



# **CONDITION 4**

## **Summary and Synthesis Report**

**Stock discrimination  
research overview for  
Patagonian toothfish in the  
Falkland Islands**

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**Directorate of  
Natural Resources  
*Fisheries***



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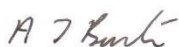
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## PURPOSE OF THIS DOCUMENT

This document serves to provide an update on the progress made with regards to the current projects being undertaken by the Falkland Islands Fisheries Department (FIDF) on Patagonian toothfish stock discrimination in the Southwest Atlantic as a component of the voluntary Condition 4. Each project is discussed individually and a synthesis of their results to date is presented at the end. These projects were chosen based on the recommendations of Parker (2015).

## PROJECT TITLES, STATUS AND REPORTS

1. Use of otolith shape to inform stock structure in Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in the Southwest Atlantic  
Status: COMPLETED  
Output: *Lee et al. Toothfish Shape Analysis* (accepted for publication in *Marine and Freshwater Research*)
2. Otolith trace elemental analyses of Patagonian toothfish (*Dissostichus eleginoides*) using ID-ICPMS  
Status: ONGOING  
Expected Output: *Toothfish otolith microchemistry report*
3. Variations in morphology of adult Patagonian toothfish (*Dissostichus eleginoides*) as a means of stock identification  
Status: ONGOING  
Expected Output: *Toothfish morphometry report*
4. Utility of otolith growth histories in understanding the stock structure of Patagonian toothfish (*Dissostichus eleginoides*) in the Falkland Islands  
Status: INCORPORATED INTO LONG-TERM PH.D. PROJECT  
Expected Output: *Dissertation Chapter on toothfish demographics*
5. Tag-recapture study using conventional and satellite tags to examine movement of Patagonian toothfish (*Dissostichus eleginoides*) in the FICZ/FOCZ  
Status: ONGOING  
Expected Output: *Toothfish tag-recapture report*

## PROGRESS TO DATE

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**Project 1:** Use of otolith shape to inform stock structure in Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in the Southwest Atlantic → *Lee et al. Toothfish Shape Analysis*

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### 1.1. Overview

Notothenioids of the genus *Dissostichus* display complex life-history characteristics, supporting the potential for high levels of connectivity through the widespread dispersal of eggs and juveniles across their distribution. The delineation and connectivity between regional and within localised adult population groupings is not well understood. An analysis of patterns in otolith shape was investigated for geographic variability in the southwest Atlantic.

### 1.2. Current status

The manuscript entitled “Use of otolith shape to inform stock structure in Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in the Southwest Atlantic”, has been accepted for publication as an original research paper in *Marine and Freshwater Research*.

### 1.3. Time frame

The paper will be publically available once it is officially published with the next 2 – 3 months.

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**Project 2:** Otolith trace elemental analyses of Patagonian toothfish (*Dissostichus eleginoides*) using ID-ICPMS → *Otolith microchemistry prelim report*

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### **2.1. Overview**

Regional otolith microchemistry was extensively characterised by Ashford (2005, 2006, 2007, 2012). However, the aim of this study is to examine the stock structure of Patagonian toothfish, utilising a time-series approach based on examining the elemental signals in the nucleus and the edges of otoliths from individual cohorts of juvenile toothfish (1 – 6 years old) on the Falkland Islands shelf. The elemental signatures from the otolith edge provide information on the environment experienced by the fish prior to capture, whereas the otolith core represent the larval and early pelagic juvenile life stages and may contain information on spatial segregation during early life stages and patterns in recruitment linked to variable oceanographic conditions among years.

### **2.2. Current status**

Total catch and biological data for Patagonian toothfish has been collected by Scientific Fisheries Observers stationed onboard commercial trawlers operating over the shelf region of the Falkland Islands over a ten year time period (2006 – 2015). Otolith samples from fish <70 cm TL were collected, processed and aged following the methodology described in the attached 2014 Age structure report, however coverslips were not mounted onto sectioned otoliths. For each sample year, 150 otoliths from fish between 1 – 6 years old (+/- 25 fish per year class) were chosen for trace element analysis. Minor and trace element signatures were examined (by Laser ablation ICP-MS) at the Centre for Trace Element Analysis housed in the Department of Chemistry, University of Otago (Dunedin, New Zealand).

The interpretation of data so far (see the *Otolith microchemistry report*) has been challenging, but it is hypothesised that there are two groups from the same spawning grounds, but having established in different nursery grounds. However, further work was necessary and subsequently undertaken to address this. This work is currently underway and is summarised below.

### **2.3. Further work**

Future analyses of the data set will include:

1. Assessing whether sex, age, maturity, size, location and year affect the concentration of the different elements.
2. Assessing whether the patterns of clustering/groupings of populations differ between years, and examine what may be driving these temporal differences.
3. Compare the microchemistry between the otolith core (already measured) and otolith edge (samples being run now). It is hypothesized that fish migrating the least distance will remain in waters with similar chemical characteristics, and therefore will reveal little change between otolith core and edge microchemistry.
4. Compare otolith edge microchemistry on small toothfish in shallow waters with changed in sea surface temperature to reconstruct the environment in which individuals have originated.
5. Assess the degree of accuracy in predicting the classification of different otoliths based on the microchemistry and biological to different clusters.

#### **2.4. Time frame**

A revised summary of this work will be converted to a manuscript for publication in 2018.

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**Project 3:** Variations in morphology of adult Patagonian toothfish (*Dissostichus eleginoides*) as a means of stock identification → *Toothfish morphometry prelim report*

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### **3.1. Overview**

This project is being used to develop morphometric ratios for Patagonian toothfish head and body shape. The aims are 1) to find possible morphological and morphometric characters that differentiate two populations of toothfish that inhabit waters below and above the Polar Front, and to find if various commercial stocks of toothfish in the southern part of South America represent an interbreeding population; and 2) to confirm possible morphological and morphometric differences by genetic analysis of samples taken from the same fish. In addition, the results will allow for the reconstruction and estimation of toothfish size and shape measurements when only a few measurements are known. This is particularly relevant with reference to the estimation of the sizes of toothfish that have been depredated by marine mammals in the longline fishery.

### **3.2. Current status**

Patagonian toothfish samples from four areas have been collected and analysed to date: Chile, South Georgia, South Sandwich Islands, and Falkland Islands. No significant morphometric differences have been found between the four areas. There are some morphological differences in lateral line shape and gill raker teeth that have been qualitatively described. Genetic results seem to support these qualitative differences, with South Georgia and South Sandwich Islands toothfish having distinct COI and control region genes from Falkland Islands and Chile toothfish.

### **3.3. Further work**

Whole genome genomics will now be run on toothfish from the Falkland Islands and South Georgia to determine whether the preliminary genetics results are a sign of incipient or recent speciation.

### **3.4. Time frame**

Results from the genomic study should be obtained in mid-2018, after which the final report will be written. If results are conclusive, a peer-reviewed publication will be produced.

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**Project 4:** Utility of otolith growth histories in understanding the stock structure of Patagonian toothfish (*Dissostichus eleginoides*) in the Falkland Islands → *Toothfish demographics prelim report*

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#### **4.1. Overview**

Life history traits, such as growth variability may express underlying stock structure through their linkage to genetics, demographics and the environment. Biological and catch data collected along the continental shelf of the Falkland Islands indicates that annual recruitment and the regional growth of individuals is highly variable. However, the environmental and ecological mechanisms driving variability in growth and recruitment are poorly understood.

The aim of this study is to examine the use of growth variability to inform stock identification of Patagonian toothfish in the Falkland Islands. The specific objectives of the research are to examine (1) individual growth trajectories, (2) hatch-date distributions and (3) age-length data on a temporal and spatial basis and further inspect variability in the results in relation to population densities and a range of environmental variables (temperature, dissolved oxygen, primary productivity etc).

An additional aspect that is to be looked at in this project is the use of otoliths biochronologies to assess how growth variability is influenced by interacting intrinsic (individual variability, age, sex, cohort) and extrinsic (time, temperature, fishery activity, spatial structure) components (Thresher et al., 2007). The radial growth rates of otoliths typically correlate highly and linearly with somatic growth rates of fish. As such, the width of each annual ring indicates individual growth for that year. This property of otoliths allows for the reconstruction of individual growth histories in fish thereby allowing for the assessment of changes in fish size and growth rates on a historical basis. These methods are clearest for the inner portions of otoliths, corresponding to the juvenile and young adult life history stages. This information, encoded in annual variation in increment widths among and between individuals, is a potentially powerful means of extracting detailed information on temporal and spatial effects on fish ecology and the factors that affect their populations.



#### **4.2. Current status**

This project now forms a component of a PhD study being undertaken on Patagonian toothfish stock structure in the Falkland Islands which was initiated in January 2017. To date, the work has been specifically related to project planning, data consolidation and the processing of samples in the laboratory for future analyses.

The FIFD has been undertaking its own ageing on Patagonian toothfish throughout the FOCZ since 2002. In addition, full biological sampling including length, weight, sex and maturity has been collected since 1994. As such historical biological and age data have been collected and processed following the same methodology from throughout the FICZ and FOCZ since 2002. Four regions have been included in project planning to date: the eastern FOCZ, northern FOCZ, southern FOCZ or Burdwood Bank and shallow water FICZ. These initial data explorations have included length and age frequency distributions, a comparison of length-weight regressions as well as area specific von Bertalanffy growth functions.

Otolith images have been captured for individuals from the 2013 and 2014 age samples. The program ImageJ has been used to start recording measurements of individual increments and radii of otoliths.

#### **4.3. Further work**

The next phase of the project will be to undertake more detailed analyses and statistical comparisons between life-history parameters among regions. This will include depth-standardised comparisons in size and age structures.

Following this, individual fish growth rates based on otolith biochronologies are to be assessed and possible links to intrinsic and extrinsic factors analysed.

#### **4.4. Time frame**

This project has been allocated as high priority for the toothfish scientist to whose PhD this work will contribute. Data analyses and preliminary results for the demographic comparison will be prepared in 2018. The additional aspect looking at otolith biochronologies is more data intensive and long-term. Preliminary results are likely to be available by the end of 2018.

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**Project 5:** Tag-recapture study using conventional and satellite tags to examine movement of Patagonian toothfish (*Dissostichus eleginoides*) in the FICZ/FOCZ  
➔ *Toothfish tag-recapture prelim report*

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### **5.1. Overview**

In June 2016, a pulsed-tagging programme for Patagonian toothfish (*Dissostichus eleginoides*) within the FICZ/FOCZ was initiated with an aim to tag 3000 toothfish by May 2019. In addition, 5 pop-up satellite archival transmitting (PSAT) tags were acquired to deploy on toothfish in June 2017. Due to the size of the PSAT tags, this aspect would focus specifically on short term (<6 months) movement patterns of large adult toothfish, to investigate the hypothesis that toothfish migrate from their feeding grounds all around the Falkland Islands to the spawning grounds around the Burdwood Bank. As well as investigating movement in a horizontal plane, depth and temperature data from the tags will be examined to investigate vertical movements and to gain a greater insight into the daily behaviours of toothfish in their natural environment.

Specific objectives to the project would include, but not be limited to:

- Analyse movement patterns of adult fish within the FOCZ
- Establish linkages between adults on the slope to the North, East and South of the FOCZ to the spawning grounds on the Burdwood Bank.
- Provide evidence for the stock structure of toothfish in the Falkland Islands

Additional benefits arising from a mark-recapture study would include the validation of growth estimates and the potential for the validation of abundance estimates.

### **5.2. Current status**

Over 400 toothfish were tagged and released during the initial pulsed-tagging cruise (June 4th to 18th 2016), and a subsequent 600 were tagged and released in June/July 2017. Between June 2016 and February 2018, 36 were recaptured. This is a 3.20% recapture rate. On average, these fish were recaptured within 232 days of release and generally within 30 km of the original tagging location. Three of the five PSAT tags have popped up and reported to date. All three have reported within 162 km of the initial deployment site, and all have remained within the FOCZ.

In February 2018, 1161 additional tags were deployed on toothfish, including 10 with mark-recapture satellite tags. These satellite tags are scheduled to pop-up in July/August 2018 during the spawning season.

In addition to the tags deployed by the FIFD, one tag deployed by Argentinian researchers in Argentina waters was recaptured in Falkland Islands waters. This tag was deployed on a toothfish in June 2013 about 100 km west of the FOCZ border, and was recaptured by the CFL Hunter in January 2018 175 km from where the tag was deployed. This is the first Argentinian tag recaptured in Falkland waters, despite over 5000 tags having been deployed by Argentina.

Analysis of the recaptures so far suggests that toothfish demonstrate a remarkable level of site fidelity.

### ***5.3. Further work***

So far, 2285 of the 3500 conventional tags have been deployed. Tagging efforts will continue through observer tag deployments and another tagging cruise scheduled in October 2018. A full assessment of all recaptures will likely take several years after the last tags are deployed.

### ***5.4. Time frame***

Recaptures will continue to be analysed until March 2018 to be used in the final analysis of stock discrimination, which is scheduled to be done by 31 March 2018. PSAT tag data will be analysed in March 2018 and the final condition report will be written in April 2018.

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**Integration and Synthesis of Results:** Overarching recommendation regarding stock structure of toothfish on the Patagonian shelf

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**Overview**

Based on the recommendations of Parker (2015), a range of methodologies were employed to examine the stock structure of the Patagonian toothfish in Falkland Islands waters. These include tagging-based, otolith-based, morphology-based, and genetic-based methods (see above and corresponding reports). As such, there is a need for an overall evaluation that integrates the results from these disparate projects into one overarching recommendation. Although a “weight of evidence” approach could have been employed (Weed, 2005) if some of the results were in conflict with each other, results seem to agree on the general patterns of toothfish stock discrimination.

**Synthesis evaluation**

Results from the 5 stock discrimination projects point to a multi-scale pattern of toothfish stock discrimination in the southwest Atlantic. At the largest spatial scales, there is a very clear differentiation between toothfish from South Georgia/South Sandwich Islands and the Patagonian shelf (based on morphology and genetics). The genetic flow between these two areas seems small enough that an incipient speciation may be underway.

On the Patagonian shelf, otolith shape analysis suggests several different populations, with predictable differences in otolith shape between populations in Chile and in the Falkland Islands. Both of these populations have otolith shapes that overlap with high seas populations of toothfish. Furthermore, the otolith microchemistry evidence suggests that two spawning/nursery areas may be contributing to the overall population within the FICZ/FOCZ, one of which is most likely Burdwood Bank inside Falkland waters, and the other is an as-yet unknown location with warmer waters.

At the most local scale, the tagging data do not show adult toothfish making any large-scale movements. Therefore the stock on which the longline fishery is conducted (primarily mature individuals) is composed almost entirely by individuals that remain in Falkland waters.

### ***Harvest strategy implications***

Due to the lack of evidence for stable frequent connections between the toothfish fished in Falkland Islands waters, and the toothfish in Chilean and Argentinian waters, there is no need to revise the harvest strategies at this time. The management of Patagonian toothfish will continue to assume that there is one discrete stock present in Falkland Islands waters.

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