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ORIGIN OF YELLOWFIN TUNA (*Thunnus albacares*) IN THE HAWAIIAN ISLANDS: PRELIMINARY ASSESSMENT OF NATAL SIGNATURES IN OTOLITHS

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Origin of yellowfin tuna (*Thunnus albacares*) in the Hawaiian Islands: preliminary assessment of natal signatures in otoliths

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Abstract

The purpose of this project is to examine the potential of using tuna hard parts as natural markers to refine our understanding of population structure of tropical tuna. Yellowfin tuna (*Thunnus albacares*) were selected for study as tagging data and recent studies suggest that the movement patterns of yellowfin may be highly variable and more restricted than other tunas. Hawaiian yellowfin provide a good test case as local spawning is well documented but immigration of yellowfin from other areas is likely. This study will provide information on the source(s) of yellowfin recruits (age-1 and age-2) to Hawaii-based surface fisheries through the analysis of natural tracers (stable isotopes) in otoliths. Our first step will be to develop a baseline that describes the chemical signatures in the otoliths of age-0 yellowfin from putative spawning and/or nursery areas in Hawaii and the broader WCPO. The isotopic composition of age-0 bigeye tuna (*T. obesus*) will also be analyzed to provide a comparison analysis of a species that contrary to yellowfin, is not known to spawn in Hawaiian waters. Preliminary data from age-0 yellowfin tuna indicate stable isotopic composition in otoliths of individuals from the Hawaiian Islands, an offshore seamount area, and the Equatorial Western and Central Pacific were significantly different (MANOVA $P < 0.01$). In general, otoliths of yellowfin from the Equatorial regions were depleted relative to areas in and around Hawaii, with intermediate values observed for individuals collected from an offshore seamount in the Hawaii EEZ. Cross validated classification success from quadratic discriminant function analysis was 88%, indicating the approach has promise for identifying yellowfin tuna from different spawning sites. After building our baseline data set to include likely nursery areas, otolith core material from age-1 and age-2 yellowfin tuna from the Hawaii-based fisheries will be compared to baseline data using mix-stock procedures. This will allow us for the first time to investigate the relative contribution of locally spawned versus transient yellowfin tuna to Hawaii-based fisheries.

Introduction

Refining our understanding of population structure and varying degrees of stock mixing is critical to the effective management of WCPO tuna stocks. This may be particularly critical for yellowfin tuna (*Thunnus albacares*) whose movement patterns may be more restricted in comparison to other species. Recent stock assessments indicate that the WCPO yellowfin tuna fishery is fully exploited with a high probability that overfishing is occurring. On a sub-regional scale, Hawaii-based fishers claim a greatly reduced local abundance of yellowfin tuna of all size classes over time. Currently, the origin of yellowfin tuna in Hawaiian waters remains unknown although local spawning is well documented. A better understanding of the origin of recruits to Hawaii-based fisheries is needed to effectively manage the resource. Resolving these issues of semi-residency and local recruitment of versus mixing of yellowfin is also of great interest to the Pacific island

countries and territories of the broader WCPO which will require corroborative data from a variety of approaches, including otolith chemistry, genetics, and tagging.

Otolith chemistry is a promising approach for determining contribution rates of yellowfin tuna recruits from different spawning sites and nurseries in the WCPO because material deposited in the otolith during the first year of life serves as a birth certificate that identifies an individual's area of origin. Previous studies have demonstrated the utility of otoliths to determine the origin of highly migratory species, including tunas in the Pacific Ocean (Gunn and Ward 1994; Rooker et al. 2001). The aim of the proposed work is therefore to characterize the origin of age-0 yellowfin tuna in the Hawaiian Islands and surrounding WCPO using natural tracers, and here we present preliminary data on the signatures of yellowfin tuna from three putative nurseries. Assuming ambient conditions in regional nurseries are distinct, we plan to use the approach to determine source(s) and contribution rates of yellowfin tuna recruits to Hawaii-based fisheries.

Materials and Methods

Age-0 yellowfin tuna otoliths were collected and analyzed from three nursery areas in the WCPO: 1) Hawaiian Islands (Inshore FADs), 2) Cross Seamounts, 3) Western Equatorial Pacific (Moro Gulf Philippines). Collections were taken in 2007-2008 and either obtained by hook-and-line research cruises or provided by purse seine fisheries. Within each nursery area, sub-samples from multiple collection dates and locations were taken to ensure that signatures were representative of each nursery and not affected by a single school of fish. Specifically, Hawaiian Island sub-samples were obtained from four different collection dates and four inshore FADs in nearshore waters of Oahu (n=20) and a single collection from an inshore FAD located inshore of Kauai (n=7). Collections off the Cross Seamounts (n=12), located approximately 240 km south of Oahu, were from one collection date, while sub-samples from the Western Equatorial Pacific (n=20) were obtained from two locations collected over three sampling dates.

Stable isotopes of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in the otolith cores of age-0 yellowfin tuna were used to represent each nursery. Whole otoliths were first soaked in doubly deionized water ($DDIH_2O$), moved to a 3% hydrogen peroxide solution for 5 min to eliminate any biological residue, and then transferred into a new $DDIH_2O$ bath for 5 min to remove surface residues. One sagittal otolith was embedded in Stuers epoxy resin and sectioned using a low speed ISOMET saw to obtain 1.5 mm transverse sections that included the core. Following attachment to a MicroMill sample plate, the portion of the otolith (core region) corresponding to an age of 3 months was removed from the otolith section using a NewWave ©MicroMill System. Powdered core material was then analyzed for $\delta^{13}C$ and $\delta^{18}O$ on a Finnegan Mat Delta Plus Stable Isotope Mass Spectrometer maintained at the University of Arizona's Environmental Isotope Laboratory. Stable $\delta^{13}C$ and $\delta^{18}O$ isotopes are reported relative to the PeeDee belemnite (PDB) scale after comparison to an in-house laboratory standard calibrated to PDB.

Multivariate analysis of variance (MANOVA) was used to test for differences in $\delta^{13}C$ and $\delta^{18}O$ of otolith cores of age-0 yellowfin tuna among nursery areas. Pillai's trace statistic was used to test for significance. Univariate tests for both $\delta^{13}C$ and $\delta^{18}O$ were then analyzed using analysis of variance (ANOVA) models. Quadratic discriminant function analysis (QDFA) was used to evaluate the accuracy of individual age-0 yellowfin tuna to their respective nursery area. Classification success reported here was based on a jackknifed approach. QDFA does not have

the homogeneity of covariance matrices assumption and is robust to moderate deviations from normality (McGarigal et al. 2000). Statistical significance was determined at the alpha level of 0.05.

Results and discussion

Multivariate analysis of variance indicated a significant difference in stable isotopes of otolith cores of age-0 yellowfin tuna from the three nursery areas (Pillai's trace=2.98; P=0.02). Univariate tests for both $\delta^{13}C$ and $\delta^{18}O$ indicated significant differences among nursery areas ($\delta^{13}C$ ANOVA; F=27.35; P<0.01; $\delta^{18}O$ ANOVA; F=95.74; P<0.01). Specifically, age-0 yellowfin tuna collected from Hawaiian Islands had enriched $\delta^{13}C$ and $\delta^{18}O$ values relative to conspecifics from the Western Equatorial nursery area (Figure 1) (Tukey HSD; P<0.01). Fish collected from the Cross Seamounts showed intermediate values in both $\delta^{13}C$ and $\delta^{18}O$ relative to the Western Equatorial and Hawaiian Island nursery areas (Figure 1), but $\delta^{13}C$ values were not significantly different than Hawaiian Islands (Tukey HSD; P<0.05). Results of QDFA indicated that overall classification success to nurseries was relatively high at 86%. Preliminary results suggest $\delta^{13}C$ and $\delta^{18}O$ are promising markers to discriminate age-0 yellowfin tuna from nursery areas in the Pacific Ocean. Future efforts will be devoted toward building our baseline data set to include additional nursery areas, and using this baseline to predict the origin of age-1 and age-2 yellowfin tuna from the Hawaii-based fisheries.

Future work

To date, otoliths have also been collected from age-0 yellowfin tuna from the Solomon Islands, the Marshall Islands, Mexico, Palmyra Atoll and the Line Islands of Kiribati. In addition, age-0 bigeye tuna have been collected from the Hawaiian Islands (inshore FADs), the Cross Seamount and the Line Islands of Kiribati. Samples from Mexico, the Solomon Islands and Marshall Islands are clearly outliers and based on conventional tagging data are not likely points of recruitment to Hawaii. However, their analysis will provide information to assess the potential of using isotopic signatures to define rates of movement for yellowfin tuna. The analysis of yellowfin and bigeye tuna samples taken directly south of Hawaii will be particularly interesting and are more relevant to examining contribution rates and origin of Hawaiian yellowfin tuna and bigeye tuna. These analyses will continue during Y-1 into Y-2 of the project.

Commencing in Y-2 of the project, Age-1 and Age-2 yellowfin otoliths will be collected from Hawaiian Island fisheries. Otolith core material from these samples will then be compared to our Y-0 baseline data using mix-stock procedures to investigate the relative contribution of locally spawned versus transient yellowfin tuna to Hawaii-based fisheries.

Literature Cited

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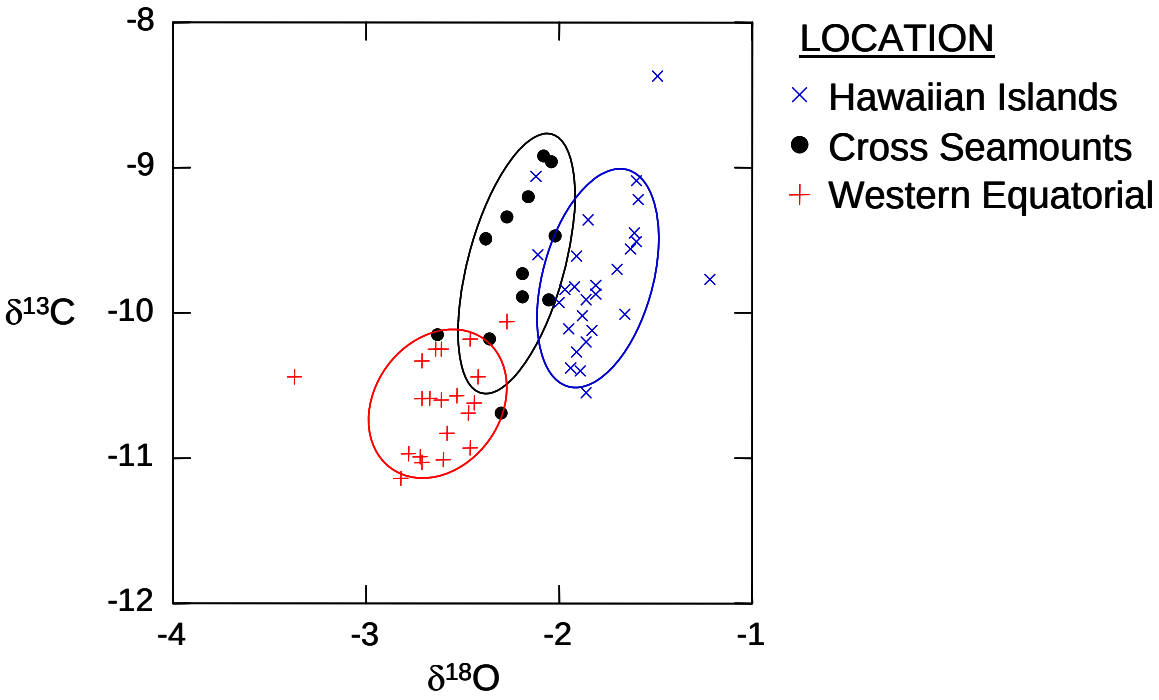

Figure 1. Biplot of age-0 yellowfin tuna collected from Hawaiian Islands, Cross Seamounts, and Western Equatorial nursery areas. Plots are based on $\delta^{13}C$ and $\delta^{18}O$ stable isotopes in otolith cores and ellipses represent 1 standard deviation around the mean.