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ScienceDirect
Fisheries Research 90 (2008) 147–157
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Evidence for fine geographical scale heterogeneity in gene frequencies in yellowfin tuna (*Thunnus albacares*) from the north Indian Ocean around Sri Lanka

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Received 30 May 2007; received in revised form 30 September 2007; accepted 12 October 2007

Abstract

Yellowfin tuna are currently considered by the member nations of the Indian Ocean Tuna Commission to constitute a single stock in the Indian Ocean due to a lack of knowledge about yellowfin tuna population structure in this region. Previous studies of Indian Ocean yellowfin tuna based on morphology and fisheries data have hinted at the presence of multiple stocks in the region, and further, that stocks may mix in the north western Indian Ocean around Sri Lanka. To better understand the genetic stock structure of yellowfin tuna in the north western Indian Ocean, we examined genetic variation in 285 yellowfin individuals collected over a period of 4 years from six fishing grounds around Sri Lanka and a single fishing ground in the Maldive Islands. We screened variation in both the mitochondrial ATP*ase* 6 and 8 region (498 bp) and three microsatellite loci. Significant genetic differentiation was detected among sites for mitochondrial DNA ($\Phi_{ST} = 0.1285$, $P < 0.001$) and at two microsatellite loci ($F_{ST} = 0.0164$, $P < 0.001$ and $F_{ST} = 0.0064$, $P < 0.001$), while spatial analysis of molecular variance of mtDNA data identified three genetically heterogenous groups namely; western, south eastern and all remaining sites. These results suggest the possibility that genetically discrete yellowfin tuna populations may be present in the north western Indian Ocean.

Keywords: ATP*ase*; Indian Ocean; Microsatellites; Population structure; *Thunnus albacares*; Yellowfin tuna

1. Introduction

Yellowfin tuna (YFT) constitute the second largest tuna fishery worldwide (FIGIS, 2006). Among the principal market tuna fisheries, YFT were responsible for a global catch of 1.5 million metric tonnes (mt) in 2006 (FIGIS, 2006), which represents 32% of all tuna fished commercially that year. In the Indian Ocean, YFT also represent the second largest tuna catch comprising 25% of the total catch there (IOTC, 2006). As a result of expansion of an industrial fishery equipped with purse seine nets, the Indian Ocean YFT catch has increased more than seven fold from 66,200 mt in 1982 to 506,900 mt by 2004 (IOTC, 2006). The Indian Ocean Tuna Commission expressed alarm in a recent report at the increasing rate of the YFT catch in the region which it considered well above the maximum sustainable yield (IOTC, 2006). Moreover, unlike industrial YFT fisheries in the Atlantic and Pacific Oceans, the Indian Ocean tuna fishery provides a very important resource for developing coastal nations and constitutes the major food protein source for very large populations in the region. Depletion of Indian Ocean YFT stocks could compromise food security in a number of developing nations in the Indian Ocean. In Sri Lanka, the YFT fishery comprises 32% of the tuna fishery and provides the major animal protein source for an island population of 20 million. Currently Sri Lanka produces approximately 30,000 mt of YFT from its EEZ (IOTC, 2007), and a collapse of YFT stocks in the region may compromise food security there, and also an important export industry.

Currently, YFT in the Indian Ocean are considered to constitute a single stock (IOTC, 2006) but this recognition is based on only limited knowledge and scientific assessment of YFT population structure. Some recent analyses of fisheries data from the Indian Ocean have suggested however, the presence of more than a single stock in the region (IOTC, 2006). The majority of YFT stock assessment studies to date, have been undertaken in the Pacific and Atlantic Oceans, while Indian Ocean stocks have yet

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doi:10.1016/j.fishres.2007.10.006

to be studied in any detail. Early genetic studies that attempted to delineate stocks in the Pacific and Atlantic Oceans using allozymes and mitochondrial DNA (mtDNA) RFLP markers, did not recognise any inter- or intra-oceanic population structuring (e.g. Sharp, 1978; Ward et al., 1994; Scoles and Graves, 1993). Recently, genetic studies of Indian Ocean YFT attempted to detect population differentiation between collections of 40 individuals taken from sites in the far eastern and far western Indian Oceans using mtDNA (Chow et al., 2000) and nDNA (Nishida et al., 2001) markers but reported no evidence of significant differentiation. This may have resulted however, from a lack of sensitivity in the molecular markers employed and the lack of statistical power provided by the relatively small sample sizes examined.

A global genetic study of YFT in the Atlantic, Indian and Pacific Oceans that screened both allozyme and mtDNA RFLP markers by Ward et al. (1997) argued for existence of at least four discrete stocks in the three major oceans identified as; Atlantic, Indian, west-central Pacific and east Pacific. Use of genetic markers with high resolution (e.g. mtDNA sequencing, nuclear DNA microsatellites) and larger sample sizes, has meant that some genetic studies on tuna species were able to detect significant population differentiation even within ocean basins. A study of YFT from eight sites in the western Pacific using microsatellite markers identified very low, but significant differentiation (Appleyard et al., 2001). While a very recent study of YFT in the Atlantic and Pacific Oceans employed RFLP markers to show low genetic differentiation between the Atlantic and Pacific populations while no genetic differentiation was evident within oceans (Ely et al., 2005).

In the Indian Ocean, most YFT stock delineation studies that have been conducted to date, have been based on morphometry/fish length data or weight frequency data only and have produced inconsistent results. Kurogane and Hiyama (1958) suggested that three stocks were present, identified as western and two eastern, while Morita and Koto (1970) suggested two stocks were present that they referred to as ‘eastern’ and ‘western’ based on morphometric data. Nishida (1992) used industrial long line fishery data from across the Indian Ocean to suggest that eastern and western stocks were limited by 40–90°E and 70–130°E, respectively. In addition, he recognised two minor stocks ‘far eastern’ and ‘far western’. Interestingly, this report also suggested that the major eastern and western stocks in the Indian Ocean may mix around Sri Lanka.

Reliable and informative data on YFT population structure will be essential to allow development of better management strategies for the species in the Indian Ocean and will help to conserve wild stocks in the future. While non-genetic methods can only infer different fish breeding units, a population genetics approach can directly test the hypothesis that genetically different breeding units may exist (e.g. Ward, 2000). Lack of detailed population genetic studies on Indian Ocean YFT stocks has constrained development of scientific management strategies for the species, and so the IOTC currently manages Indian Ocean YFT as a single stock.

Although YFT are generally considered to be highly migratory fish, recent tagging studies have shown that they can show limited dispersal and often remain close to their natal waters (e.g. Yesaki and Waheed, 1992; Schaefer and Fuller, 2006). If this observation were broadly true, it could result in fine geographical scale genetic heterogeneity. Studies that have reported evidence for fine geographical scale population structure in some otherwise pelagic marine fish have increased recently (e.g. Atlantic cod: Ruzzante et al., 1998; Knutsen et al., 2003, and Atlantic bluefin tuna: Carlsson et al., 2004).

Given this background, here we examined the extent of genetic differentiation among YFT populations collected between 2001 and 2004 in waters of the north western Indian Ocean around Sri Lanka and the Maldive Islands using mtDNA markers and three microsatellite loci. The objective was to test for genetic differentiation among major fishing grounds around Sri Lanka to evaluate whether YFT catches in this region could represent heterogeneous stocks.

2. Materials and methods

2.1. Sampling

YFT samples were collected from commercial fishing operations from six sites around Sri Lanka and a single site in the Maldive Islands (Fig. 1). Sampling sites were selected to represent major fishing grounds in Sri Lankan waters, and a single collection was included from the Maldive Islands as an outgroup to compare the levels of genetic diversity of YFT populations from two geographically remote regions. Samples were collected between 2001 and 2004, with muscle tissue collected for approximately 50 individuals per site (Table 1). Individuals varied in length from 55 cm to 70 cm at all sites except for the KK and KR sites where individuals were generally larger (mean length of 138 cm and 90 cm, respectively). Muscle tissue samples were removed from fish and stored in 95% ethanol for later genetic analyses.

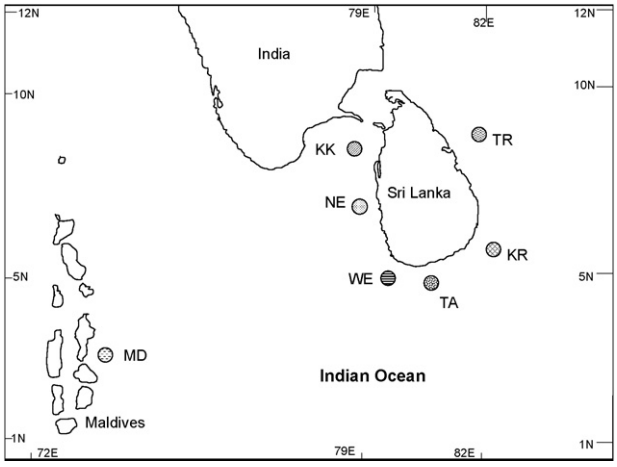

Fig. 1. Sampling sites of YFT in the north western Indian Ocean.