Analysis of environmental factors affecting king mackerel landings along the east coast of Florida

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SEDAR38-DW-07

22 November 2013

Please cite this document as:

Barile, P.J. 2013. Analysis of environmental factors affecting king mackerel landings along the east coast of Florida. SEDAR38-DW-07. SEDAR, North Charleston, SC. 14 pp.

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November 22, 2013

Introduction

King Mackerel, *Scomberomorus cavalla*, are commercially important scombrids endemic to the western Atlantic from Massachusetts to Brazil, that constitute significant fisheries in the south Atlantic and Gulf of Mexico (GOM) with nearly 6 million pounds commercially harvested, annually, between these two regions. The King Mackerel fishery has been jointly managed by the Gulf of Mexico and South Atlantic Fishery Management Councils since 1983 under the Coastal Migratory Pelagic (CMP) Fishery Management Plan (FMP). These stocks were originally managed as one stock from North Carolina to Texas, but were later separated as two distinct “migratory groups” in 1985 as the result of Amendment 1 of the CMP-FMP.

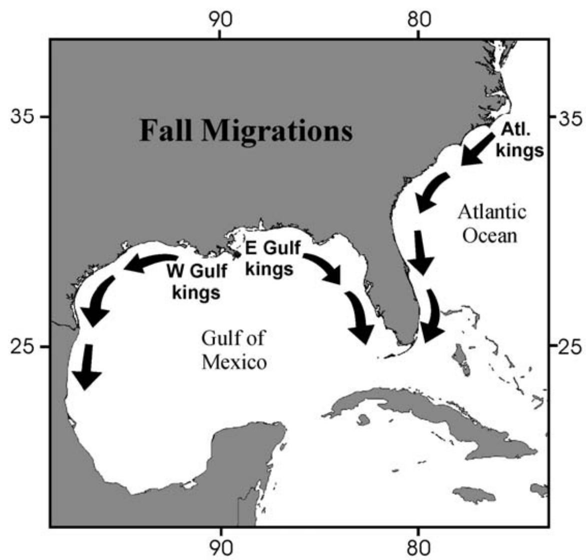

Figure 1. Fall migration patterns of Gulf of Mexico and Atlantic king mackerel stocks. From Patterson et al. 2004.

Winter migrations of king mackerel from both the Gulf and Atlantic stocks enter warmer southeast and south Florida waters, know as the “mixing zone” (Figure 2.) where water and air temperature is moderated by the Florida current. These migrations are presumed to occur as king mackerel are “isothermal,” in a temperature range close to ~ 72° F (Beaumariage 1973).

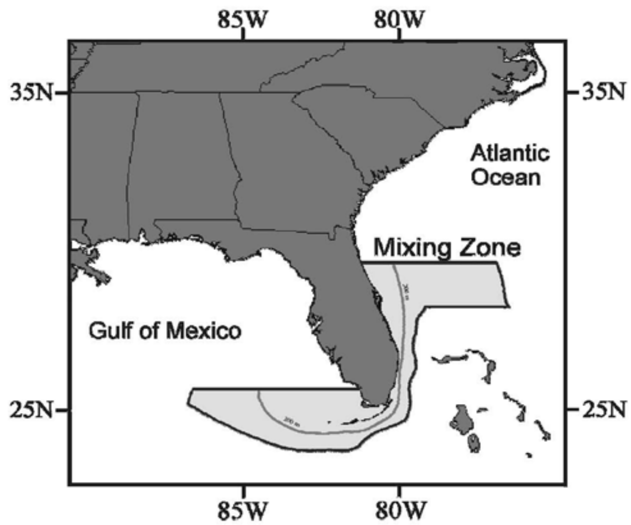

Figure 2. Winter mixing zone for Gulf of Mexico and Atlantic king mackerel stocks. From Patterson et al. 2004.

From the perspective of management of both the Atlantic and GOM mackerel stocks, changes in temperature regimes within this zone may have measurable and predictable effects on the composition of stocks within the mixing zone.

The following information suggests several meteorological and climatological mechanisms that may influence the physical conditions in the mixing zone, and thereby the migration and persistence of Atlantic and GOM stocks into southeast and south Florida. In light of recent evidence that climate change is responsible for subtle temperature related changes in distribution of fisheries species along the western Atlantic (see Pinsky 2013), these environmental drivers should be considered in all present and future stock assessments in the GOM & south Atlantic. These physical data can be incorporated into fisheries models to indicate “catchability” of stocks. These environmental drivers include:

1) Meteorologically significant seasonal weather patterns, e.g. historically cold winters

2) Regionally significant climatological events, e.g. El Nino & La Nina events

3) Regionally (south Atlantic bight) significant summer upwelling events.

Several sources of environmental information are available to incorporate into fisheries models. They include: 1) historical sea surface temperature data from fixed stations, 2) NOAA-NDBC buoy data, and 3) sea surface temperature data derived from global satellite imagery. Further, archived and real-time meteorological data are available from NOAA-NWS stations.

In the example below, NOAA-NDBC temperature data, from the following sites, were compared with landings data in the "mixing zone" in east Florida.

1) Meteorological data- NOAA National Data Buoy Center (NDBC)

Cape Canaveral Buoy (inshore) Station 41113, 3nm E. of Port Canaveral
surface water temp. (since 2006), n= 1488 samples/ month

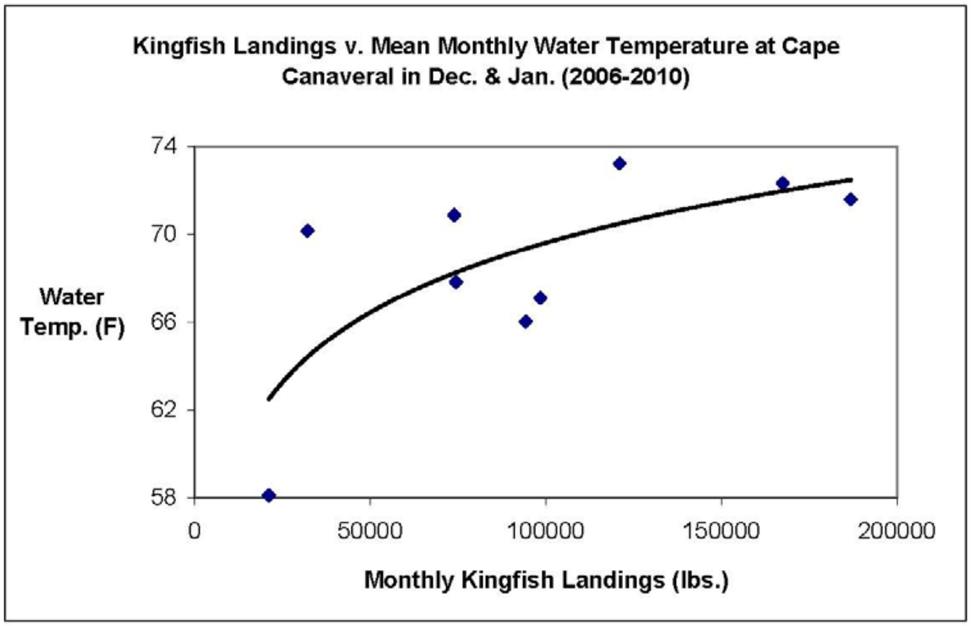

Figure 3. Monthly king mackerel landings at Cape Canaveral for Dec & Jan winter months (2006-2010) versus mean monthly sea surface water temperature at NDBC Station #41113.

2) Climatology- El Nino (ENSO, cold) vs. La Nina (warm) winters in E. FL

In the southern United States, El Nino southern oscillation (ENSO), an its alternative climatological pattern, La Nina, are recognize to have distinctive impacts on winter weather patterns. Winters in El Nino years tend to be colder and wetter, whereas La Nina winters are generally warmer and dryer.   Studies characterizing the dynamics of the king mackerel stocks in the winter east Florida "mixing zone" have been performed in the span of historically cold versus warm winters over the past four decades. A summary of the regional weather during these studies will be presented later (Table 1.) in this paper. However, there is considerable evidence that there was increasing intensity and frequency of ENSO events in the last 2 decades of the past century. The role of ENSO events must be considered in context with population dynamics of this species that responds predictably to water temperature.

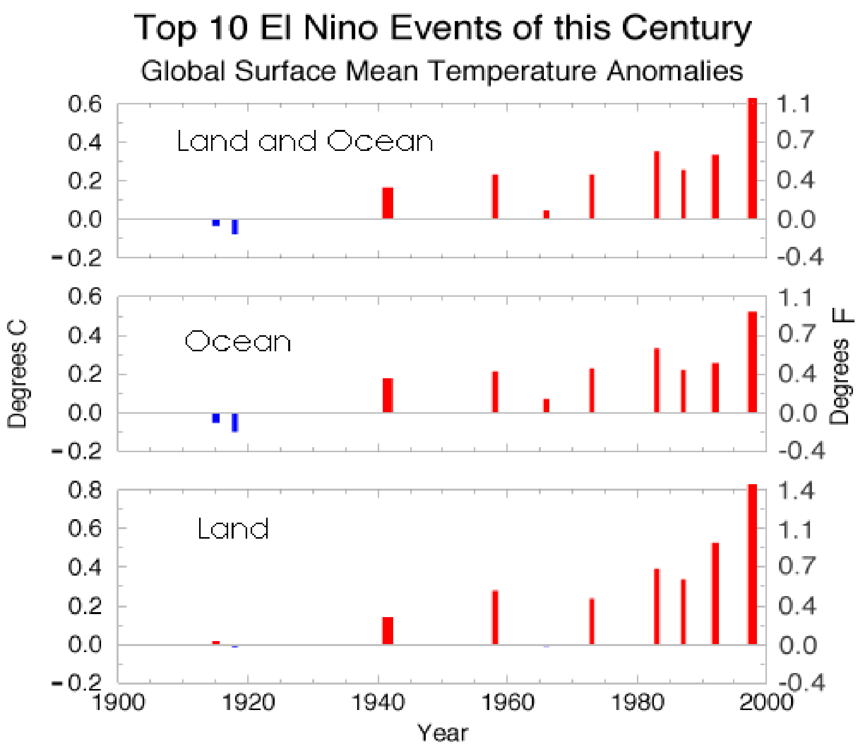

Figure 4. ENSO temperature anomalies over the past century.

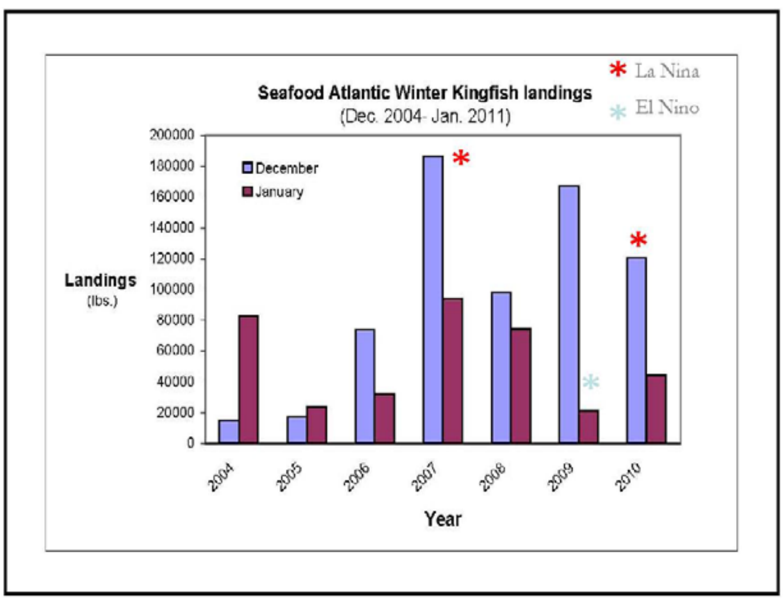

Figure 5. King Mackerel landings from 2004-2010 at Cape Canaveral during ENSO anomalies from.

3) Cold summer upwellings may reduce landings of king mackerel in the south Atlantic bight.

There are a considerable number of literature references to cold upwelling events in the south Atlantic bight in the past several decades. These events may drop coastal water temperature from the high 70's and low 80's F during summer months to the 50's F within a few hours, and persist for several weeks. There is evidence that the periodicity and magnitude of these meteorologically driven events (see Hyan 2010) may have increased in recent decades (see Figure 6). It is very likely that persistent cold water upwelling events in the summer, such as the severe upwelling of 2003, may reduce king mackerel landings (Figure 7.). There is a need for better resolution in coastal temperature readings. For example, the NOAA-NDBC system off the coast of east Florida has only produced temperature time series data since 2006. Clearly a system of complimentary bottom temperature measurements would aid in resolution of temperature anomalies and biological responses.

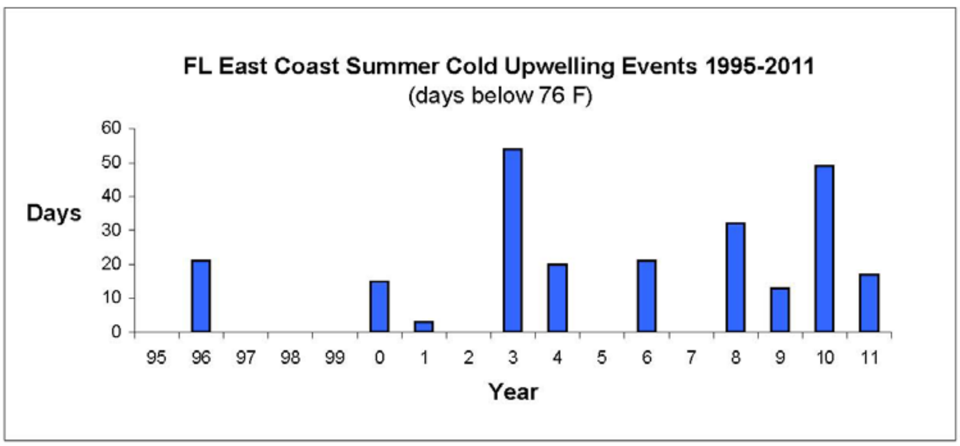

Figure 6. Number of July and August days with sea surface temps < 76F on the east coast of FL from 1995-2011 (data from NOAA/NWS- Melbourne, FL).

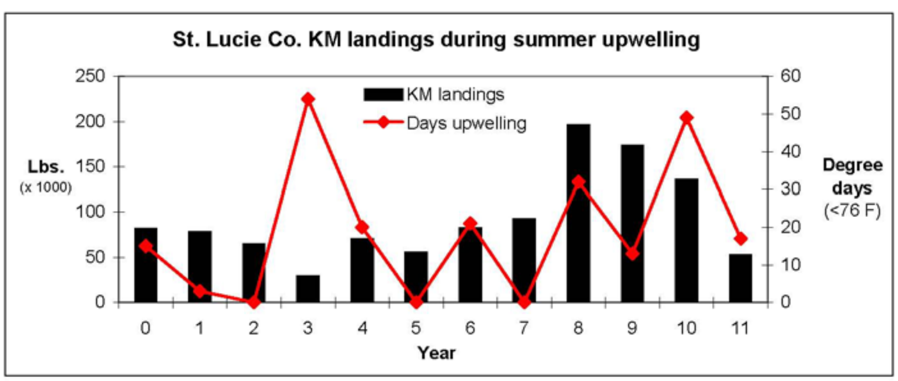

Figure 7. St Lucie Co. King Mackerel landings from 2000-2011 and E. FL NOAA/ NWS sea surface temperature data of days during June and July with temperature below 76 F.

Does winter season meteorological condition and climatology drive the relative (GOM vs. Atlantic) king mackerel stock abundance in the east Florida "mixing zone ?

<u>Early management policy and supporting scientific evidence</u>

The establishment of a "winter mixing zone" comprised of the two distinct migratory groups of King Mackerel in south Florida was a management tool to support the conservation and recovery of the Gulf migratory group that had been designated as "overfished" in the mid-1980's. Despite the fact that mixing of the stocks in the winter was not well understood, the stock in the mixing zone was assigned to the Gulf migratory stock somewhat arbitrarily as a "conservation" measure of protection to that group (Patterson et al. 2004). This assignment of 100% of the "mixing zone" stock to the Gulf migratory group was supported by rudimentary King Mackerel "tag and release" studies from 1975-79 performed by the Florida Department of Natural Resources (FDNR, as reviewed by Sutter et al. 1991). There were several problems with using the results of this work for characterizing the stock composition and migration patterns of the winter mixing zone stock as either Gulf or Atlantic stock. In fact, these findings may have mis-characterized the composition of the winter mixing zone stock.

First, of the total King Mackerel tagged (n=9090) in the mixing zone, including Ft. Pierce and Jupiter, only 8% of those fish (n=750) were recovered. For the Ft. Pierce winter release, only 22% of those fish recovered (n=122 of 543) were collected beyond the Dade-Monroe Co. or Volusia-Flagler Co. boundaries. The largest proportion of those fish re-captured outside of the immediate zone, 7% (n=37 fish) were re-captured in the more southern portion of the mixing zone in the Florida Keys within 1-3 months of the tagging. Interestingly, only a total of 47 fish, of the 6,416 released from Ft. Pierce, and the total of 543 re-captured, were collected in the Gulf zones. Yet, Sutter et al. (1991) assert that 88% of the king mackerel released from the Ft. Pierce winter mixing zone had moved "Gulfward." Instead of concluding that these fish were migrating to reside in the Gulf during the spring and summer, it may have been more plausible that these Ft. Pierce fish had not finished their full southerly migration to south Florida, before returning north the next spring. This is supported by FL Keys tagging data in the same study that reported no difference between the quantity of fish recaptured further north in the Gulf versus the south Atlantic. Further, for the king mackerel tagged in Jupiter, more (~64%) of those fish migrated north along the Atlantic side rather than to the Gulf. Clearly, the findings of the 1970's FDNR were not particularly supportive of the concept of characterizing the "winter mixing zone" as 100% Gulf stock. The reporting of these findings appears biased toward such a preconceived characterization. Indeed, these studies may have never supported management of stock in the winter mixing zone (DeVries et al. 2002).

In contrast, findings from more recent tag and re-capture studies have not supported the findings used to support the original characterization of the winter mixing zone stock as dominated by the Gulf migratory group. Fable (1993) reported that only 12% (207 recovered of 3901 tagged) of King Mackerel tagged on the east coast of

Florida in the winters of 1988-89 and 1989-90, were recaptured in the Gulf of Mexico, and belong to the Gulf migratory group.

In an analysis of all tag and re-capture studies from 1985 to 1992, Cummings-Parrack (1993) reported that only 3% of king mackerel tagged in the south Atlantic were re-captured in the Gulf of Mexico. As a result of these studies, the Mackerel Stock Assessment Panel, in 1993, concluded that the variations in relative migratory group stock size and age structure are *dynamic*. The Panel suggested that an understanding of inter-annual variability would significantly improve the biological basis for management of the stocks comprising the winter mixing zone.

The SEDAR 16 King Mackerel Data Workshop (DW) Life History Group analyzed all of the tag and recapture data from 1961-2005 which further diminish the value of this data in support of the significant contribution of Gulf stock in the winter mixing zone. Of the 24,987 King Mackerel that were tagged since 1961, only 5% (n=1227) were re-captured. No fish released in the GOM were re-captured north of the FL-GA line in the Atlantic. Of the 12,896 fish tagged and released in the mixing zone, only 4% (n=527) were recaptured.

Interestingly, most of the fish released in the mixing zone (78%, n=90) travelled north into Atlantic zone (north of Volusia/ Flagler Co. line), while fewer (22%, n=20) travelled into the Gulf of Mexico (north of Collier/Monroe Co. line). Of the 1288 fish tagged during the spring-summer (April-October) in the mixing zone, only 3 of those fish (2.8%) migrated into the Gulf of Mexico, with the other 113 recaptured fish either remaining in the mixing zone or travelling north of the Volusia/ Flagler Co. line in the Atlantic. In summary and contrary to previous interpretation of this data, a more recent vector analysis of these tagged and recaptured fish, suggests that the Gulf stock are more strongly migrating to the SW versus SE Florida coast; and further, Atlantic stock is a primary contributor to the winter mixing zone in SE Florida (see Fig. 8.).

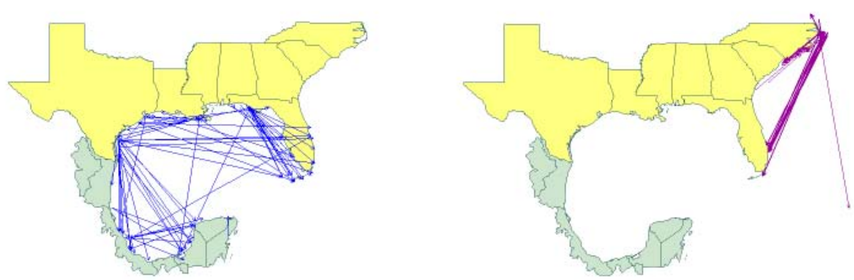

Figure 2.15.6 (Fig. 17 in S16-DW-10). Vector displacement maps of king mackerel tag recoveries from the non-mixing areas of the Gulf of Mexico (left) and Atlantic (right) regions.

Figure 3. Vector displacements of non-mixing zone King Mackerel tag recoveries from SEDAR 16 DW- Life History group, pg. 40, Fig 2.15.6)

Subsequent King Mackerel mixing zone stock characterization

Recent state-of-the-art research utilizing “natural tags” has provided a more scientifically reliable assessment of the source of the SE Florida winter mixing zone King Mackerel stock. Devries et al. (2002) characterized otolith morphometrics using image analysis software in summer King Mackerel stocks in the upper Gulf of Mexico and eastern Atlantic zone. This analysis produced a statistically discrete characterization of the Gulf migratory stock versus the Atlantic migratory stock for samples collected between 1986 to 1993 for model development, with another significant collection in the summer of 1996. The following December (1996) to February 1997, 463 “winter mixing zone King Mackerel were collected during 21 collections and otoliths sampled from commercial landings at 4 sites between Cape Canaveral and West Palm Beach, FL (see Figure 9.). This spatially and temporally explicit sampling in the winter mixing zone indicated that 99.8% of the King Mackerel in the SE Florida winter mixing zone were Atlantic stock. This finding, based on a more reliable method than antiquated “tag and release” methods previously used, is almost exactly opposite of previous findings and subsequent assessment and management with respect to the composition of the winter mixing zone stock.

D.A. DeVries et al./Fisheries Research 57 (2002) 51–62

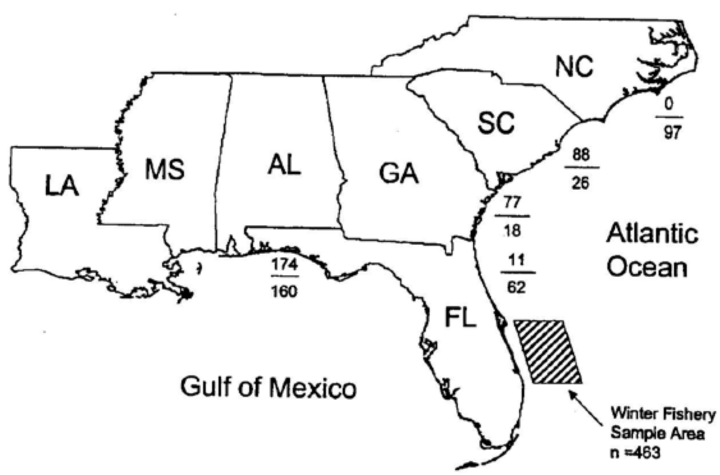

Figure 9. Sampling sites (and number of samples) for king mackerel otolith analyses. Note hatched area for winter mixing zone sample collection. From DeVries et al. 2002.

Additional work utilizing “natural tags,” specifically, otolith shape and microchemistry have been used to characterize stocks in the winter mixing zone comprised of Gulf and Atlantic migratory groups. Patterson et al. (2004) analyzed otolith shape with image analysis software and otolith microchemistry (Barium, Calcium, Magnesium, Manganese and Strontium) with mass spectrometry. Otolith samples were collected from landed fish in the spring and summers of 2001 and 2002 in the upper GOM and south Atlantic, respectively, to parameterize otolith characteristics of Gulf and south Atlantic stocks when separated. Subsequently, fish were collected in three portions of the winter mixing zone, SE Florida, the Florida Keys, and SW Florida (Figure 10.). For the 2001-02 winter season, a mean of nearly 85% Atlantic migratory group was estimated for the SE FL mixing zone, and decreased to ~ 40% contribution for SW Florida. This value was generally consistent between shape and microchemistry analysis methods and also between male and female fish.

This trend decoupled, somewhat, during the 2002-03 winter between method and sex. Where shape analyses was consistent between years in estimating the contribution of Atlantic stock (85% in 2001-01, and 72% in 2002-03), the male fish off of SE FL were estimated at 27% south Atlantic stock using the microchemistry analyses, whereas females still represented over 60% of the south Atlantic stock. Interestingly, the microchemistry method for the winter 2002-03 data set estimated the SW Florida male stock at 75% Atlantic fish. In summary, this evidence supports characterization of the SE Florida winter mixing zone stock as dominated by the Atlantic migratory group. Whereas, only the Florida Keys and SW Florida appear to constitute a true winter mixing zone of Gulf and Atlantic King Mackerel. Inconsistencies in model results with respect to stock compositions in Patterson et al.'s (2004) findings may result from: 1) incomplete model development of the microchemistry method, 2) lower sample size than utilized in the Devries et al. (2002) study, and 3) specific inconsistency in the fish sample protocol across spatial and temporal scales between the two winter season data collections.

More recent state-of-the-art studies utilizing otoliths as "natural tags," as reviewed during SEDAR 16 King Mackerel stock assessment, have provided additional support that the winter mixing zone off of SE Florida is dominated by Atlantic stock, whereas Gulf stock pre-dominates stock composition along the SW Florida coast. Specifically, carbon and oxygen isotope methods were used by Patterson and Shepard (2008) to evaluate stock source in the 2007 winter mixing zone, as outlined in SEDAR 16 DW-26. These results indicated that 93.6% of the fish in the SE Florida (zone III) were from the Atlantic migratory group, while only 21.4% of the Atlantic migratory group were present in the SW Florida (zone I) portion of the mixing zone. Recent otolith shape analyses for winter mixing zone fish by Clardy et al. (In Press) which indicated that 85% of the fish in the SE Florida (zone III) were from the Atlantic migratory group, while only 15% of the Atlantic migratory group were present in the SW Florida (zone I), are consistent with other otolith shape analyses findings as well as the previously mentioned otolith isotope analyses (see Shepard et al. In Press). In summary, the SEDAR 16 King Mackerel DW Life History group stated "A consistent pattern of greater estimates of Gulf group contribute to stock off of SW Florida, and greater estimates of the Atlantic group contribute off of SE Florida has been observed <u>among</u> studies."

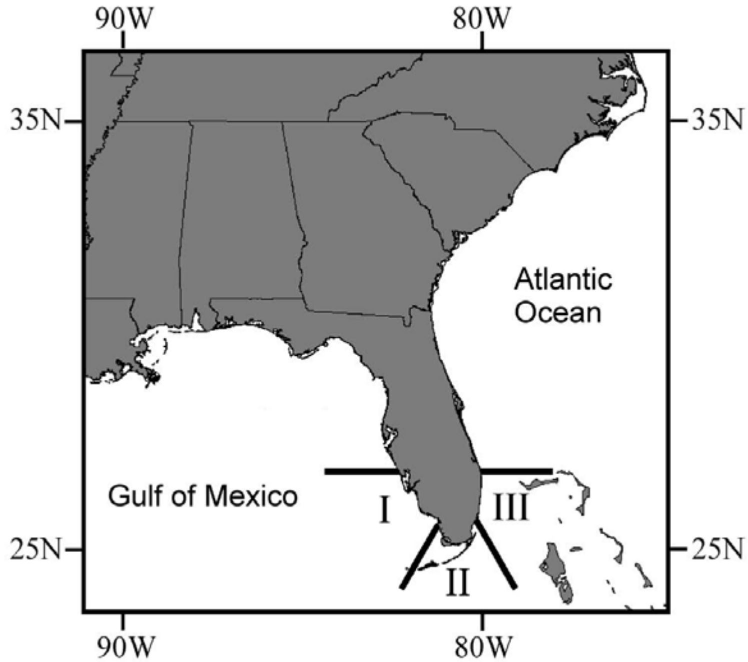

Figure 10. King mackerel winter mixing sample collections zones. From Patterson et al. 2004.

<u>Management of the winter mixing zone should be based upon best available science</u>

A summary of the results from the available stock characterizations of King Mackerel in the winter mixing zone should prompt a management re-assignment of Gulf and Atlantic stock composition in the winter mixing zone. The findings from previous stock composition studies of the winter mixing zone have repeatedly been misinterpreted since the 1970's and should be re-evaluated in the SEDAR 28 King Mackerel benchmark stock assessment. Specifically, the peer-reviewed scientific evidence suggests a revision of the existing classification of the winter mixing zone with respect to the information now available on the migratory behavior of the Atlantic King Mackerel stock.

In fact the SEDAR 16 King Mackerel, Data Workshop - Life History work group presented a working hypothesis indicating that the "winter mixing zone" is actually restricted to south Florida instead of southeast Florida (see Figure 6.)

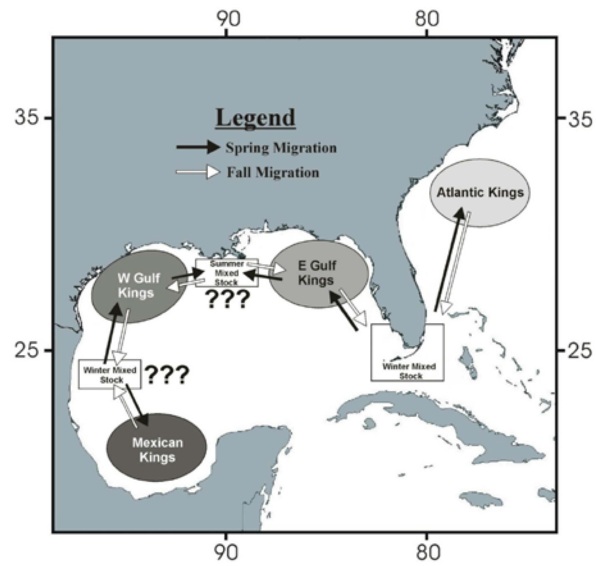

Figure 4.2. Hypothesized population structure and migratory pathways of king mackerel in U.S. waters and Mexican waters in the western and southern Gulf of Mexico. All migratory pathways have been documented with tagging data.

Figure 6. SEDAR 16 King Mackerel Data Workshop- Life History group's depiction of Atlantic and Gulf stock migratory behavior. Note reduced zone size of south Florida "winter mixed stock" from current regulatory map from Figure 2. (map from SEDAR 16 DW, LHG report- Fig.4.2)

Lastly, the table, below (Table 1.), summarizes the general meteorological conditions during each of the "mixing zone" studies described above. It is clear that resolution of long-term temperature regimes (extremes in meteorological conditions) need to be considered when characterizing south Atlantic versus GOM king mackerel stock utilization of the east Florida winter "mixing zone"

Table 1. Southeast Florida winter mixing zone studies of Atlantic versus Gulf of Mexico stock composition as a function of average winter (temperature) climate conditions.

Year	Study	Technique	SE FL Stock dynamic	Climate Conditions**
06-07	Patterson & Shepherd. 2008	Otolith stable Carbon & Oxygen isotopes	85% Atl. stock	Warm**
02-03	Patterson et al. 2004	Microchemistry	21-29% Atl. stock*	Cold***
	Clardy et al. 2008	Otolith shape	40-72% Atl. stock*	"
01-02	Patterson et al. 2004	Microchemistry	86 % Atl. stock	Warm**
	Clardy et al. 2008	Otolith shape	85 % Atl. stock	"
96-97	Devries et al. 2002	Otolith shape	99.8% Atl. stock	Cold***
89-90	Fable 1993	Tag and Recapture		
88-89	Fable 1993	Tag and Recapture		
77-78	FDEP, Sutter 1991	Tag and Recapture	29.4% Atl. stock	Cold***
76-77	FDEP, Sutter 1991	Tag and Recapture	"	Cold***
75-76	FDEP, Sutter 1991	Tag and Recapture	"	

* Winter 02-03' mixing zone king mackerel compared to summer 01-02' Gulf and South Atlantic king mackerel

** NOAA-NWS December and January monthly average air temperature for Melbourne & Vero Beach., FL. Warm denotes > 4° F over historical monthly average for December, January.

*** NOAA-NWS Top ten coldest December-February temperature average in historical record for Melbourne & Vero Beach., FL. Cold season averages were > 4° F below historical air temperature averages.

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