	4	0.4
SMA	yellow	1595	59	3.7	0	0	59	3.7
SMA	blue	169	9	5.3	0	0	9	5.3
SMA	Total	1764	68	3.9	0	0	68	3.9
All	yellow	2501	72	2.9	11	0.4	61	2.4
All	blue	269	17	6.3	6	2.2	11	4.1
All	Total	2770	89	3.2	17	0.6	72	2.6

Table 3. Lengths at release and capture, number of days at large and corresponding growth rate for recaptured monkfish by management area.

Management Area	Length at release (cm)	Days at Large	Length at recapture (cm)	Growth rate (cm year^{-1})
NMA	64	217	66	3.4
NMA	74	459	80	4.8
NMA	59	381	71	11.5
NMA	84	212	91	12.1
NMA	67	215	74	12.7
NMA	58	342	71	14.4
NMA	73	143	79	15.3
NMA	69	129	74	15.6
NMA	48	118	53	17.0
Mean	*66*	*246*	*73*	*11.9*
SMA	70	110	71	3.3
SMA	69	41	69	4.5
SMA	64	185	66	4.9
SMA	69	141	71	5.2
SMA	68	206	71	5.3
SMA	55	166	58	7.7
SMA	73	253	79	9.4
SMA	67	84	69	10.9
SMA	62	66	64	11.1
SMA	73	173	79	12.7
SMA	57	109	61	13.4
SMA	65	147	70	13.7
SMA	58	130	64	16.8
SMA	73	147	80	17.4
Mean	*66*	*140*	*69*	*9.7*

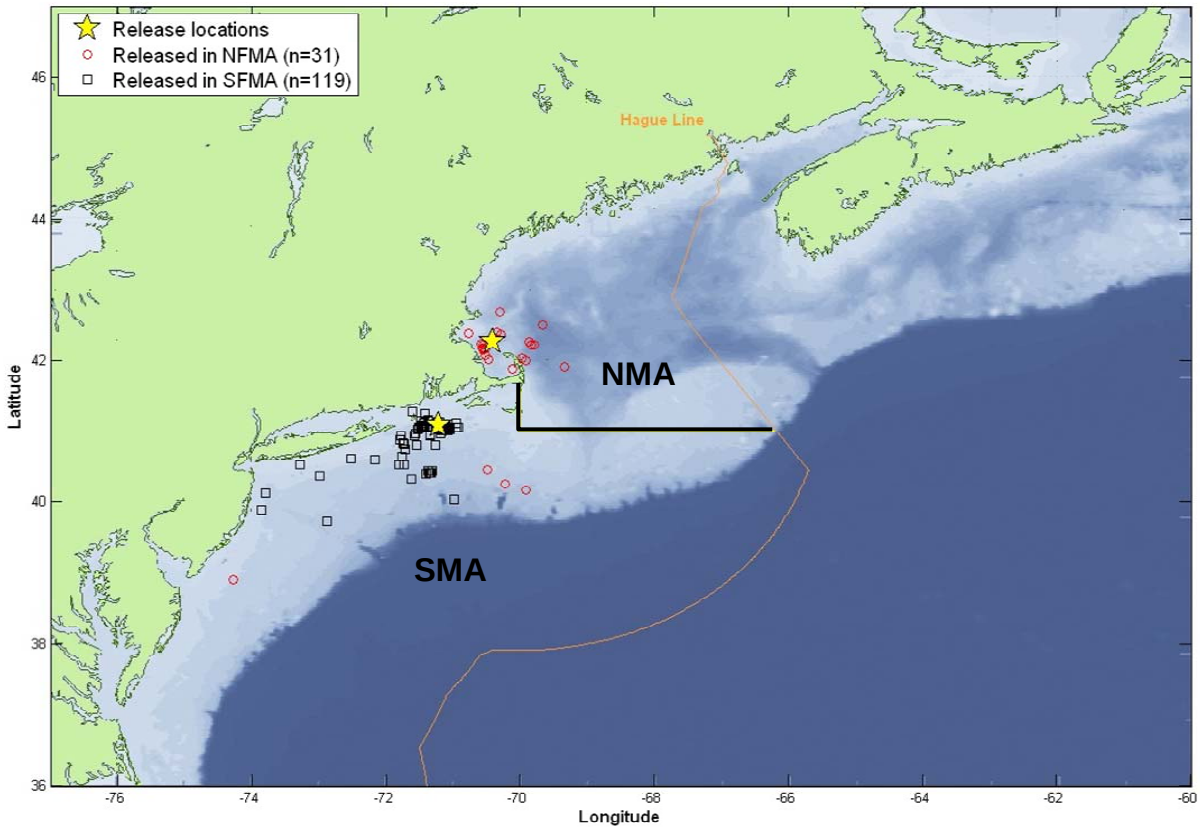

Figure 1. Map showing location of release (note that release sites are close enough within each area to be represented by one star) and recapture locations in the SMA and NMA. Open circles and squares denote the location of fish recapture sites for fish tagged in the NMA and SMA, respectively (see legend).

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

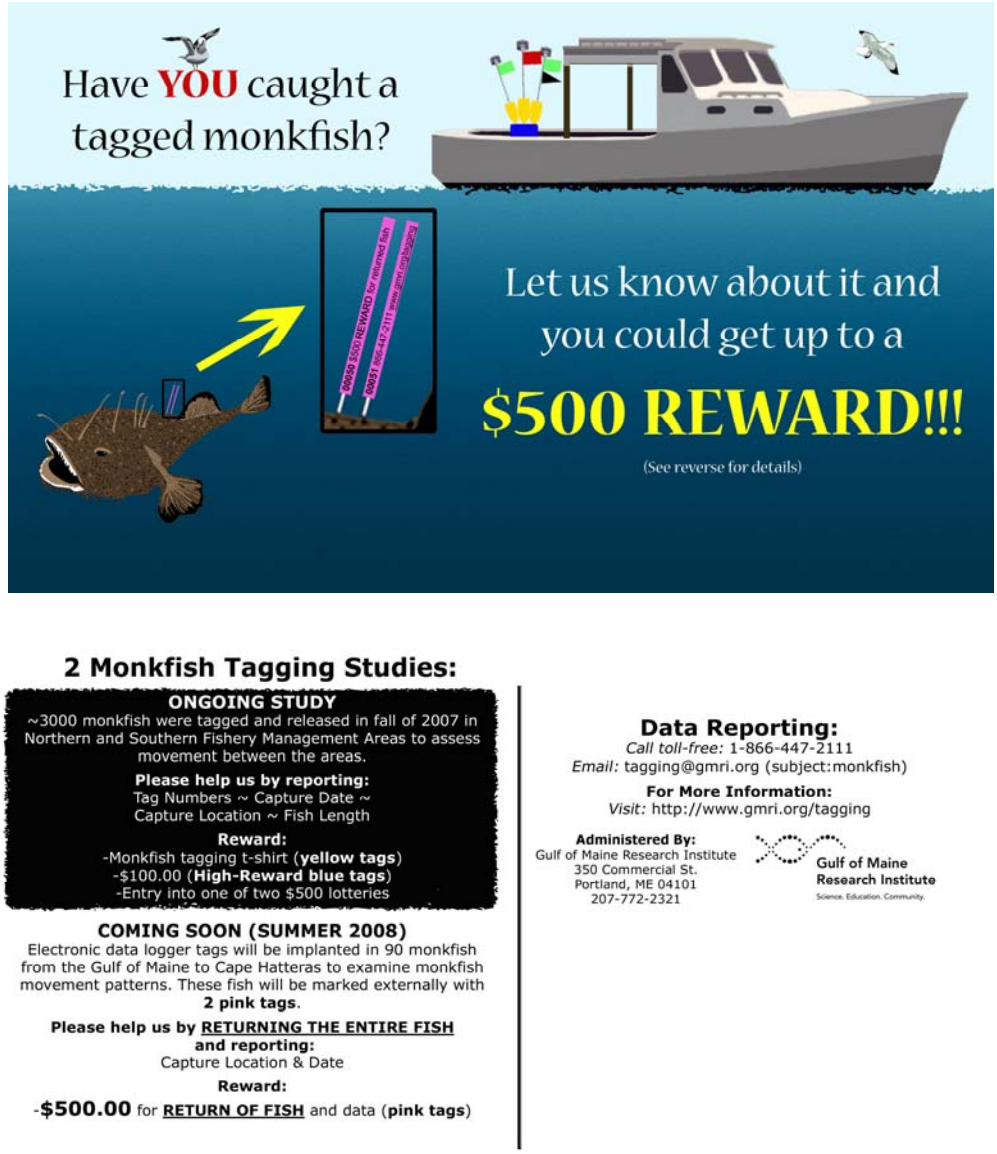

Figure 3. Image of front and back of postcard sent by mail to all monkfish permit holders. Note that this outreach effort overlapped with outreach for a 2008 RSA study to tag monkfish with data storage tags.

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.

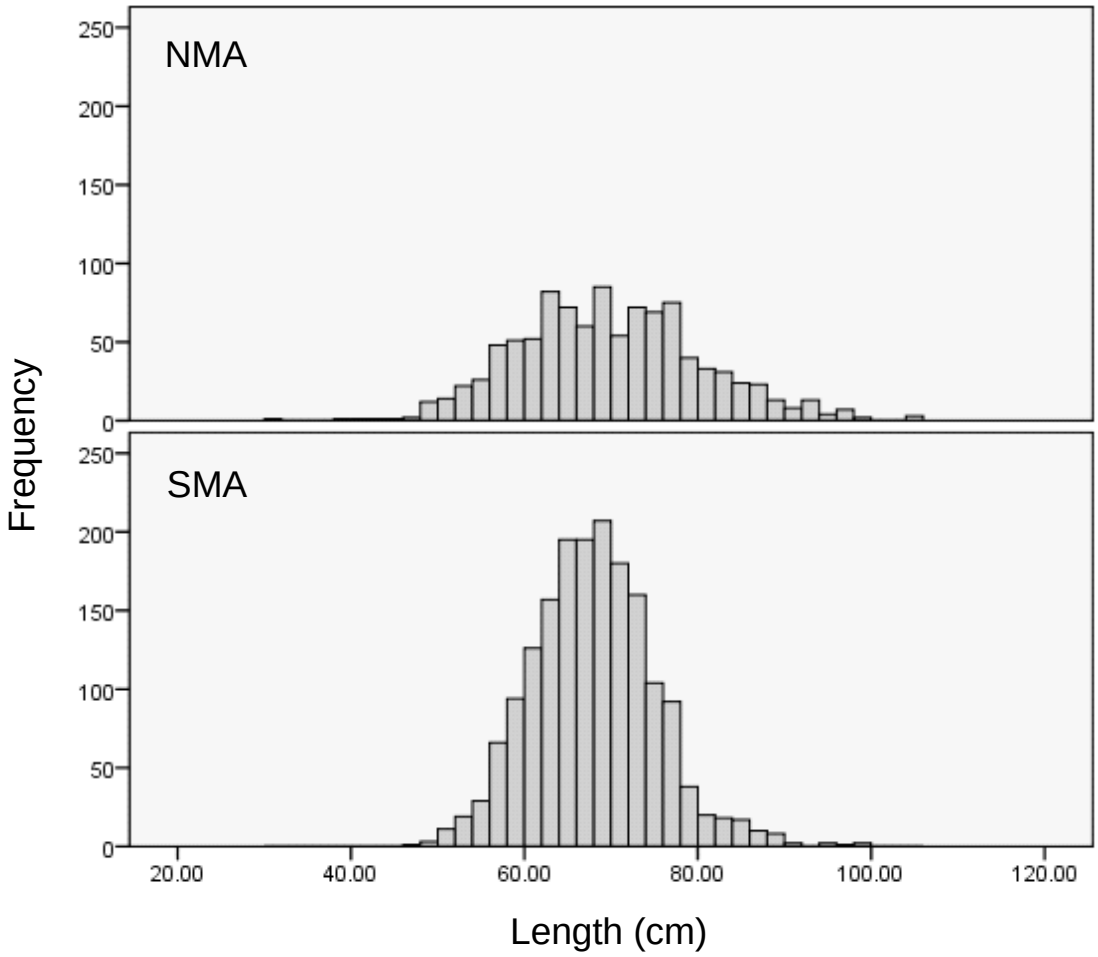

Figure 5. Length-frequency distributions for all monkfish tagged and released in the Northern and Southern Management Areas. Length frequency distributions of recaptured monkfish (length at release) are similar.

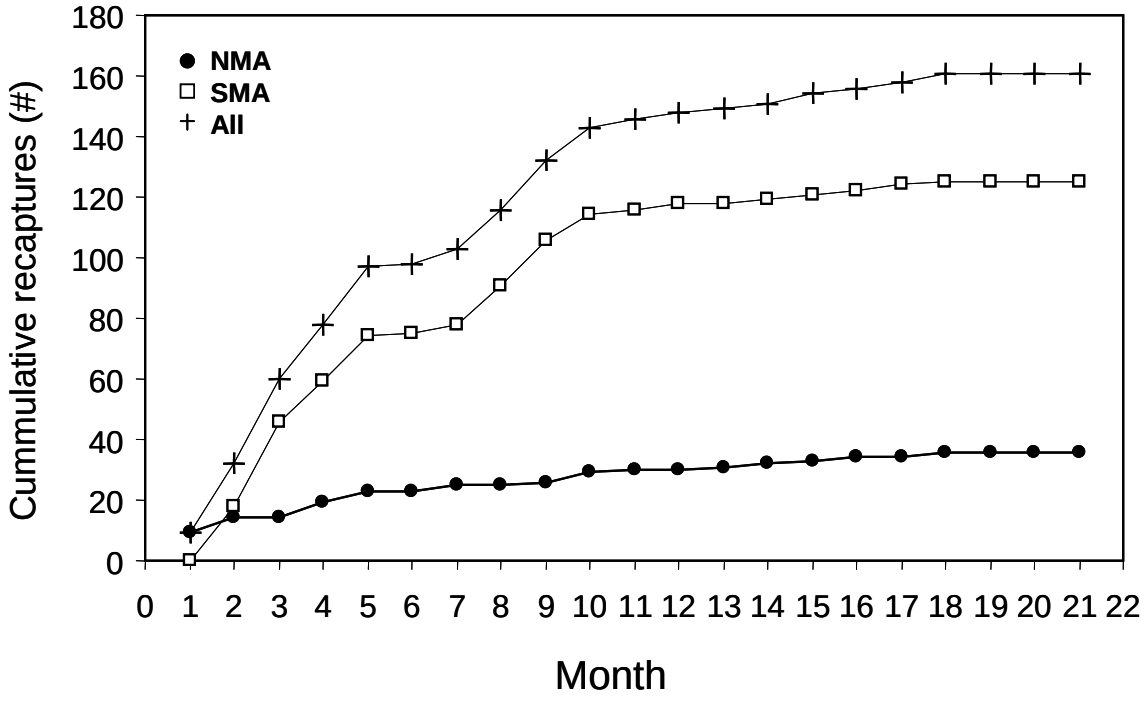

Figure 6. Cumulative recaptures of monkfish in the Northern and Southern Management Areas.

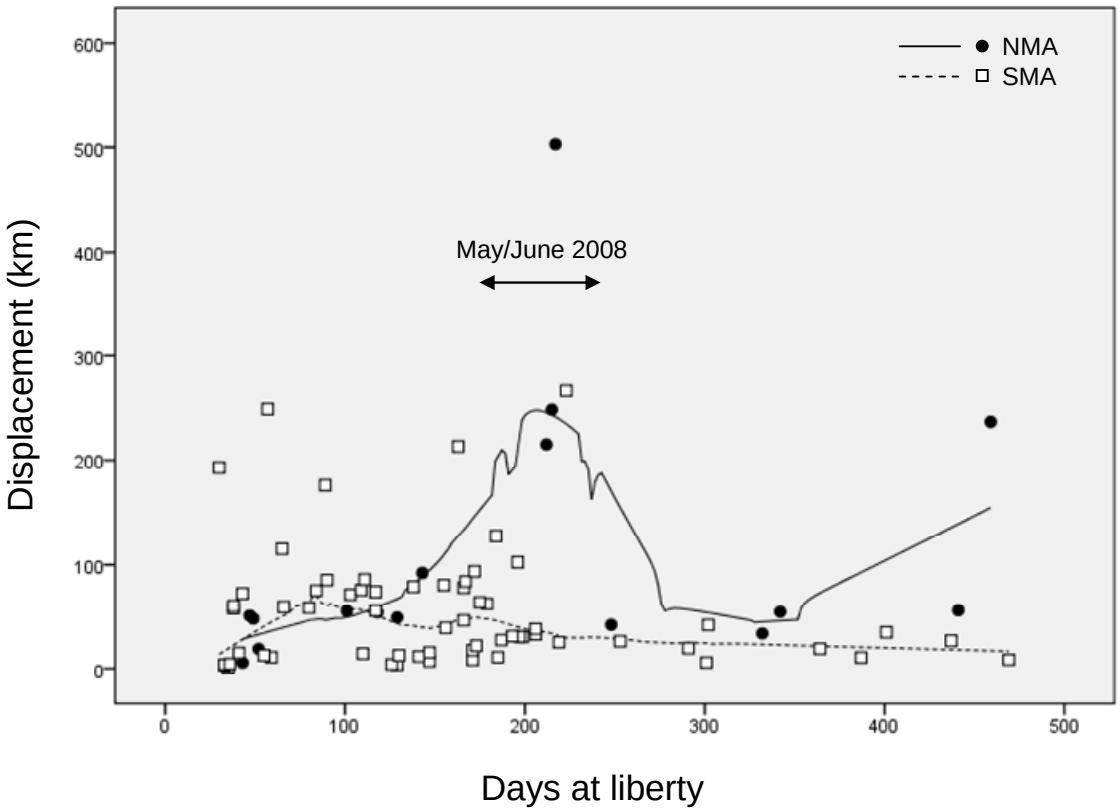

Figure 7. Total straight line displacement between release and recapture sites versus days at liberty by release area. Lines represent LOESS best fit (SPSS Version 16.0).

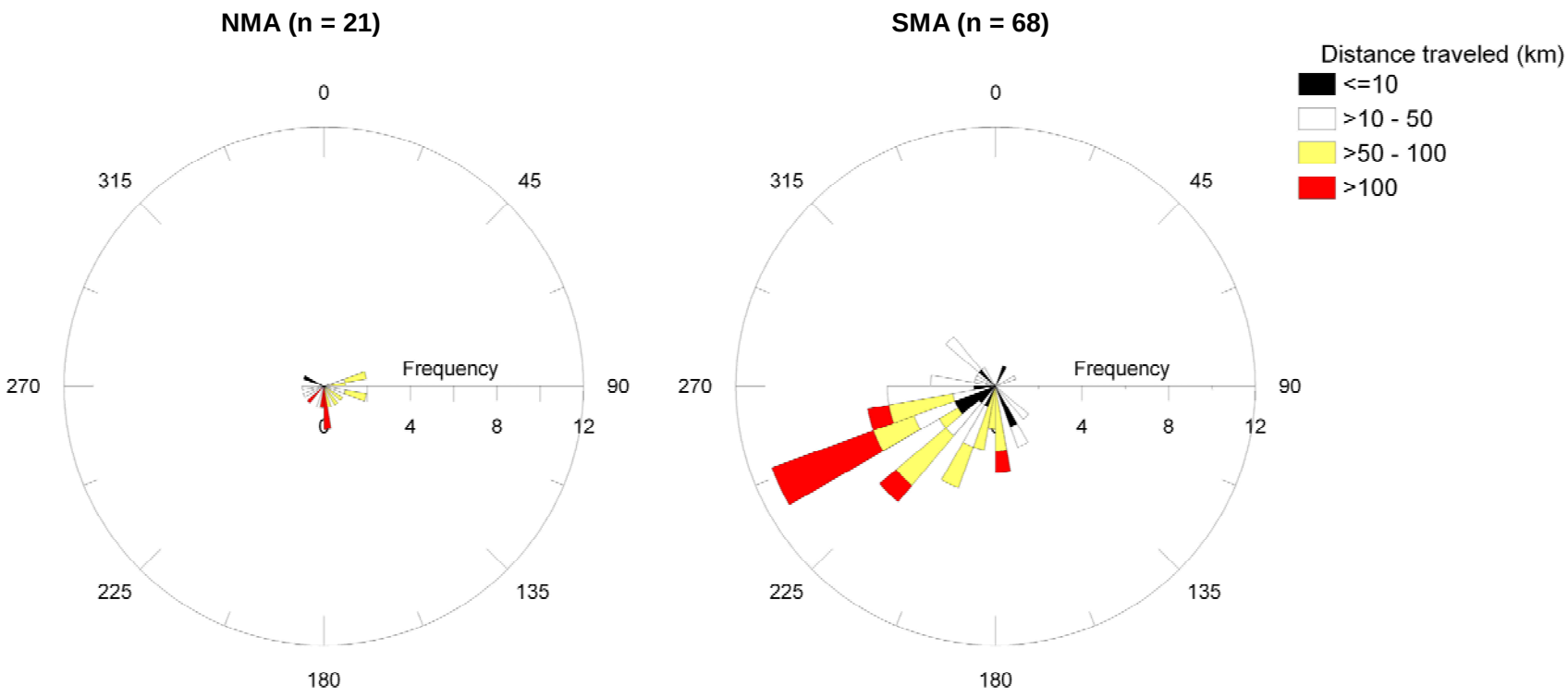

Figure 8. Rose diagram showing distance and bearing for monkfish movements in the Northern and Southern Management Areas. Long (> 100 km) and mid-range (50-100 km) movements are mostly to the southwest in the SMA; long range movements in the NMA are to the south; mid-range are to the east. Sample sizes for filtered tag recaptures are shown.

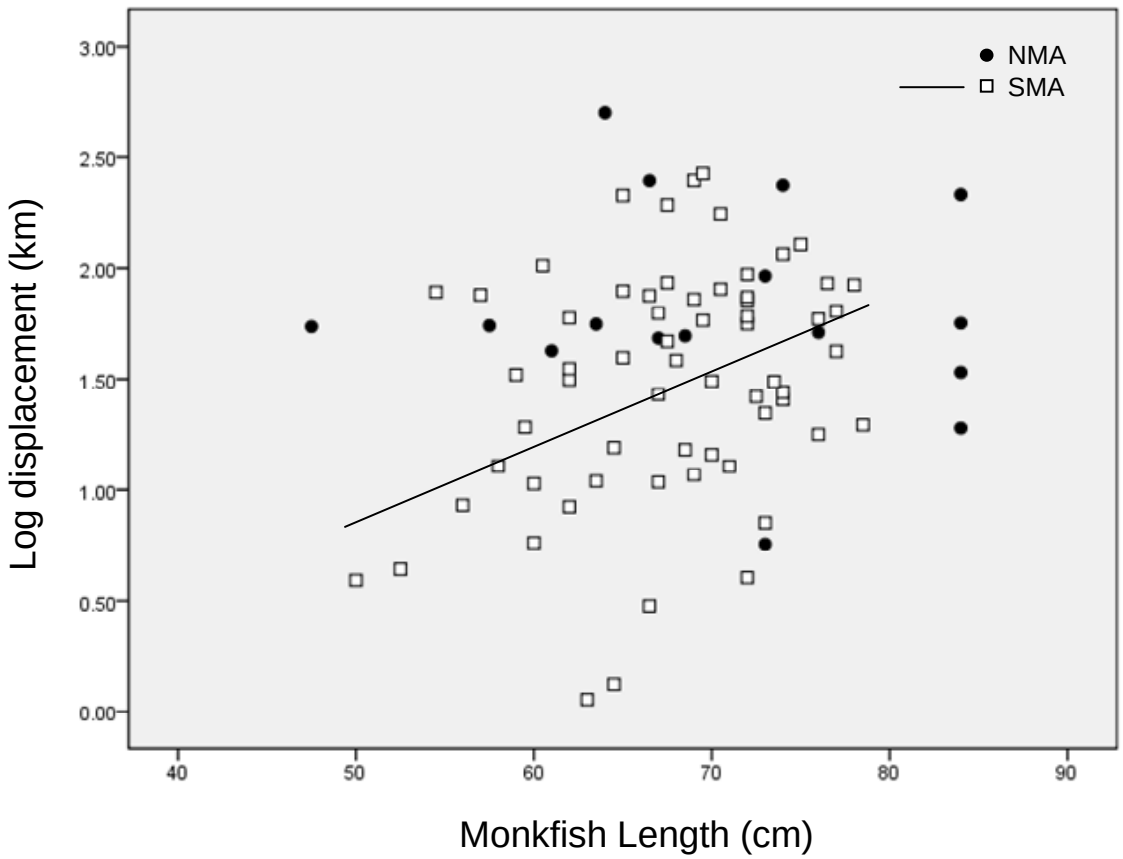

Figure 9. Log displacement (km) versus length for monkfish tagged and released in the NMA and SMA. Relationship is significant for all data combined and for SMA (solid line) but not NMA alone (see text for equations).

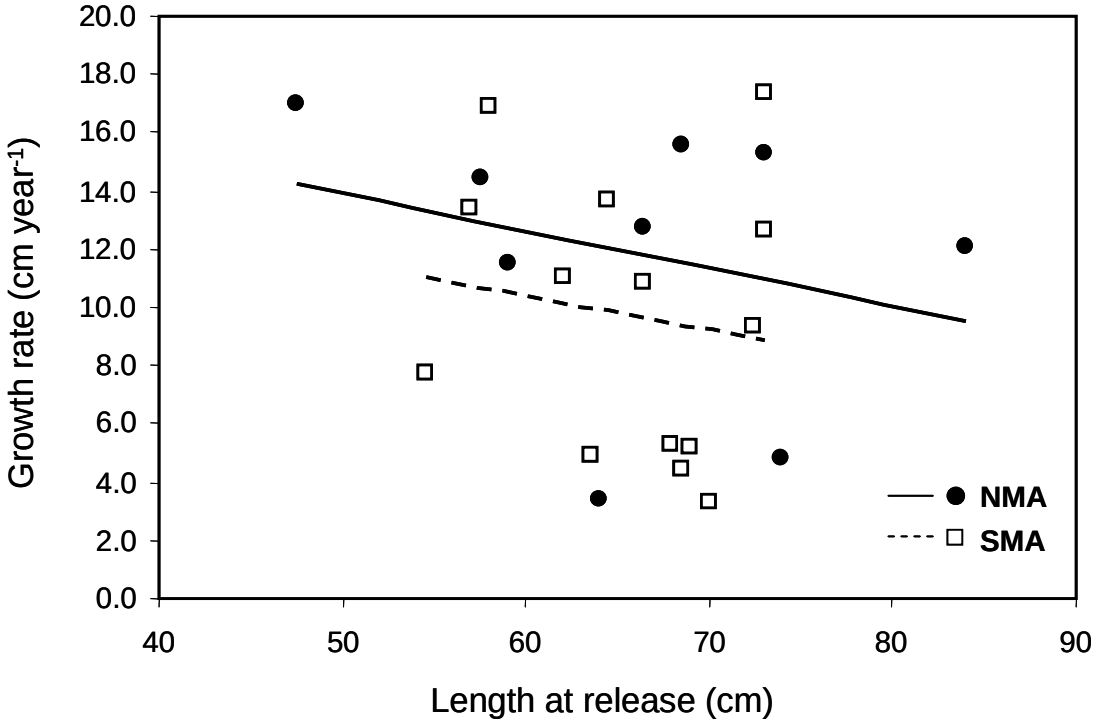

Figure 10. Length versus growth rate for monkfish from Northern and Southern Management Areas. Regression lines are not significant.

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

June 3, 2009

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.

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. Your fish was originally released within site 3.

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,

Nicole Stephens
Research Technician