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SCIENCE DIRECT
Fisheries Research 77 (2006) 138–147
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Application of elliptical Fourier analysis of otolith form as a tool for stock identification

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Received 31 May 2005; received in revised form 23 August 2005; accepted 12 October 2005

Abstract

Geometric morphometrics is a relatively new tool to fisheries research showing promise as a means of enabling researchers to cheaply and quickly categorise fish to individual stocks based on variations in otolith form, most commonly size and shape. In this study we introduce the method of elliptical Fourier analysis using two widely separated populations of striped trumpeter (*Latris lineata*) as a case study and compare the interpretation of results based on both unconstrained and constrained ordination techniques. There were no significant differences in otolith morphometrics between sex or age classes within each region. All form descriptors were standardised for fish length, thereby minimising confounding effects on any potential inter-regional otolith form differences. Non-metric multidimensional scaling was not sufficient to elucidate differences in otolith form between populations. However, using constrained canonical analysis of principal coordinates and canonical discriminant analysis, regional differences became evident with allocation success of 75 and 87%, respectively. Based on this study differences in otolith form reflect that the two tested striped trumpeter populations have reasonable phenotypic anonymity. This study further supports the usefulness of shape analysis and constrained non-parametric statistical tests as tools for stock discrimination and introduces elliptical Fourier analysis to the study of otolith morphometrics.

Keywords: *Latris lineata*; Stock structure; Elliptical Fourier Function; Constrained ordination methods; Age; Growth

1. Introduction

Stock identification is an integral component of modern fisheries stock assessment (Begg et al., 1999) and also for understanding the population dynamics of a species in an ecological sense. There are many techniques appropriate for studying stock structure (for review see: Ihssen et al., 1981; Begg and Waldman, 1999). Geometric morphometrics is one such technique. It is a robust tool for analysing both physiological and morphological form, and has been used to discriminate between unique fish stocks or populations (Adams et al., 2004).

Form, defined as a model composed of various attributes of an object, is an aspect of fundamental importance in morphological investigations (Chen et al., 2000). Within ichthyology a range of form components; for example, size, colour, shape, and patterning, are used to identify and classify individuals into particular groups (Ihssen et al., 1981; Adams et al., 2004). Otoliths contain characteristics that are stock specific (Ihssen et al., 1981) and are regarded as an ideal subject for morphometric analysis due to their species specificity and limited extent of individual variability in growth, relative to variability in somatic growth (Campana and Casselman, 1993).

Several methods have been used to describe and compare form in morphological studies including ratios of linear dimensions, biorthogonal grids, Euclidean distance matrix analysis, thin plate splines, Eigen shape analysis, and several variations of Fourier analysis (Chen et al., 2000). Elliptical Fourier functions represent a precise method for describing and characterizing outlines, efficiently capturing outline information in a quantifiable manner (Kuhl and Giardina, 1982; Lestrel, 1997). The method does not require equal intervals along the outline and therefore can accommodate

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doi:10.1016/j.fishres.2005.10.013

significantly more complex shapes than polar Fourier functions, the approach that has traditionally been used in stock discrimination studies based on fish otoliths (Bird et al., 1986; Castonguay et al., 1991; Campana and Casselman, 1993; Torres et al., 2000). Polar Fourier functions are constrained to a series of radii originating from a barycentre of the study specimen, each radius can only intersect the perimeter once. In the case of otoliths that are particularly convoluted, or where the rostrum has significant curvature it would be possible for radii to intersect the perimeter at more than one point. Elliptical Fourier functions alleviate this problem by not relying on a radiating centroid, instead generating harmonics by calculating x and y co-ordinates as a function of a third variable (t).

In this paper we compare otolith form and somatic growth in two widely separated striped trumpeter (*Latris lineata*) populations. The study species has a broad geographic distribution, occurring around the temperate latitudes of southern Australia, New Zealand (Last et al., 1983), including the sub-Antarctic Auckland Island (Kingsford et al., 1989), the Gough and Tristan Da Cunha Island groups in the southern Atlantic Ocean (Andrew et al., 1995), the Amsterdam and St. Paul Island groups in the southern Indian Ocean (Duhamel, 1989) and the Foundation seamount in the southern Pacific Ocean (Roberts, 2003). Samples of fish from Tasmania, Australia, and the St. Paul/Amsterdam Island regions were examined and compared and we demonstrate the advantages of using elliptical Fourier analysis and constrained ordination techniques to assess differences in otolith morphology.

2. Materials and methods

2.1. Sampling and otolith collection

Latris lineata from the east coast of Tasmania (TAS: 40°36′S, 148°47′E) were sampled between the years 2000 and 2003 (n = 199). Two collections were also made from the St. Paul and Amsterdam Islands (SPA: 37°50′S, 77°30′E), one collected between December 2001 and January 2002 (n = 206) and the second during April 2003 (n = 200) (Fig. 1). All fish were caught using line-fishing methods from depths greater than 90 m and were either examined fresh or frozen prior to processing. Fork length (mm) and sex were recorded from each individual, and the sagittal otoliths (herein referred to as otoliths) were removed. Otoliths were cleaned, air-dried and stored in individually labelled vials.

2.2. Age and growth

Individuals were aged by interpreting the increment development on transverse sections of their respective otolith (Tracey and Lyle, 2005). All counts and increment measurements were made without knowledge of fish size, sex or date at capture.

Validation of first increment and annual periodicity of subsequent increment deposition for *Latris lineata* from TAS has been shown by Tracey and Lyle (2005). In this study it was assumed that the incremental structure was analogous for individuals sampled from SPA. A random sub sample of 335 otoliths was read a second time by the primary reader, and a sub sample of 50 otoliths by a second reader experienced in otolith interpretation. The precision of repeated reads was assessed by determining percentage agreement between repeated reads and calculation of the average percent error (Beamish and Fournier, 1981).

A re-parameterised version of the von Bertalanffy growth function (VBGF) was fitted to the length-at-age data (Francis, 1988), using least squares regression:

$$L_t = l_\tau + \frac{(l_\nu - l_\tau)(1 - r^{2(t-\tau)/\nu-\tau})}{1 - r^2}$$

where

$$r = \frac{l_\nu - l_\omega}{l_\omega - l_\tau}$$

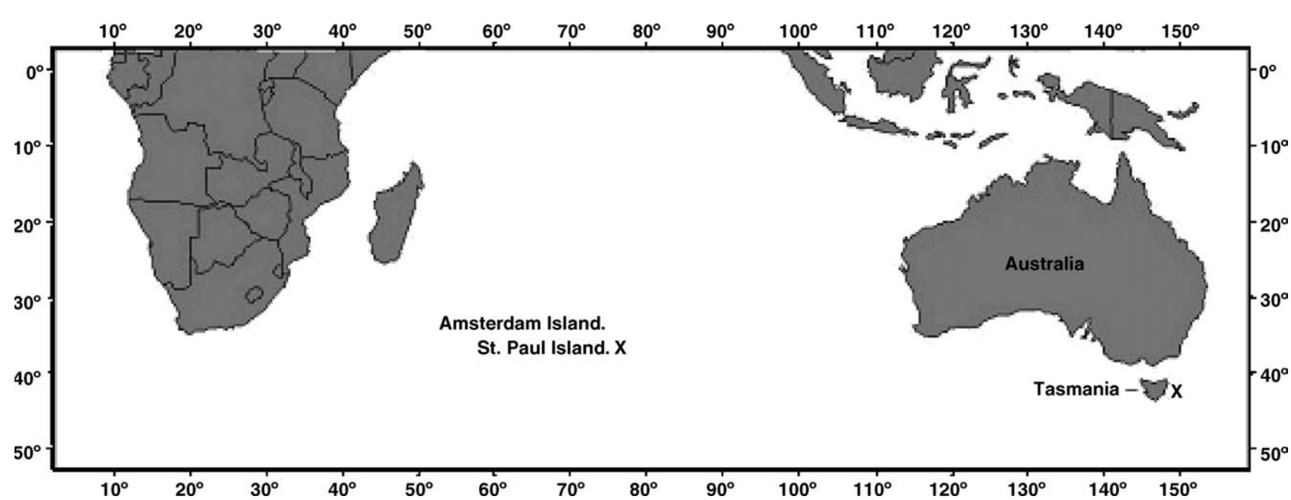

Fig. 1. Map of the Indian Ocean and bordering continents, sampling locations depicted by (×).