Updated analysis of the king mackerel mark and recapture data from the NMFS SEFSC Cooperative Tagging Center

By

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Summary

Conventional tagging data of king mackerel available at the SEFSC Cooperative Tagging Center were reviewed and summarized. Overall 24,987 records of king releases were available since 1961, with a total of 1,227 recaptures. Most tagged kings belonged to the Gulf of Mexico stock (20,775 or 83%), with much lower numbers of Atlantic kings (4,212 or 17%). In summary, available mark-recapture data supported the assumption of two main migratory groups, one in the Atlantic US coast and one in the Gulf of Mexico. Also, tag recaptures corroborated that the South Florida east coast and Florida Keys are an area of mixing for both stock particularly during the winter months. However, the data also showed that not all the population migrates during the winter months, at least in the Gulf of Mexico. Independent of the stock or region of tag-release, most of the tag-recaptures were within the same area of release (60% or more), even when observations are restricted to fish at large for more than 30 days and recapture at different season. The lower percentages of recaptures corresponded to fish tagged in the so-called no-mix area and recovered in the opposite no-mix area region. In fact, no recaptures have been recorded from king tagged in the Gulf of Mexico and recovered in the Atlantic north of Florida.

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Introduction

Current assessments of king mackerel (*Scomberomorus cavalla*) assume two separate stock units, one in the US Atlantic coast (ATL) and a Gulf of Mexico (GOM). The Florida peninsula and the Florida Keys constitute the physical boundary between stocks, however evidence suggests that mixing between stocks occurs, particularly during the winter when both units migrate southwards. At present, for management purposes, the GOM stock extends from Texas to the latitude line dividing Monroe and Collier Florida counties from April 1st through October 31st (summer), and it moves towards the Florida east coast from November 1st through March 31st (winter) up to the Flagler-Volusia county line. Correspondingly, the ATL stock extends from Maine to the Flagler-Volusia boundary in winter and to the Monroe-Collier boundary during the summer months (Fig 1). The region delimitated by the Flagler-Volusia and Monroe-Collier county lines is commonly referred to as the 'mixing zone'.

Mark and recapture experiments on king mackerel have been carry out since the 1970s, intended to determine the migratory patterns and stock boundaries (Fable et al 1987, Sutter et al 1991, Schaefer and Fable 1994). Most of the tag-releases were done during the 1980s and early 1990s (Table 1). At the NMFS SEFSC, a Cooperative Tagging Program database has collected most of the scientific and user-release and recapture information for king mackerel. Overall, 24,987 records of king releases are available since 1961, with a total of 1,227 recaptures. Using the current definition of stock units, most of tagged fish belong to the GOM stock (20,775 or 83%), with much lower numbers of ATL kings (4,212 or 17%) (Table 1). The objective of this document was to update and review the available mark-recapture data for king mackerel available at the NMFS SEFSC tagging database with emphasis on tags release and/or recovered within the so called mixing zone.

Figures 2 and 3 present Dorling cartogram maps of the tag releases by stock unit; each circle represents the number of tag releases within a 0.25 square degree lat-lon area, and the size of the circle is proportional to the number of released tags. For the GOM, 7,879 tagged king mackerel were released outside of the mixing zone (38%) while 12,896 were released within the mixing zone (62%). In contrast, for the ATL stock, 1,288 tags were released within the mixing zone (31%) and 2,924 (69%) outside the mixing zone (Table 1). Table 2 presents the number of returned tags in any area from tagged king mackerel stock unit and no mix vs. mixing zone definitions. Overall, recapture rates ranged from 4% to 9% by stock unit and area of release, for king ATL stock 116 returns were recorded from releases within the mixing zone (1288 tag releases), compared to 117 returns from the no-mix area (2916 tag releases). For the GOM stock, 527 returns were recorded from 12,896 releases within the mixing zone, and 460 returns from 7879 tag releases from the Gulf no-mix area. Figures 4 and 5 also present the Dorling cartograms of tag returns by stock and 0.25 square degree lat-lon areas. For the ATL stock, the returns rates were higher for the mixing zone releases compared to the no-mix area (9% vs. 4.0%), however it is not possible to test if this difference was significant or not, given differences in the mark-recapture experiments, fishing effort distribution, tag-return promotions, etc. In contrast, for the GOM stock, the rates of recapture were more comparable (4.1% mixing zone, 5.8% no-mix area). If the releases are split by the season definition currently used (summer (Mar-Oct) and winter (Nov-Dec)), for the GOM

stocks tag releases are primarily in the summer in the northern Gulf of Mexico (5900 releases with 405 returns), and in the winter in the mixing zone (12,896 releases and 527 returns) (Fig 6). However, Fable et al (1987) tagged large size kings south of Louisiana (off Grand Island) during the winter (1979 releases with 55 returns), proving that not all fish migrate southwards during the winter in the Gulf of Mexico.

Figures 7 shows the area of recapture for the tagged kings released in the Gulf of Mexico from the no-mix area (7878) and mixing zone (12,896). From the no-mix area releases, a total of 460 returns have been reported; 416 (90%) were recovered within the same GOM no-mix area, while 44 (10%) were recovered in the mixing zone; no returns were reported from the no-mix area in the Atlantic (Fig 8). Of the mixing zone releases a total of 527 returns were reported; 417 (79%) from within the mixing zone, 20 (4%) from the Gulf no-mix area, and 90 (17%) from the Atlantic no-mix area. Same analysis for the ATL stock unit is shown in Figure 9, with 2,924 tag releases on the no-mix area of which 124 returns were reported, 103 (83%) within the ATL no-mix area, 18 (15%) from the mixing zone, and 3 (2.4%) from the Gulf no-mix area (Fig 9). For the ATL stock mixing zone releases (1,288), a total of 116 returns were reported, 87 (75%) from the same mixing zone, 26 (22%) from the Atlantic no-mix area, and 3 (2.6%) from the Gulf no-mix area.

The vector of displacement (straight line between point of release and recapture) for the GOM stock unit (current stock definition) (Fig 10) shows that king mackerel travels throughout the Gulf of Mexico (including the Mexico coast) and the south eastern Atlantic coast. The longest displacement was 1,813 km, but the median was only 112 km with 75% of recaptures within 308 km or less distance travel (Fig 11). As reported by prior authors (Sutter et al 1991, Schaefer and Fable 1994), there was no relationship between straight distance and days at large. For the GOM unit, 50% of returns are within 188 days of release, and 75% or returns were at large less than 455 days. However, GOM king mackerel has been recaptured after 7.6 years at large (Fig 12). For the ATL stock unit, the vector map shows that movements followed the South Atlantic coast of US, from North Carolina down to the Florida Keys. There were few fish (<5) that migrated to the eastern Gulf of Mexico, with only one into the Caribbean (Fig 13). The longest displacement was 1,448 km, with a median of 85.6 km. The histogram of displacement distance shows a cluster of observations at about 1000 km (Fig 14). No relationship was observed between travel distance and days at large; most recaptures (75%) were within 2 years at large, with a median of 357 days. The longest fish at large was 5.6 yrs (Fig 15).

Assuming that migratory movements are annual, if we look at the months at large (discounting complete year(s) at large) versus displacement distance, there was a more clear indication of movements. Figure 16 shows the displacement distance box plot for a month at large, by stock unit. This plot shows that a fraction of the ATL stock tagged population travel longer distances at about 2 through 9 months at large, the histograms by month suggest two groups of observations: a so called “local” fish that travel 200 km or less, while another group which travels over 500-700 km or more particularly during or at the peak of the following season. In the case of the GOM stock (lower plot), the “local” group extends to about 300 km, with the ‘’migratory’’ group traveling about 600 or more km. Both stocks showed the lowest displacement at 0 or 11 months at large.

Excluding tag releases from the mixing zone, Figure 17 shows the vectors of displacement for the GOM and ATL stock units. The GOM stock shows wide movements between the eastern and western Gulf, including the southern Gulf on the Mexico coast and Yucatan peninsula, with movements also to the South Florida Keys and the east Florida coast. On the other hand, the ATL stock shows a more north-south-north pattern following the coast line with no fish moving into the Gulf region. The vector plot of only tag-releases on the mixing zone (Figure 18) shows the distribution of recaptures; fish tagged during the summer months (ATL stock definition) moved preferentially towards the north Atlantic, with only 1 fish moving southwards to the Florida Keys. In comparison, the fish tagged during winter months (GLF stock definition) shows both movements towards the north Atlantic and the Gulf of Mexico. Figures 19 and 20 show the same information, but summarized in numbers and percentages.

Overall in the mixing zone, there has been about 14 thousand king mackerel tagged and released, with 643 returns from these fish. Most of tags and returns are from the winter months (92% and 82%, respectively). However, of the recaptures, most of them were within the mixing zone (417 of winter releases or 79%, and 87 of summer releases or 75%), followed by recaptures in the north Atlantic no mixing area, (90 of winter releases or 17%, and 26 of summer releases or 22%); finally the lowest percentage of recaptures were from the Gulf of Mexico region (20 of winter releases or 4%, and 3 from summer releases of 3%). If we restrict the analysis to recaptures of fish that were at least 30 days at large and that were recovered in a different season than the tag release event, the distribution of tags recovers by region changed slightly but followed the same patterns, i.e. most of tags recaptures were from the mixing zone itself (66% winter releases and 60% summer releases), followed by recaptures in the North Atlantic (28% and 40%, respectively), and only 17 recaptures in the Gulf of Mexico (6% of winter releases) (Fig 21).

In summary, the available mark recapture data supported the assumption of two main migratory groups, one in the Atlantic US coast and one in the Gulf of Mexico. In addition, tag recaptures corroborated that the South Florida east coast and Florida Keys are an area of mixing for both stock particularly during the winter months. However, data also showed that not all the population migrates during the winter months, at least in the Gulf of Mexico. Independent of the stock or region of tag releases, most of the tag returns were within the same region of release; in fact, more than 60% of returns were from the same area of release, even when observations were restricted to fish at large for more than 30 days and recaptured at different season. The lower percentages of recaptures corresponded to the fish tagged in the so-called no-mix area and recovered in the opposite no-mix area region. In fact, no recaptures have been recorded from king tagged in the Gulf of Mexico and recovered in the Atlantic north of Florida.

Tag releases in the mixing zone showed a preferential recapture also within the mixing zone, followed by recaptures in the Atlantic north of Florida at rates of 17% to 40% depending upon the season of release and or the days at large. Fewer fish released in the mixing zone were recovered in the Gulf of Mexico, from only 3% to 6%.

Literature cited

Sutter F. C., Williams R.O. and M.F. Godcharles. 1991. Movement patterns and stock affinities of king mackerel in the Southeastern United States. Fish. Bull. 89(2): 315-324.

Fable W.A., Trent L., Bane G.W. and S.W. Ellsworth. 1987. Movements of king mackerel, *Scomberomorus cavalla*, tagged in Southeast Louisiana, 1983-85. Mar. Fish. Rev. 49(2): 98-101.

Schaefer H.C. and W.A. Fable. 1994. King mackerel, *Scomberomorus cavalla*, mark-recapture studies off Florida's east coast. Mar. Fish. Rev. 56(3):13-23.

Table 1. King mackerel tag releases by current stock definition, region and year available at the NMFS SEFSC Cooperative Tagging Center database. Mixing zone corresponds to the area between the Monroe-Collier and Flagler-Volusia counties in Florida all year around.

Tag release					
	Atlantic		Gulf		Total
Year	No Mix	Mixing	No Mix	Mixing	
Unknown	8				8
1961	11			16	27
1962	1	3	1		5
1963		2		1	3
1964			2		2
1965	3				3
1966				2	2
1969			1		1
1974	3				3
1975	1	6	1	1	9
1976	1	1	10		12
1977		1			1
1978			2		2
1980			2	4	6
1983	18		1475		1493
1984	22		194	1	217
1985	436		529	449	1414
1986	986	7	706	456	2155
1987	802	1003	1126	9	2940
1988	167	7	1001	688	1863
1989	68	125	197	1359	1749
1990	103	18	250	1808	2179
1991	111	19	644	1156	1930
1992	43	57	691	3319	4110
1993	4	10	415	2137	2566
1994	10	12	172	664	858
1995	82	9	230	820	1141
1996	5		219	3	227
1997	14	8	7	3	32
1998	8		4		12
1999	11				11
2000	3				3
2001	2				2
2005	1				1
Total	2924	1288	7879	12896	24987

Table 2. Number of tag releases and corresponding recaptures of king mackerel by stock unit, region and year.

	Atlantic stock unit				Gulf of Mexico stock unit			
	No mix area		Mixing zone		No mix area		Mixing zone	
Year	Releases	Returns	Releases	Returns	Releases	Returns	Releases	Returns
1961	11						16	
1962	1		3		1			
1963			2				1	
1964					2			
1965	3							
1966							2	
1969					1			
1974	3							
1975	1		6		1		1	
1976	1		1		10			
1977			1					
1978					2			
1980					2		4	1
1983	18	1			1475	49		
1984	22	1			194	13	1	1
1985	436	10			529	39	449	16
1986	986	39	7		706	35	456	20
1987	802	27	1003	96	1126	73	9	2
1988	167	16	7		1001	148	688	27
1989	68	9	125	15	197	42	1359	91
1990	103	5	18		250	10	1808	86
1991	111	7	19	1	644	16	1156	26
1992	43		57	4	691	12	3319	75
1993	4		10		415	8	2137	134
1994	10	1	12		172	2	664	26
1995	82		9		230	7	820	22
1996	5				219	6	3	
1997	14	1	8		7		3	
1998	8				4			
1999	11							
2000	3							
2001	2							
2005	1							
Total	2916	117	1288	116	7879	460	12896	527

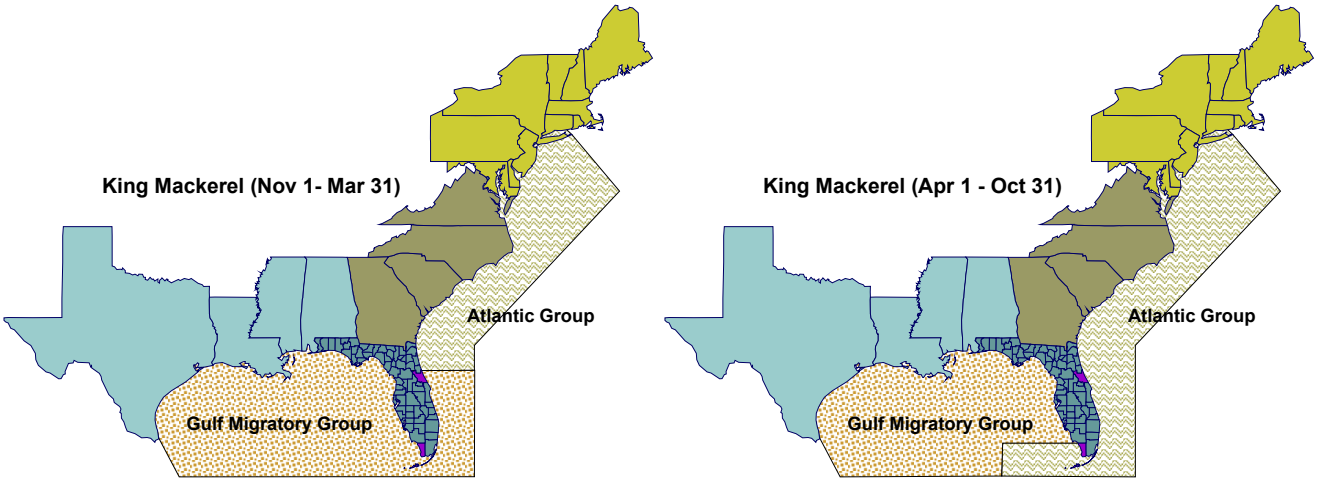


Figure 1. Current definitions of stock boundaries for Gulf and Atlantic king mackerel stocks.

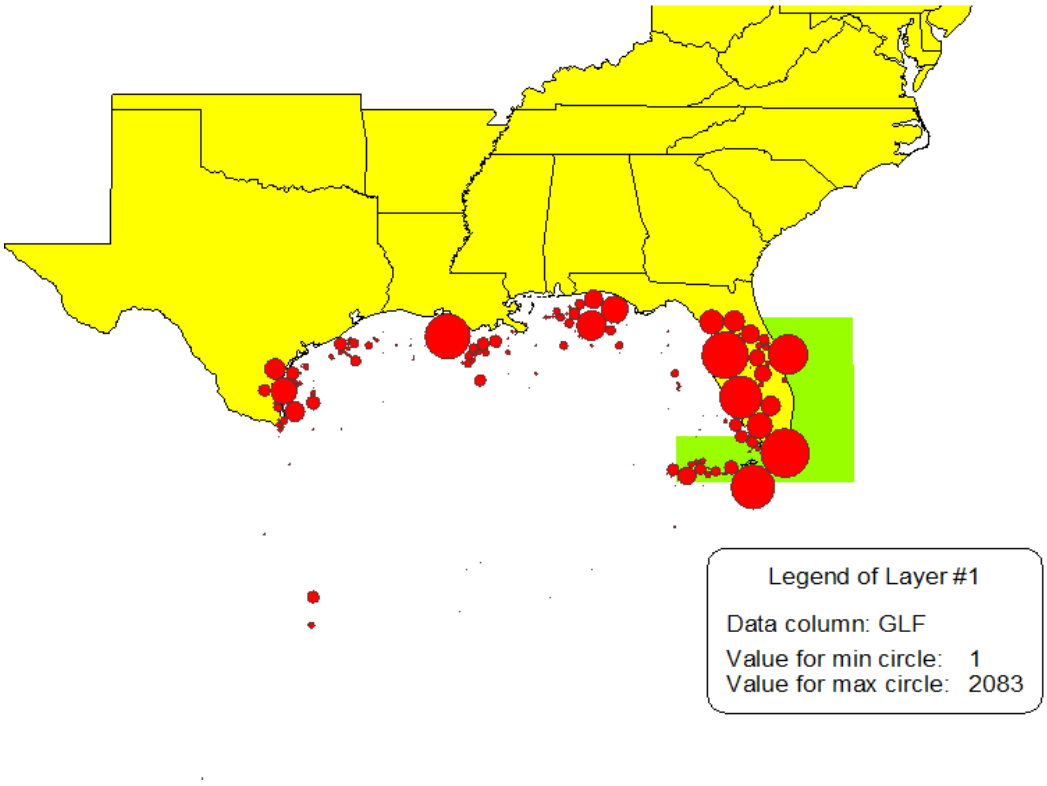


Figure 2 Dorling cartogram maps of king mackerel Gulf stock unit releases. Each circle represents the number of tag releases within a 0.25 square degree area all years; size of circle is proportional to number of releases. Highlighted area corresponds to the mixing zone.

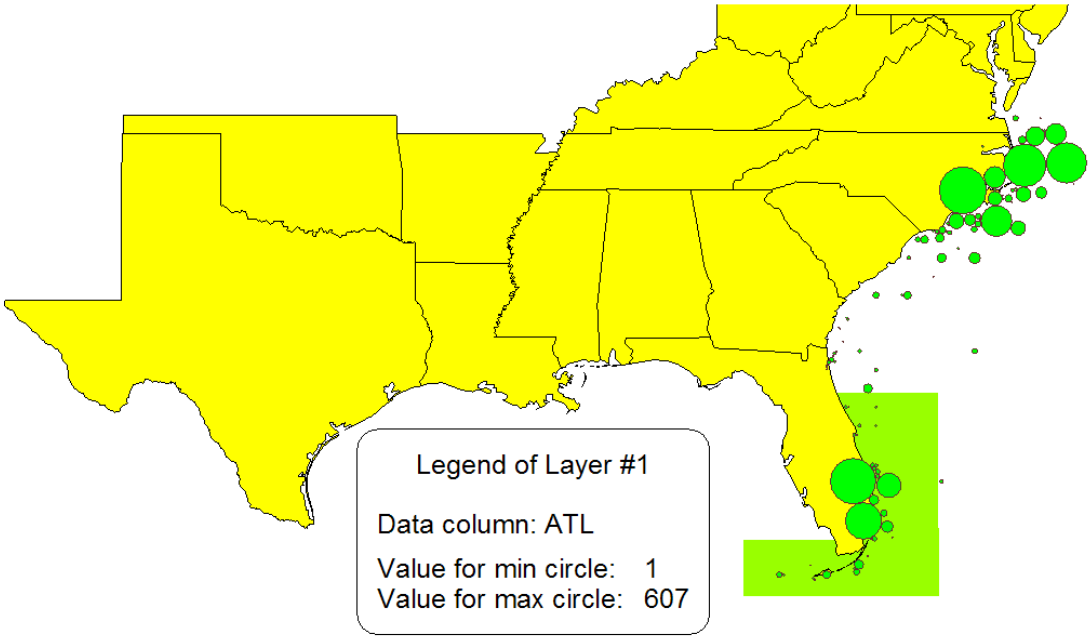


Figure 3 Dorling cartogram maps of king mackerel Atlantic stock unit releases. Each circle represents the number of tag releases within a 0.25 square degree area all years; size of circle is proportional to number of releases. Highlighted area corresponds to the mixing zone.

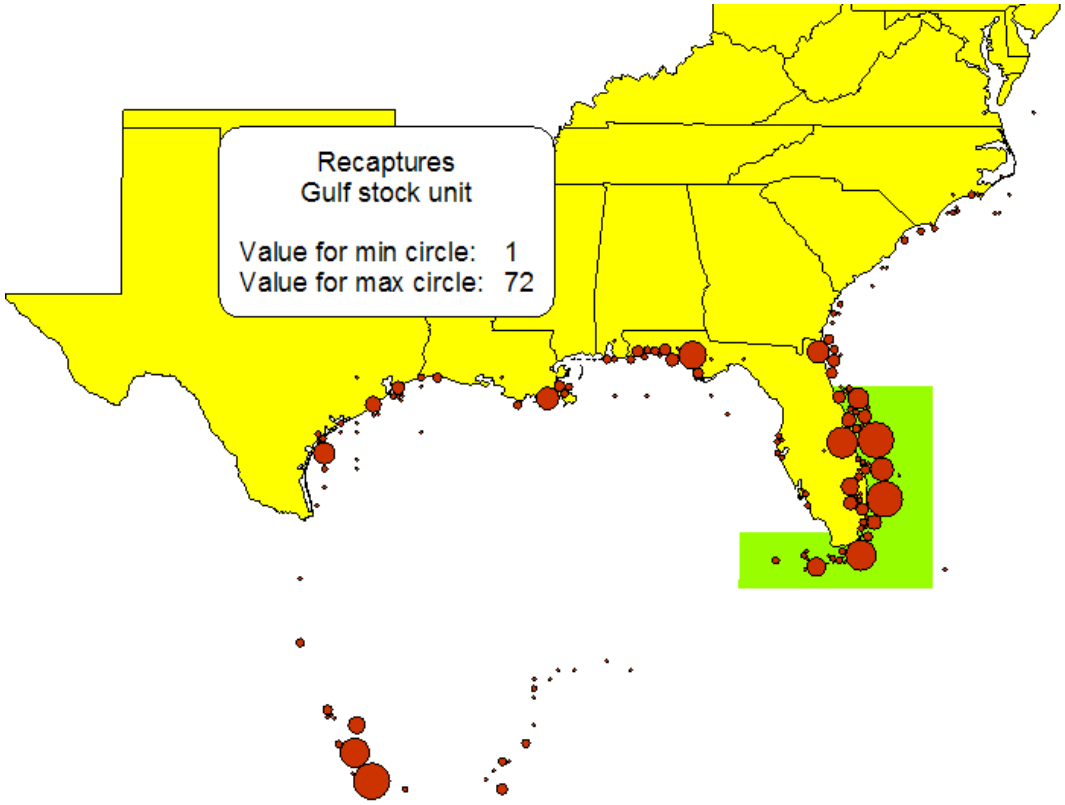


Figure 4. Dorling cartograms king Gulf recaptures. Size circle is proportional to number of recaptures.

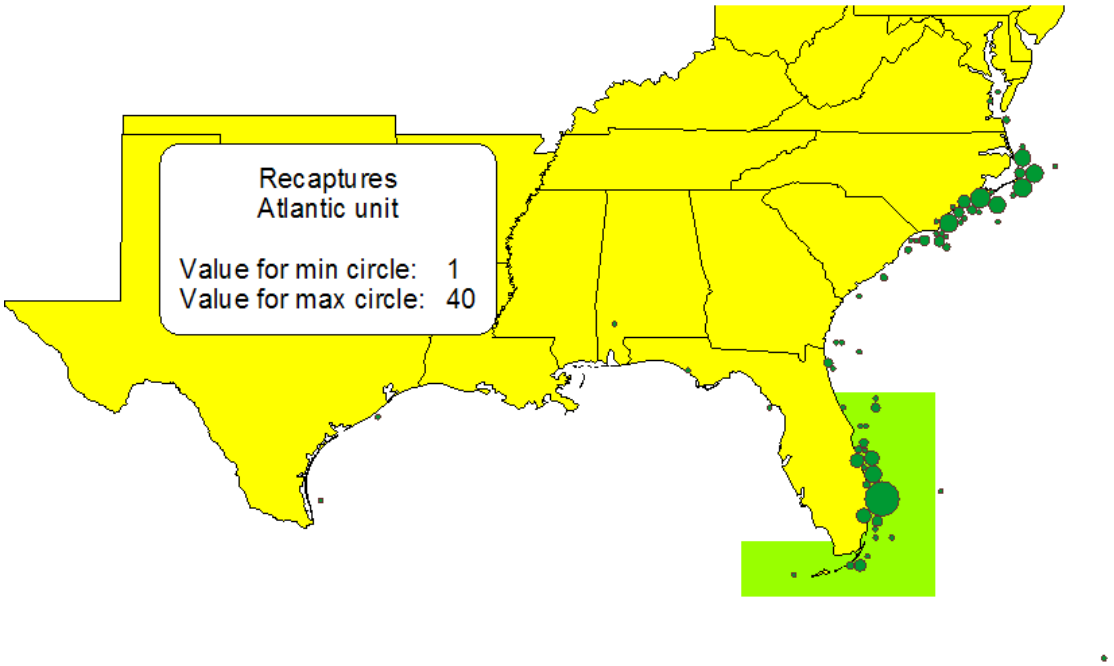


Figure 5 Dorling cartogram king Atlantic recaptures. Size circle is proportional to number of returns.

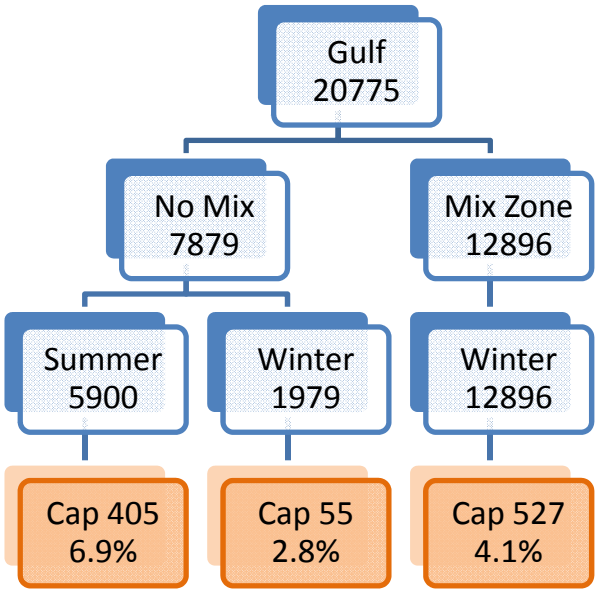


Figure 6. Tree distribution of tag releases from the Gulf stock unit current definition and corresponding number of returns (bottom line).

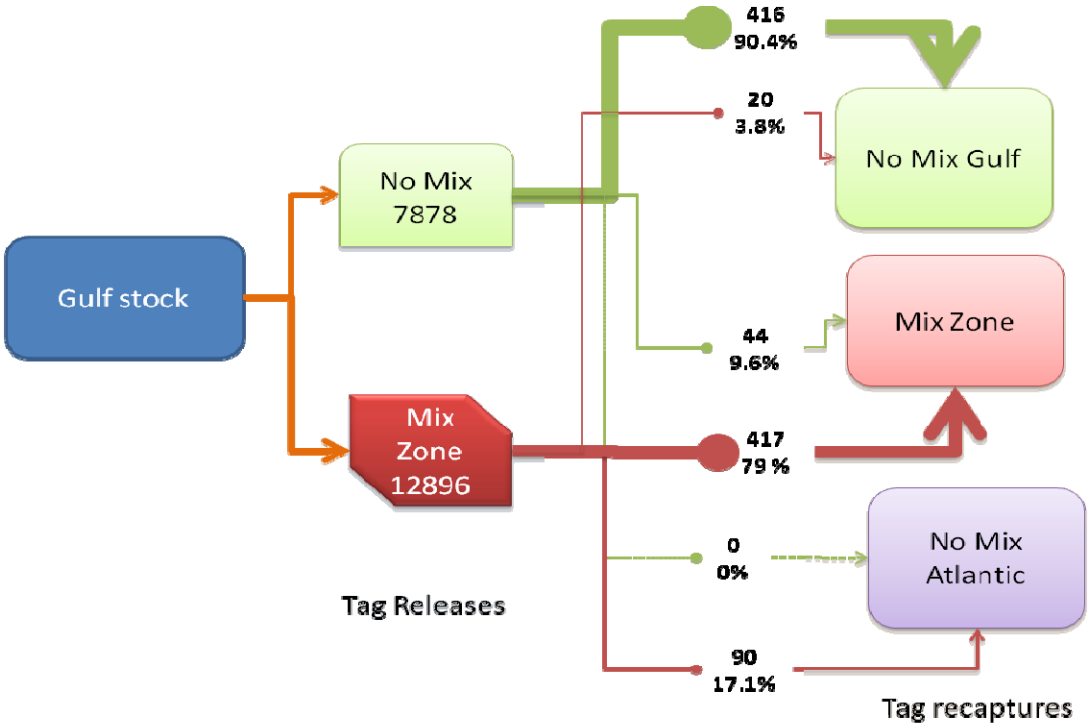


Figure 7. Distribution of tag releases and returns by region from king mackerel Gulf stock unit, percentages correspond to the total from each region of tag release.

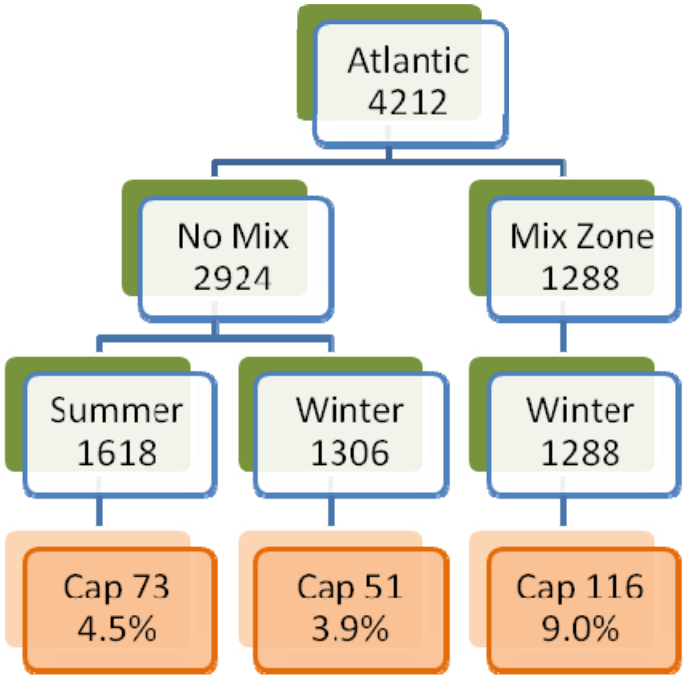


Figure 8. Tree distribution of tag releases from the Atlantic stock unit current definition and corresponding number of returns.

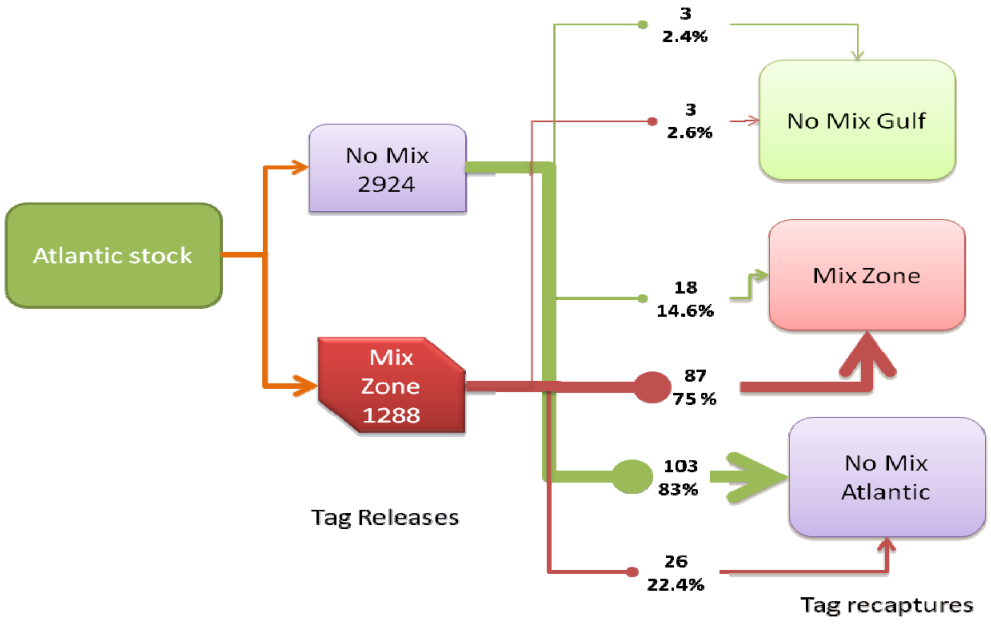


Figure 9. Distribution of tag releases and returns by region from king mackerel Atlantic stock unit, percentages correspond to the total from each region of tag release.

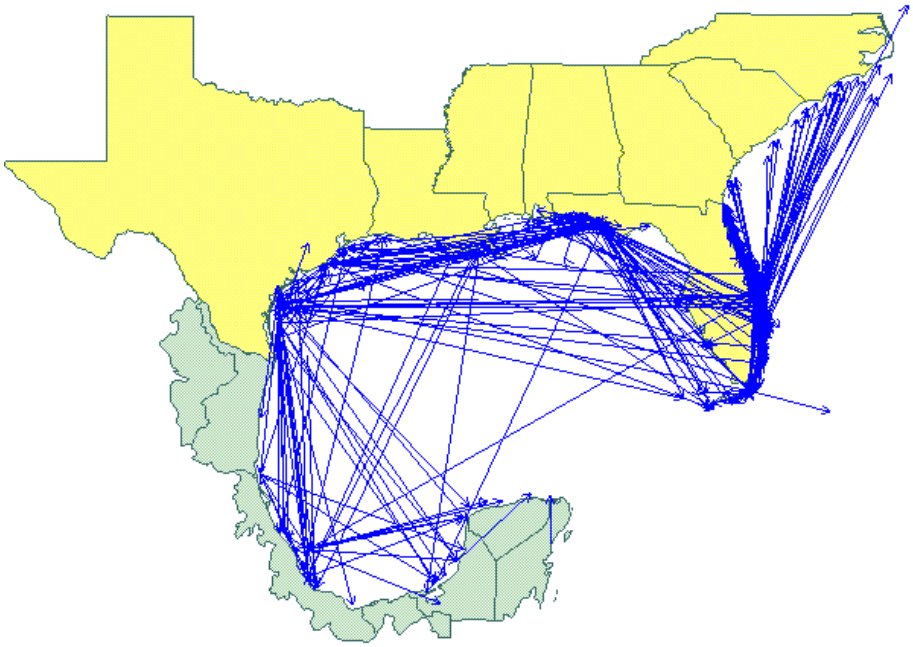
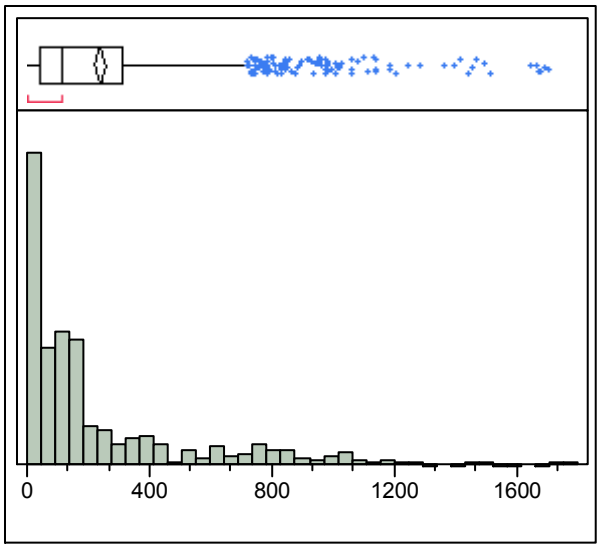


Figure 10. Vector displacement map of tag release and recapture (arrow) for king mackerel Gulf stock unit. The line represents the minimum travel distance between point of release and recapture.



Quantiles

100.0%	maximum	1812.7
75.0%	quartile	308.1
50.0%	median	112.5
25.0%	quartile	36.5
0.0%	minimum	0.0

Moments

Mean	238.042
Std Dev	319.57094
N	981

Figure 11. Frequency distribution of straight distance displacement (km) between release and recapture locations for king mackerel Gulf stock unit.

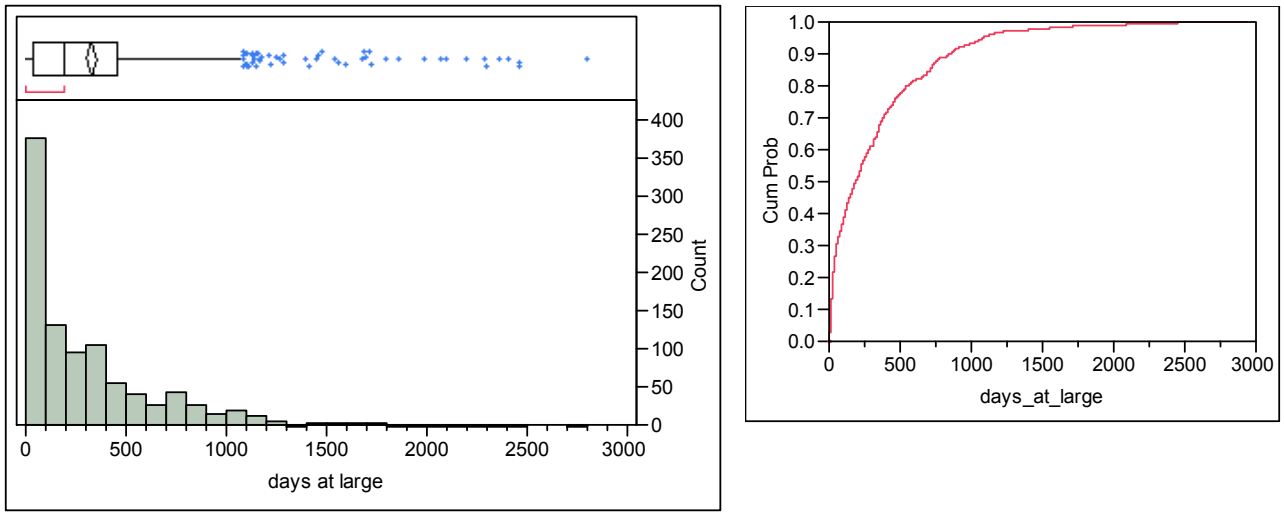


Figure 12. Frequency distribution and cumulative probability distribution of days-at-large from king mackerel Gulf stock unit tag and recaptured fish.

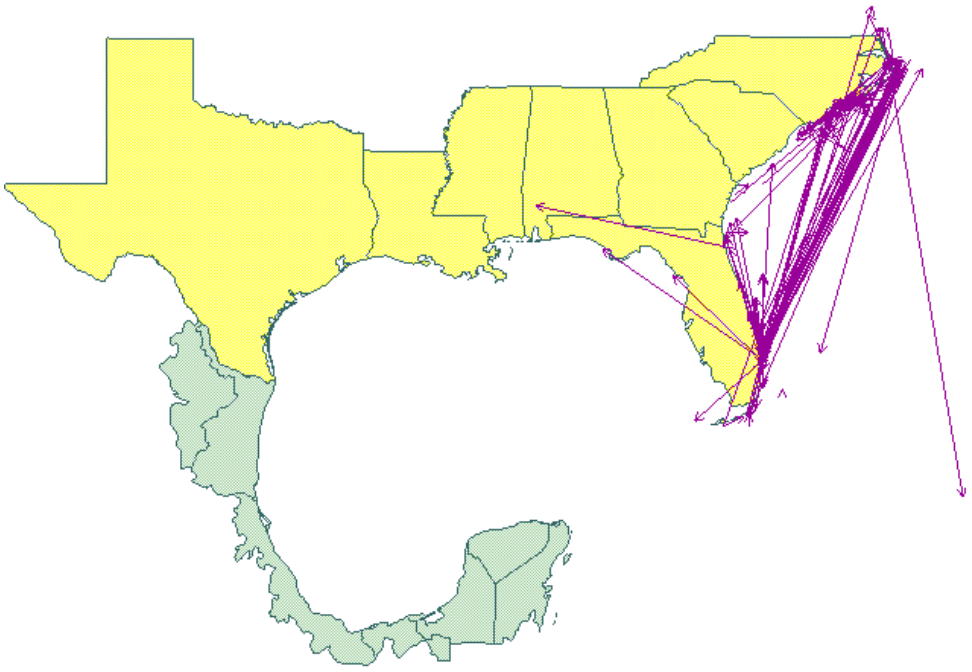
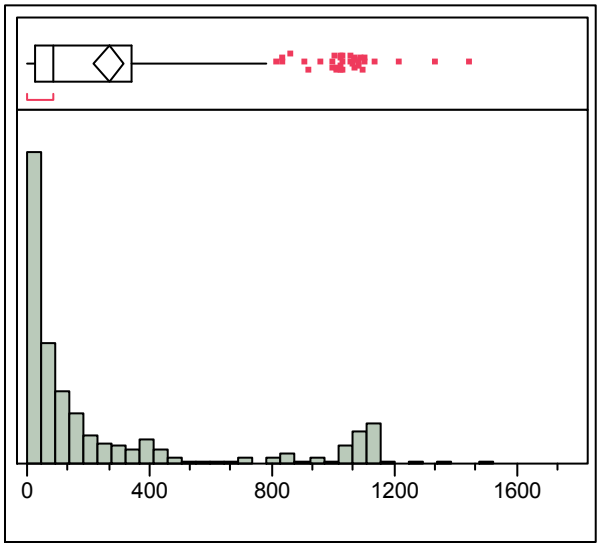


Figure 13. Vector displacement map of tag release and recapture (arrow head) for king mackerel Atlantic stock unit. The line represents the minimum travel distance between point of release and recapture.



Quantiles

100.0%	maximum	1448.1
99.5%		1428.8
97.5%		1100.9
90.0%		1024.6
75.0%	quartile	340.5
50.0%	median	85.6
25.0%	quartile	27.1
10.0%		11.8
2.5%		0.4
0.5%		0.0
0.0%	minimum	0.0

Moments

Mean	267.16075
Std Dev	365.85714
Std Err Mean	24.019698
upper 95% Mean	314.48644
lower 95% Mean	219.83506
N	232

Figure 14. Frequency distribution of straight distance displacement between release and recapture locations for king mackerel Atlantic stock unit.

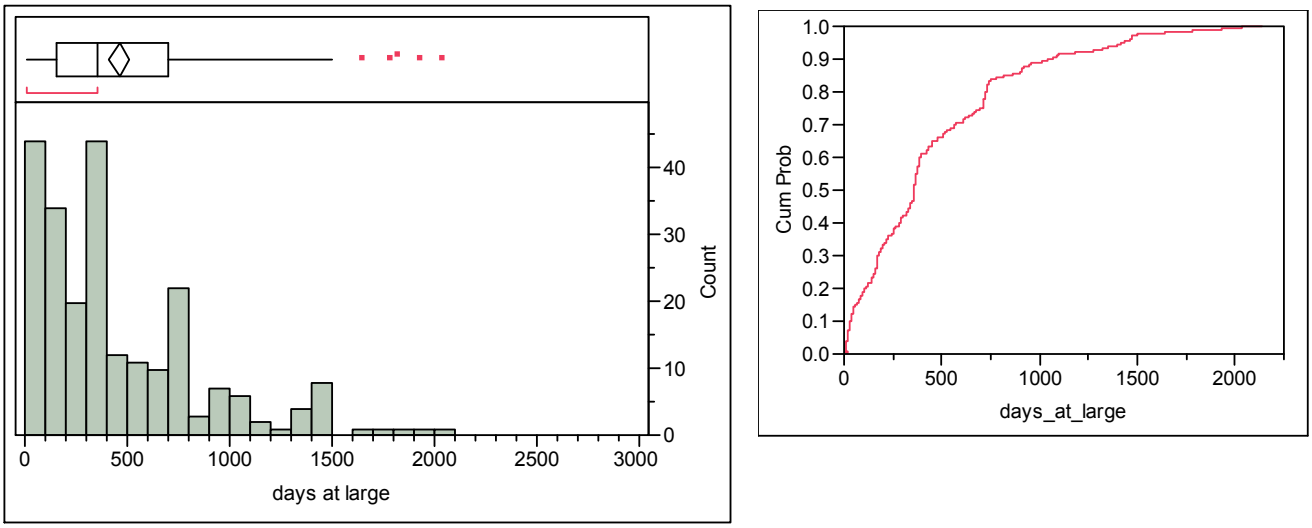


Figure 15. Frequency distribution and cumulative probability distribution of days-at-large from king mackerel Atlantic stock unit tag and recaptured fish.

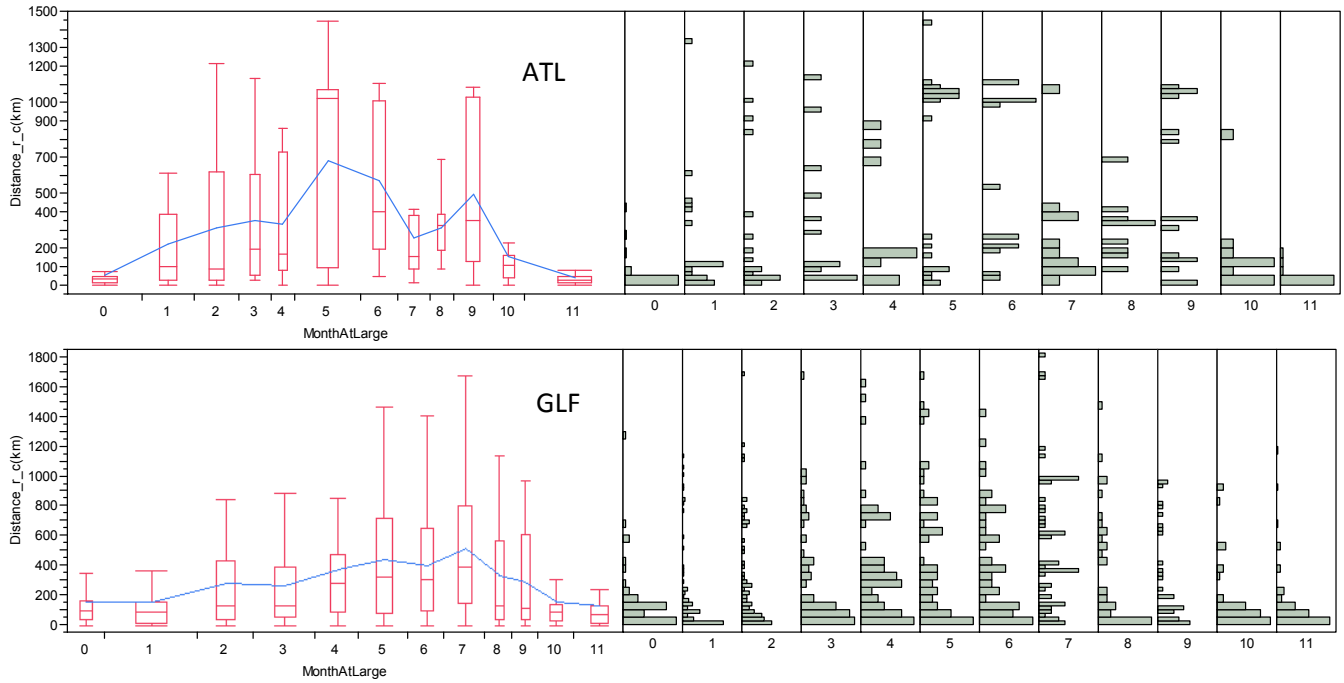
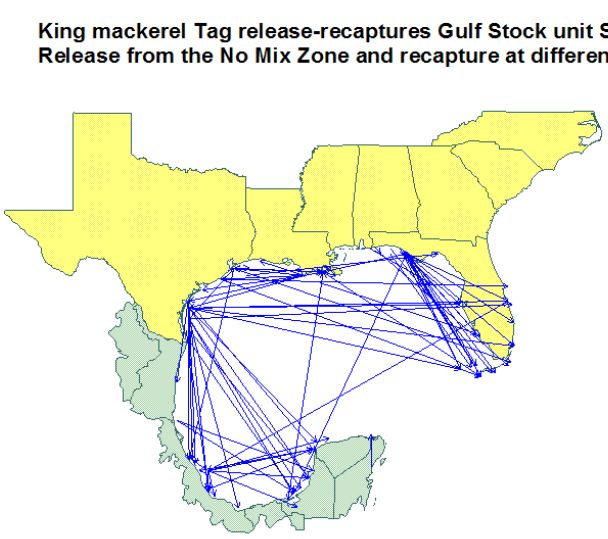


Figure 16. Boxplot and histograms of displacement distance (km) versus month at large for king mackerel tag-mark-recaptured observations, top panel Atlantic stock, bottom panel Gulf stock unit.



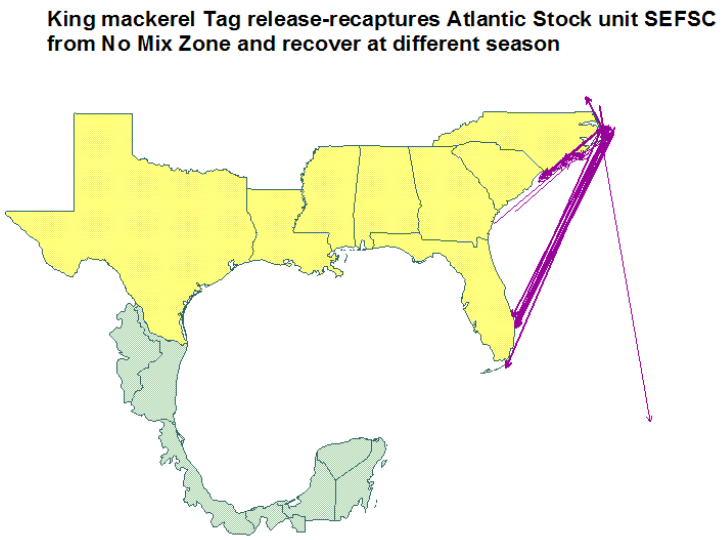
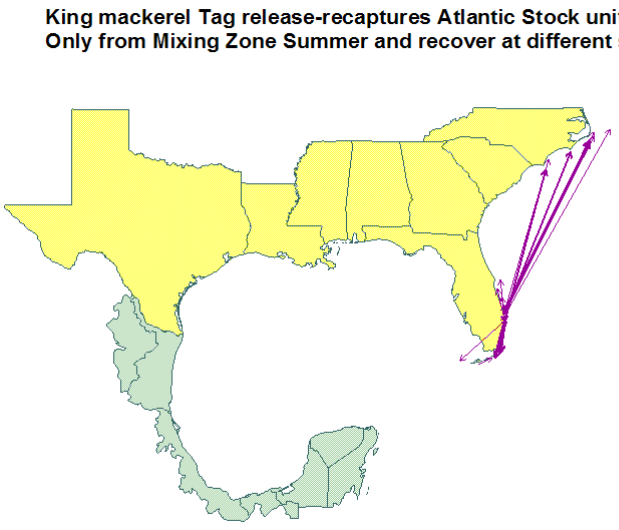


Figure 17. Vector displacement maps of king mackerel tag recoveries from none mixing areas of the Gulf (left) and Atlantic regions.



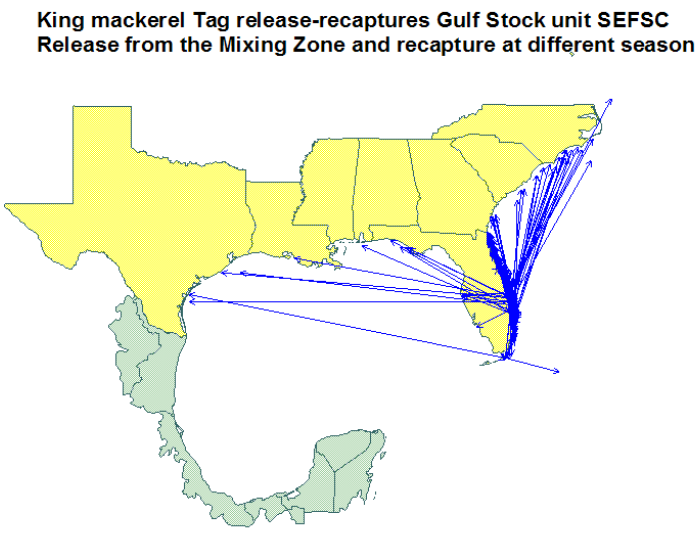


Figure 18. Vector displacement maps of king mackerel tag recoveries from the mixing area, summer (left) and winter (right).

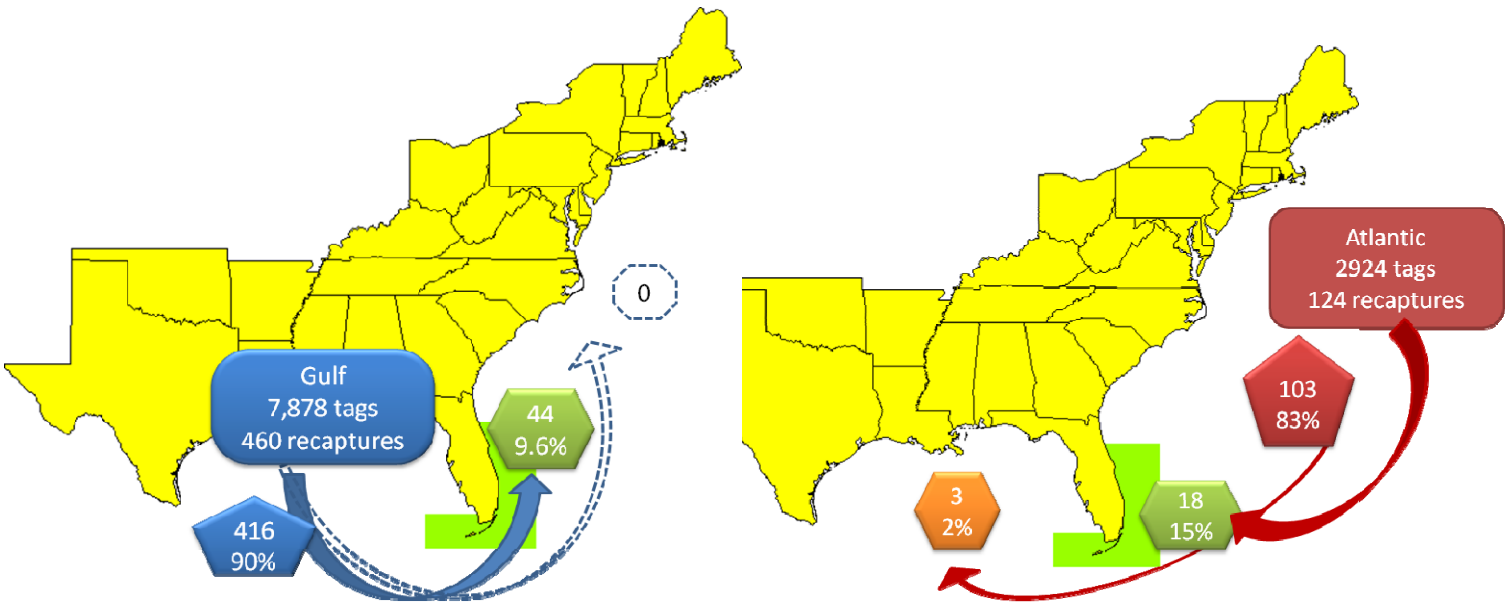


Figure 19. Summary of tag recoveries from the Gulf (left) and Atlantic (right) no mixing area release for king mackerel

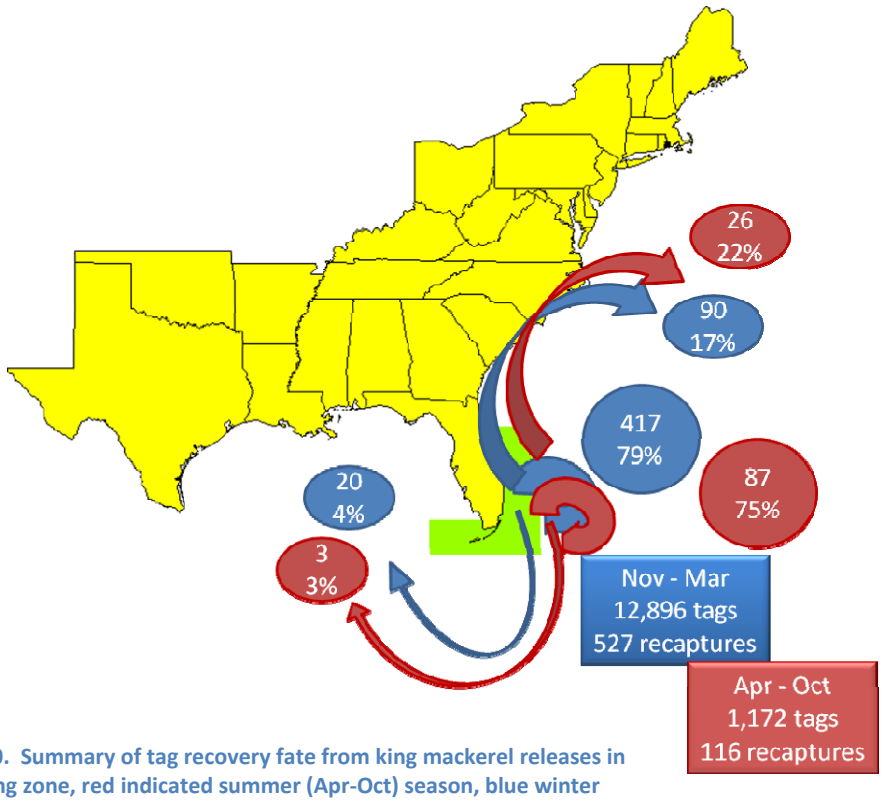


Figure 20. Summary of tag recovery fate from king mackerel releases in the mixing zone, red indicated summer (Apr-Oct) season, blue winter (Nov-Mar). Percent values refer to total by season.

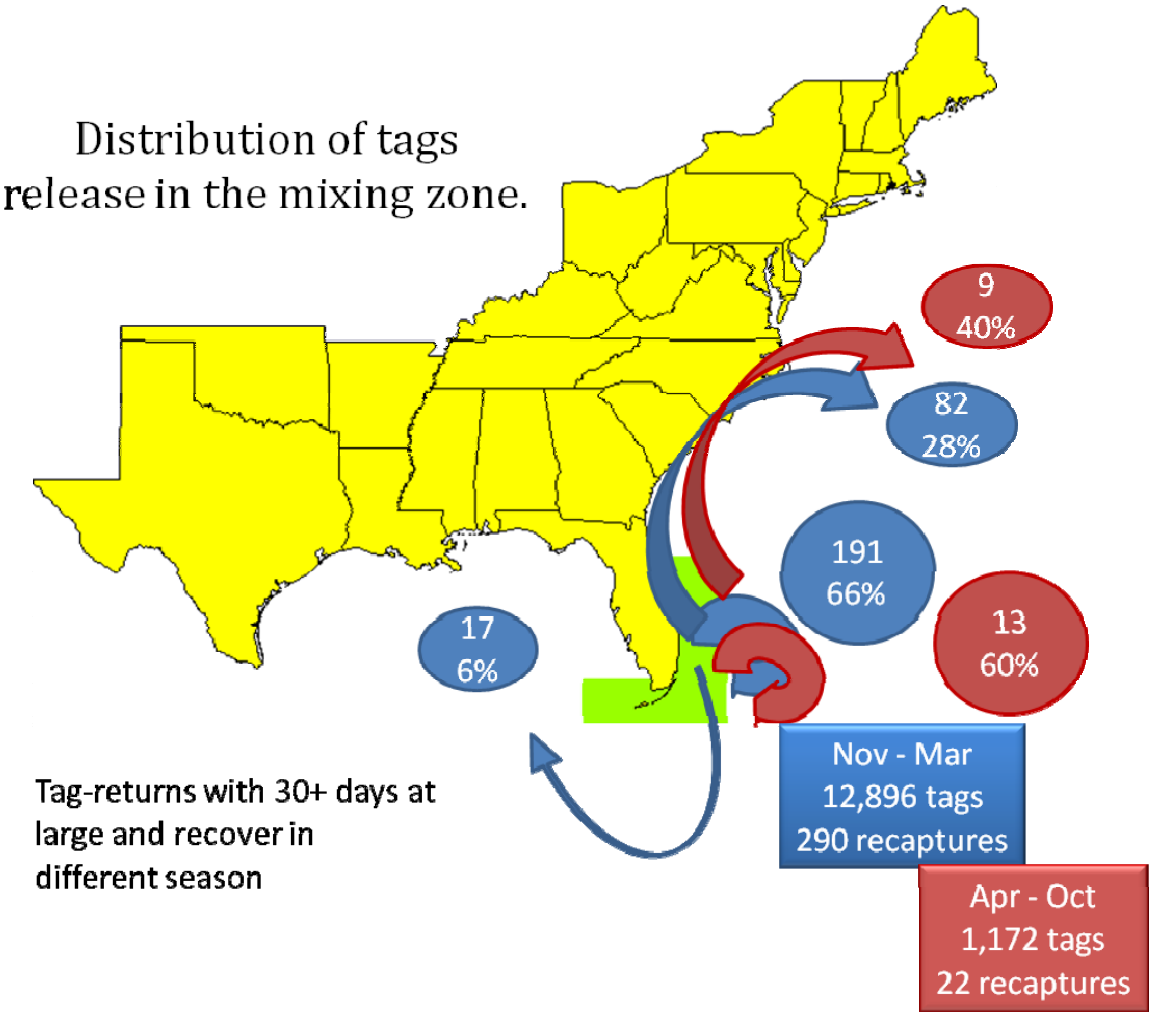


Figure 21. Summary of tag recovery fate from king mackerel releases in the mixing zone. Only tags with 30 or more days at large and recover in different season of the release one. Red indicated summer (Apr-Oct) season, blue winter (Nov-Mar). Percent values refer to total by season.