ATLANTIC BLUEFIN TUNA STOCK MIXING WITHIN THE U.S. NORTH CAROLINA RECREATIONAL FISHERY, 2011-2012

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SUMMARY

Membership to natal population, Mediterranean or Gulf of Mexico, was assigned for North Carolina and Virginia (US) Atlantic bluefin collected during winters 2011 and 2012, including members of the abundant 2003 year-class. Maximum likelihood estimates of the sample's mixture were based on otolith stable isotope composition, $\delta^{18}O$ and $\delta^{13}C$. This sample was discriminated with a new and more robust baseline of juvenile samples. For the 2003 year-class, the estimated contribution level by Gulf of Mexico members was 98.3% ± 3.6% SD. When all ages were included (3-17 years; CFL 117-285 cm; N=218), the contribution of the Gulf of Mexico population was estimated at 76.8% ± 4.9% SD. A previously analyzed sample of similar sized fish collected from US Fisheries during 1996-2002 showed a higher contribution from the Mediterranean population (54.3%±7.2%) in keeping with past reports. These revised results support the view that the 2003 year-class, evident in U.S. fisheries during the past 6 years, was mostly of western stock origin.

RÉSUMÉ

L'appartenance à une population natale, de la Méditerranée ou du golfe du Mexique, a été assignée aux thons rouges atlantiques de Caroline du Nord et de Virginie (États-Unis) prélevés pendant les hivers de 2011 et 2012, qui comprenaient des spécimens de l'abondante classe d'âges de 2003. Les estimations de la vraisemblance maximale du mélange de l'échantillon se sont basées sur la composition des otolithes en isotopes stables (O et C). Cet échantillon se différenciait par une nouvelle ligne de base plus solide d'échantillons de juvéniles. Pour la classe d'âge de 2003, le niveau de contribution estimé des membres du golfe du Mexique était de 98,3% ± 3,6% SD. Lorsque tous les âges étaient inclus (3-17 ans, CFL 117-285 cm, N=218), la contribution de la population du golfe du Mexique a été estimée à 76,8% ± 4,9% SD. Un échantillon analysé antérieurement de poissons de même taille prélevé dans le cadre des pêcheries des États-Unis entre 1996 et 2002 a fait apparaître une contribution plus importante de la population de la Méditerranée (54,3%±7,2%), à l'instar des rapports précédents. Ces résultats révisés appuient l'idée selon laquelle la classe d'âges de 2003, manifeste dans les pêcheries des États-Unis au cours des six dernières années, est majoritairement originaire du stock occidental.

RESUMEN

Se asignó la población natal, Mediterráneo o golfo de México, al atún rojo del Atlántico de Carolina del Norte y Virginia (Estados Unidos) muestreado en los inviernos de 2011 y 2012, lo que incluía miembros de la abundante clase anual de 2003. Las estimaciones de máxima verosimilitud de mezcla de la muestra se basaron en la composición de isotopos estables de otolitos $\delta^{18}O$ y $\delta^{13}C$. Esta muestra se diferenció de una nueva y más robusta línea de base de las muestras de juveniles. Para la clase de edad de 2003 la tasa de contribución estimada de miembros del golfo de México se situó en el 98,3% ± 3,6% SD. Cuando se incluyeron todas las edades (3-17 años; CFL 117-285 cm; N=218), se estimó que la contribución de la población del golfo de México se situaba en un 28,2% ± 4,6% SD. Una muestra previamente analizada de peces de tallas similares recogida en las pesquerías estadounidenses durante el periodo 1996-2002 mostraba una mayor contribución de la población del Mediterráneo (54,3%±7,2%), lo que coincide con informes anteriores. Estos resultados revisados respaldan la hipótesis de que la clase anual de 2003, evidente en las pesquerías de Estados Unidos durante los seis últimos años, está compuesta sobre todo por ejemplares de origen occidental.

KEYWORDS

Age composition, Otolith stable isotopes, Stock composition,Tuna fisheries, Thunnus thynnus

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1. Introduction

An apparent strong 2003 year-class in US recreational fisheries was observed as the annual progression of juvenile size classes over the recent six year period (SCRS 2010). Similar historical progressions of size modes were observed for the western stock by Mather *et al*. (1995) and were attributed to strong-year classes, occurring at c. decadal intervals. Still, it is not known with certainty from which population the 2003 year-class originated. Evidence from otolith stable isotope analysis indicated that during the past two decades many school and medium size class bluefin tuna (68-205 cm curved fork length, CFL) captured in US angler fisheries originated from the Mediterranean population (Rooker *et al*. 2008; Secor *et al*. 2012a).

Here, we present revisions to previously reported population contribution levels for Atlantic bluefin tuna sampled 2011-2012 from the North Carolina (NC) recreational fishery (Secor *et al*. 2012b). This revision was necessitated by the development of a new baseline. The new baseline comprised samples of yearling Atlantic bluefin tuna juveniles collected from the two principal nursery systems (US Atlantic shelf waters or Mediterranean) during the period 1998-2011 using the same milling procedure and analytical laboratory.

2. Methods

Fish otoliths (sagittae) were sampled during the NC recreational fishing season (January-April 2011,2012), from fish landed at ports in the outer banks region. In 2012, warmer temperatures off Cape Charles, Virginia caused an aggregation to be targeted by charter and sport fishers at Virginia Beach during January and 12 of the 218 fish included in this analysis were sampled there. For convenience, we reference the entire sample as the NC sample. We worked with harbor masters and fish cleaners to obtain access to tuna carcasses shortly after fish were landed. For comparison purposes, a subset of the data reported by Rooker *et al*. (2008) was included. These fish were collected as part of the Large Pelagic Biological Survey for the National Marine Fisheries Service (1996-2002) from US mid-Atlantic and New England waters. The size range, 100-200 cm CFL, was selected to allow comparison to the more recently collected sample.

Otoliths were cleaned of adhering tissue, briefly rinsed and stored dry. A single otolith (right or left) was embedded in plastic resin and a 2.0 mm thick section cut from the center containing the juvenile and surrounding portions of the otolith (see Schloesser *et al*. 2010 for additional details on otolith processing). The juvenile portion of the otolith, specifically the area circumscribed by the first annulus, was identified with the aid of a template from measured juvenile otolith sections, which served to increase the consistency with which the first year of life was sampled. Carbonate material was rastered from that region using a New Wave Micromill ©. Otoliths for young-of-the-year juveniles were ground into powder using an acid-washed mortar and pestle. Powdered carbonate samples were analyzed for $\delta^{18}O$ and $\delta^{13}C$ at the University of Arizona Environmental Isotope Laboratory. Analytical precision was estimated at ± 0.1‰ and ±0.06‰ respectively for $\delta^{18}O$ and $\delta^{13}C$ (Schloesser *et al*. 2010). Following the micromilling procedure, otolith section thickness was reduced to permit visualization of annuli for age determination. Images were taken with a digital camera paired with a dissecting microscope. Annuli were interpreted without reference to information on the specimen by a single experienced reader using Adobe Photoshop CS2 Version 9.0 to record images and annuli counts. Interpretation of age through direct counts of otolith annuli has been verified through bomb radiocarbon dating analysis (Nielson and Campana 2008). Precision was tested between two independent readers for the entire sample and was within two annuli.

For the NC sample, there was a slight but significant difference in stable isotopes between sampling years (ANCOVA, covariate=CFL; $\delta^{18}O$: $F = 6.47$, $p = 0.01$; $\delta^{13}C$: $F = 20.2$, $p = <0.001$). In 2012 mean $\delta^{13}C$ (-9.01) was depleted in comparison to 2011 (-8.76), whereas mean $\delta^{18}O$ was enriched (-1.10) in 2012 in comparison to 2011 (-1.21). Subsequent analysis of duplicate material of a sub-sample of the same processed otoliths from both years (N=42) indicated that this difference was not due to analytical error and was therefore attributed to an inter-annual difference.

Classification of the unknown mixture to source populations was performed using a maximum likelihood estimation (MLE) method (HISEA: Millar 1990a,b). This procedure fits the mixture distribution based on (1) the source population distributions and (2) possible mixing proportions in the unknown sample. The sample subset attributable to the 2003 year-class was tested. The entire NC sample was also examined. A separate sample was derived from previously analyzed otoliths (Rooker *et al*. 2008) comprising individuals of similar size as the NC sample (100-200 cm CFL), sampled from US fisheries for the period 1996-2002. Age was estimated from CFL for this sample (Restrepo *et al*. 2010).

3. Results

The NC sample ranged from age 3 to 17 years and exhibited modes attributable to the 2003 and 2006 year-classes (**Figure 1**). According to age estimates, the 2003 year-class was well represented in the NC sample (N=43: 20% of total sample).

The MLE estimate of Gulf of Mexico (GOMEX) population contribution level for the 2003 year-class was 98.3±3.6 SD% (**Table 1; Figure 2**). The GOMEX contribution to the entire NC sample was 76.8±4.9%. Compared to other year-classes, the 2003 year-class was distinct in otolith $\delta^{13}C$ and $\delta^{18}O$ (MANOVA, p=0.03, N=218) with more depleted $\delta^{18}O$ levels (**Figure 2**). The historical sample of fish, collected 1996-2002, exhibited a higher level of stock mixing with a lower GOMEX contribution level: 54.3 ±7.2%.

4. Discussion

The revised analysis support the premise that the 2003 year-class originated predominately from the Gulf of Mexico population. In contrast to the recent NC sample, US fisheries on school and medium size class fish sampled during 1996-2002 (estimated year-classes, 1987-1996) showed higher contributions by Mediterranean origin bluefin tuna, similar to those reported previously (Rooker *et al*. 2008). Higher contributions by the western population during the past decade to US fisheries could be the result of stronger recruitments by the Gulf of Mexico population. Age structure for the NC aggregation exhibited strong 2003 and 2006 year-classes. Further evaluation of how stock-specific recruitment and movement patterns influence stock mixing among principal bluefin tuna fisheries and aggregations will require integration of empirical estimates of mixing and other parameters into spatially explicit stock assessment models (Taylor *et al*. 2011; Kerr *et al*. 2012).

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Table 1. Natal population mixture levels for Atlantic bluefin tuna sampled in North Carolina and Virginia Beach during January-April, 2011-2012. Also included are population classifications for historical samples (year-classes 1987-1992) for fish of similar size to those for the recent NC sample (Rooker *et al*. 2008). MED=Mediterranean population; GOMEX=Gulf of Mexico population; MLE=maximum likelihood estimate of population composition; SD=standard deviation.

Year-classes	**Year(s) sampled**	**Location/Study**	**N**	**Population**	**MLE %**	**MLE SD**
2003	2011-2012	Virginia and North Carolina/ This study	43	MED GOMEX	1.6 98.3	3.6
1994-2009	2011-2012	Virginia and North Carolina/ This study	218	MED GOMEX	23.2 76.8	4.9
1987-1996	1996-2002	Mid-Atlantic, New England/ Rooker *et al*. 2008	95	MED GOMEX	45.7 54.3	7.2

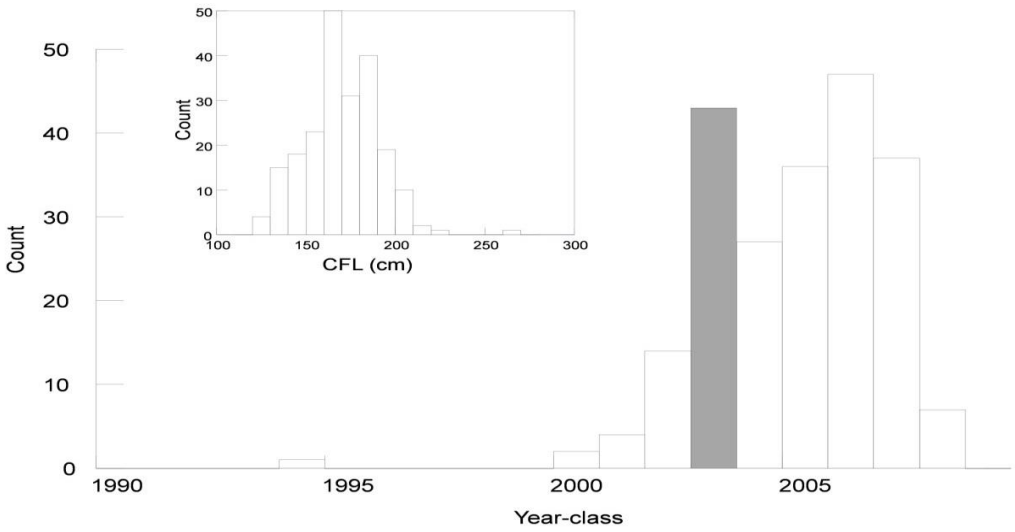

Figure 1. Estimated year-class frequency based upon age assignments for North Carolina and Virginia Beach (US) Atlantic bluefin tuna sampled during January-April 2011 and 2012. The gray-filled bar is the estimated 2003 year-class. Inset figure shows curved fork length (CFL) frequency histogram.

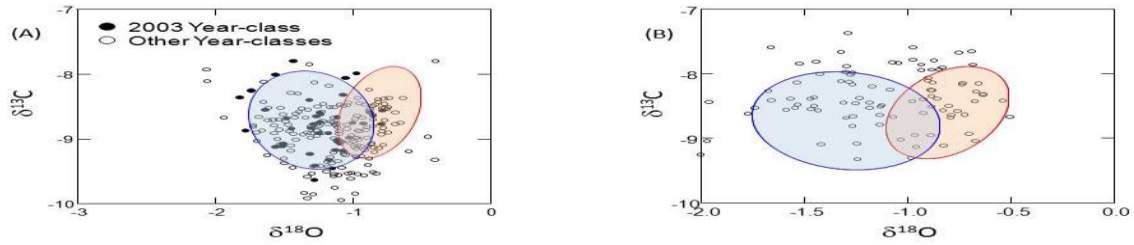

Figure 2. Stable isotope scatter plots for (A) the North Carolina Fishery sample (2011-2012), and (B) the US medium size class fishery (1996-2002). Sample ellipses (68%) from the new baseline are shaded (blue = GOMEX, red = MED).