A consistent approach to the estimation of sustainable harvests of Patagonian Toothfish in Kerguelen Plateau & South-America

by

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Dedicada a mi amada mujer *Claudia*
y a mis dos hermosas hijas, *Magdalena* y *Rocío*

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 65,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 150 figures.

I declare that this thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

Juan Carlos Quiroz
September 2014

Acknowledgements

And I would like to acknowledge ...

Abstract

This is where you write your abstract ...

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Nomenclature

Roman Symbols

A The area of the needle point

a The number of angels per unit area

N The number of angels per needle point

Chapter 1

Introduction

1.1 Rationale

The last decade have been characterized by an increasing debate about the appropriate balance between fishing exploitation and ecological conservation measures required to achieve the sustainability of oceans (Hilborn, 2013; Pauly, 1998; Worm, 2013; Worm et al., 2009). Conservation biologists and fisheries scientists have engaged in such debate where not always a common ground is achieved. In an recently analysis about global status of fisheries, Watson et al. (2013) have emphasized that global fishing effort has increased geometrically since 1950s, supporting the conservationist arguments that global catch is continuously increasing although with comparatively low rates (Juan-Jordá et al., 2011; Pauly et al., 2005), exploited populations worldwide are declining (Myers and Worm, 2003) and fishery management has been proposed as the main cause of the persistent overexploited status (Worm et al., 2006; Worm and Branch, 2012). However, fishery management have been efficient in many harvested populations, especially when economic and social aspects are considered (Hilborn and Ovando, 2014), the mean trophic level trend had increased in many fished populations (Branch et al., 2010; Sethi et al., 2010) and several assessed populations, principally in developed countries, have shown a significant recovery in biomass levels (Costello et al., 2012).

The deep-sea regions have not been exempt from this debate. Trend of target catches have moved from shallower to deeper water (Morato et al., 2006; Watson and Morato, 2013), which is considered a higher threat to ecological sustainability of extensive deep habitats because it affect the biogeochemical balance of low productive deep environments, but also increases overfishing risks of vulnerable species (Mengerink et al., 2014; Norse et al., 2012). However, recent investigations from conservationists and fisheries scientists appear to show a degree of reconciliation in this debate: it is crucial to develop specie-based management approaches (Van Dover et al., 2014; Worm and Branch, 2012), where the improvement of assessment methods (Hilborn and Ovando, 2014; White and Costello, 2014) is therefore of particular importance. Supporting this points, Zhou et al. (2014) discussed a new paradigm on how fishing effort should be allocated between target and harvested species, recommending new management approaches. An similar guidance was suggested by Clark and Dunn (2012) to deep-sea fisheries, where the inclusion of spatial dimension on both assessment and management process is crucial to dealing with sustainability of fisheries. Apparently the reconciling key points between these two debate-side are focused on specie-oriented management approach where policies harvest and modelling approaches should be coherent with the population dynamics and the food webs where the fishery occurs.

Deep-sea fish species making up the *Dissostichus* genus have been exploited in the southern and antarctic oceans during the last three decades (FAO, 2014), and regarding the general debate noted above, also arise opposing investigations about populations distribution, abundance levels, the effectiveness of management and ecosystem health (Abrams, 2013; Ainley et al., 2013; Ainley and Pauly, 2013; Candy and Welsford, 2011; Constable et al., 2000; He and Furlani, 2001; Hoshino et al., 2010; Norse et al., 2012; Sabourenkov and Miller, 2007; Ziegler et al., 2013). In addition to the philosophical background of this debate (*e.g.* food security, humanity heritage), these investigations reveal three broad issues. Firstly, species belonging the *Dissostichus* genus are presumably the most vulnerable notothenioid species on deep-sea environments, with a high risk for overexploitation due to their demographic traits, namely, large sizes, late maturity and low fertility success (see Collins et al., 2010). Secondly, despite the management of *Dissostichus* species have been based on ecosystem approaches, at least in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) areas, current harvest rules appears to be simplistic to overcome the adverse ecosystem impact from fishing activities. Finally, the investigations made available a substantial amount of fishery-independent data on Patagonian Toothfish (*Dissostichus eleginoides*), which enables to propose modelling research on this specie.

Perhaps the most difficult questions to address the issues indicated above are, where allocate the scientific efforts, into the modelling framework or on harvest policy implementation?, what kind of methods are suitable for Patagonian Toothfish?, how the uncertainty transferred to decision-makers could be reduced?, and a further question could be, what impact the improving modelling or management have on conservation of Patagonian Toothfish?. The developing of simulation-based Management Strategy Evaluation (MSE) to deal with different uncertainty sources is a promising method to answer such questions (Aranda and Motos, 2008; Milner-Gulland, 2011), but modelling approaches have also been important allowing improve the theoretical dynamic populations behind the quantitative method. For example, Candy et al. (2011) noted that comprehensive fishery models able to capture the spatial-temporal of Patagonian Toothfish require a proper, detailed and deeper data assimilation process to improve the management harvest strategies implemented by Australia and France on Kerguelen Plateau. Likewise, Ziegler (2013) and Welsford and Ziegler (2013) pointed out that lack of high quality tagging data, particularly the overlap between range size of tagged fish and those reported on the catches (tag size-overlap), is crucial to estimate robust population size. Despite the need to improve the predictive capacity of Patagonian Toothfish fisheries models and provide high-quality science information to decision-makers, theory and implementation underpinning of predictive power on population models is underdeveloped. The lack of effective approaches to accurately characterize process such as population growth derived from length-at-age data, migration patterns based on tagging data, reliable abundance index resulting from standardization of catch per unit effort (CPUE) data and suitable implementation of harvests strategies have preclude the development of comprehensive population models on Patagonian Toothfish.

This PhD research relates to the preceding questions in the context of sustainability process of Patagonian Toothfish populations. The aim of this thesis proposal is to improve both the population modelling and management approaches of Patagonian Toothfish, drawing upon the lessons that have been learned in other similar fisheries to develop a MSE tool for understanding the impact of enable and empower predictive future dynamics of Patagonian Toothfish. This PhD research will deals with issues related to population inhabiting the following regions: ***i***) Kerguelen Plateau, encompassing the areas Heard and McDonald Islands (Australian exclusive economic zone, EEZ) and Kerguelen Islands (French EEZ), ***ii***) the continental platform of Argentine EEZ on Southwest Atlantic ocean, and ***iii***) over the narrow and deep continental slopes of Chilean EEZ on Southwest Pacific ocean. These regions stand for the fisheries landings of Patagonian Toothfish over the Food and Agricultural Organization (FAO) Regions 58, 41 and 87 respectively, and represent yearly around 88% of official worldwide landings at least during the last 10 years (FAO, 2014).

1.2 Objetives

Patagonian Toothfish research is a priority area for the CCAMLR where Australia, France, Argentine and Chile are members. Consistent with the main CCAMLR' goal of conserving Antarctic marine life, particularly when higher complexities arising related to harvests shared between nations, this PhD research will designed to address the following objectives:

1. to review, discuss and expound the different Patagonian Toothfish management process implemented worldwide

2. to test the suitability of improve the actual modelling framework of Patagonian Toothfish utilized in Kerguelen Plateau and South-America

3. to develop a robust MSE approach of Patagonian Toothfish consistent with the modelling improvements identified in Kerguelen Plateau and South-America

4. to examine how the actual harvest policies implemented in Kerguelen Plateau and South-America influences the effectiveness of fishery management on Patagonian Toothfish

1.3 Thesis outline

The thesis should be structured on a chapters-base as follows:

Chapter 1 reviews weakest and successful attributes of management approaches on Patagonian Toothfish that have been implemented on southern and antarctic oceans, emphasizing a comparison between Kerguelen Plateau and South-America.

Chapter 2 provides complementary modelling approaches to improve the theoretical population dynamic of Patagonian Toothfish on Kerguelen Plateau, particularly related to demographic traits under a spatially-structured base. Fisheries models should play a important role in understanding the fisheries dynamic on Kerguelen Plateau, but there have been few attempts to improve the outcomes from this models by inclusion of demographic traits like migration patterns or spatial structure of population. This Chapter should be a contribution to recent attempts (see Extensions & Support section, pag. 5) to improve the Patagonian Toothfish fisheries assessment methods on Kerguelen Plateau.

Chapter 3 implements a set of spatially-structured scenarios to explore the implications of omitting spatial demographic structure of Patagonian Toothfish on South-America. Recent studies suggest an important connection between populations that inhabits continental platform of Argentine and slopes of Chile, however a lack on high quality data prevents the implementation of a spatially-structured empirical model. Using the findings from preceding chapters, the expected results to this chapter should show how significant biases arise due to misspecification model, and also should provide suggestions for further data collection, modelling framework and management strategies.

Chapter 4 uses a MSE approach to examine levels of understanding of how changes on implementation of harvest rules influence on success of management actions. The harvest rules defined by CCAMLR have been designed to avoid significant population reduction and ensure useful removal population consistent with an adequate ecosystem performance. Under an analogous system, but with a lower emphasis to practicing an ecosystem-based management approach, EEZ jurisdictions in South-America have defined different management Reference Points (RPs) to ensure enough escapes and avoid reducing of Patagonian Toothfish population. Both in Kerguelen Plateau as South-America, the harvest rules could be implemented using different optimal pathways to accomplish the performance of the management objectives. This Chapter addresses this topic under a spatially simulated MSE approach taken into account the outcomes from Chapter 2 & 3.

Chapter 5 presents a discussion of the thesis's key findings and conclusions, and suggests functional paths along which future research on Patagonian Toothfish might progress.

1.4 Extensions & Support

This PhD research is embedded within Australian Antarctic Science Strategic Plan implemented by the Australian Antarctic Division (AAD) and should be develop into the framework of project entitled "Development of Robust Assessment methods and harvest strategies for spatially complex, multi-jurisdictional toothfish fisheries in the Southern Ocean". The aforementioned project (hereinafter embedded project) is carried out jointly by AAD and the Institute of Marine and Antarctic Science (IMAS) from University of Tasmania. The principal investigator Dr. Dirk Welsford, and Co-Investigators Drs. Klaas Hartmann, Caleb Gardner, Philippe Ziegler, Paul Burch are the central core of this project and also make up the supervisor team of this PhD research. The project will be providing a support through the whole PhD research, giving important opportunities to achieve the objectives and guarantees that these are not overdimensioned.

Chapter 2

Patagonian Toothfish fishery in South-America: Drawing lesson from other Toothfish fisheries

2.1 Rationale

The Patagonian Toothfish fishery on South-America began late 1970's, similar to the main exploitation areas of CCAMLR (CCAMLR, 1990; FAO, 2014). However, fisheries management elements on South-America such as management objectives, harvest rules, precautionary/ecosystem approach, implementation process, transparency, stakeholders involved and stewardship levels by quota owner are almost unknown to most of scientific community. A comprehensive search on Web of Knowledge© using key topics management/toothfish + Chile/Argentine yields only 3 published sources, increasing to 15 sources when the search include Latin American repositories.

The lack of a knowledge base for fisheries management of Patagonian Toothfish on South-America shows two broad themes. First, any attempts to evaluate alternative management options (like those proposal on Chapter 4, see pag. **??**) require identify and quantify the stated management objectives (Aranda and Motos, 2008; Deroba and Bence, 2008; Milner-Gulland, 2011). Second, in the light of large and complex population dynamics such as Patagonian Toothfish (*e.g.* HIMI and kerguelen Islands; Southwest Atlantic and Southwest Pacific oceans in South-America), the use the data from different jurisdictions to implement robust population modelling (like those proposal on Chapter 2 & 3) require identify explicitly the harvest rules (Constable et al., 2000).

Therefore, a detailed review and comparison between the Kerguelen Plateau and South-America's management approaches should overcome this lack of knowledge base and also give support the following chapters of this PhD research, principally those related to improve the mathematical and statistical methods, as well as the management procedures.

2.2 Methods

From history of fisheries assessment methods, implemented models and management procedures both in South-America and Kerguelen Plateau areas, a time-line of features and actions should be constructed to characterizing and comparing weakest and successful attributes of both areas. Data of management actions and implementation of assessment methods along of fishery history should be obtained from follows sources:

- Chile:
  - Undersecretary of Fisheries
  - Fisheries Research Institute
  - National Fishing Service
  - Fishing Scientific Committees
- Argentine:
  - Undersecretary of Fisheries and Aquaculture
  - National Institute for Development and Research in Fisheries
- Kerguelen Plateau:
  - Report and conservations measures from CCAMLR
  - Scientific bibliography

In the case of South-America, most of the data come from different sources and encompass unpublished technical reports, meeting minutes, and digital database. The Chilean management has been framed since 1990 by “The General Act of Fishing and Aquaculture”, and between 2001-2012 a system for catch allocation was based on the rationale of individual transferable quota system (ITQ). However, this system lacked of explicit management objectives and a specific procedure to setting total allowable catches (TAC) using RPs. During 2012 several amendments to the General Fishing Act were introduced, the most important are: i) close the access to those fisheries subjected to TAC by allocating the ITQs to small groups of industrial fishermen over at least 40 years and ii) define the maximum sustainable yield (MSY) as the main management objective to quota-based fisheries. Similar scenarios have occurred in Argentine where the cessation of trawl fishery carried out important modifications in longline fleet management. Most of this management aspects of Patagonian Toothfish should be discussed and expounded, and also compared with the management process in others CCAMLR areas.

2.2.1 Outcomes intended

Publishing type: *Peer-reviewed article*
Target journal: *Marine Policy (Elsevier B.V.)* or *Marine Resource Economics (MRE Foundation, Inc.)*
Objectives addressed: *Objective 1, see page 3*
main milestone: *Manuscript submission by February, 2015*

2.3 Threat & Contingency

The PhD student already has access to comprehensive unpublished documentation from Chile and also to most of published reports stored on the database of CCAMLR. However, potential delays or difficulties in obtaining data from Argentina are dependent of an unsigned agreement between Chile and Argentine. This agreement has as objective to develop and implement new methodological approaches of Patagonian Toothfish and is scheduled to be signed no later than December, 2014.

Chapter 3

Patagonian Toothfish population dynamics in a spatially varying simulation framework: The case of Kerguelen Plateau

3.1 Rationale

One of the most pressing goals of the working-groups in CCAMLR is to ensure that population dynamics and assessment methods reflect the spatial distribution, demographic traits and the spatial allocation of fishing effort in Patagonian Toothfish. For instance, analyzing data from tagging programs Welsford et al. (2011) pointed out important linkages between Patagonian Toothfish populations that inhabit Kerguelen Islands (French EEZ) and HIMI (Australian EEZ), but some operational issues in the samples and extension of tagging data have limited their use (Candy and Constable, 2008). Although the recent increase in collecting high-quality data derived from tagging data have resulted in the development of a overall population model combining jurisdictional data from French and Australian EEZ (Candy et al., 2011), still remain important gaps about the paths to incorporate migration process derived from these data.

The embedded project as outlined in the previous chapter (see Extension section, page 5) must provide a strong background related to migration patterns, fishery behaviour and optimal management procedures under a spatially-structured framework to Patagonian Toothfish population in Kerguelen Plateau. Based on simulation tools, improvements in stock assessment models and the refining of harvest strategies, the project team should overcome the issues raised in the preceding paragraph.

Using the outcomes from embedded project, this chapter should provides complementary modelling and simulating approaches to improve the theoretical population dynamic of Patagonian Toothfish on Kerguelen Plateau. Furthermore, the outcomes of this chapter could be used to contrast the quantitative process carried out by both research lines — the developed methods framed in the embedded project and the findings from this PhD research.

3.2 Methods

Most of the stock assessment carried out by the working-groups in CCAMLR have using the Integrated Stock Assessment framework CASAL (Candy and Constable, 2008; Ziegler et al., 2013). In this PhD research I propose use Automatic Differentiation (AD) Model Builder (Fournier et al., 2012) because three main reason:

- Provides a high flexibility programming language to accommodate further coding changes, as well as streamlines the iterative processes such as multiple optimizations and risk evaluation framed under the MSE approaches.

- provides ascii results suitable to be read for most cross-platform application and user interface frameworks like Matlab or R-project.

- Allows the comparison of results from CASAL and AD Model Builder frameworks.

The designed steps to address this chapter involve: *i*) translate the code model of both HIMI (Ziegler et al., 2013) and Kerguelen Islands (Aude, 2012) areas from CASAL to AD Model Builder, *ii*) merge both ADMB models (*e.i.* HIMI and Kerguelen Islands) and reproduce the results of Candy et al. (2011) in Kerguelen Plateau, *ii*) extend the Kerguelen Plateau model to reflect the spatial dynamics of Patagonian Toothfish under a spatial simulation framework coherent with outcomes from the embedded project.

The results of this chapter must be discussed in the context of potential bias in key management variables such as spawning biomass levels, vulnerable stock size to fleets, exploitation rate, and relative proportion of population between areas.

3.2.1 Outcomes intended

Publishing type: *Peer-reviewed article*
Target journal: *Plos One (California corporation, USA)*
Objectives addressed: *Objective 2, see page 3*
Main milestone: *Manuscript submission by November, 2015*
Store and share code: SharePoint provided by IMAS or AAD. Alternatively, these can be placed in public repositories like GitHub [https://github.com/].

3.3 Threat & Contingency

The outcomes of this chapter largely depend on findings from embedded project and therefore unexpected delays could arise.

Chapter 4

Impact of misspecification model under a spatially structured population, the Patagonian Toothfish (*Dissostichus eleginoides*) in South America

Published as:

Quiroz, JC, Otros, N. (2015). .... *ICES Journal of Marine Science*, xx:xx–xx.

4.1 Rationale

The Patagonian Toothfish tagging programs implemented recently by Chile and Argentine have shown extensive movements of tagged fish released in the continental shelf of Argentine and later recaptured in the Chilean EEZ, as well as from Chile to Argentine (Martínez et al., 2012; Rubilar and Zuleta, 2013). In addition, a south-to-north drift pattern have been persistent from the two years tagging data collected from Chilean commercial vessels (Quiroz and Wiff, 2013). Furthermore, only one spawning area has been recognized from biological samples and this is split between Argentine and Chile in the far-southern ocean.

These movement patterns could setting a spatial dynamics similar to what is happening in Kerguelen Plateau. In fact, the principal motivation to extend the current modelling framework in Kerguelen Plateau have been the questions that arising from the tagging data programs regarding the spatial distribution of Patagonian Toothfish (Candy et al., 2011). However, the quality and quantity data obtained from South-America prevents the implementation of a spatially-structured empirical model. Uncertainty about Patagonian Toothfish movement also obscure the fleet dynamics, affecting the interpretation of fisheries models. For example, the low percentage of tag size-overlap in Chile EEZ (approx. 46%) will preclude robust estimates about population size (Candy et al., 2011; Welsford and Ziegler, 2013).

Since the similarities between of Patagonian Toothfish population dynamic in Kerguelen Plateau and South-America, it seems rational assume that the findings from spatial process on Kerguelen Plateau could be extrapolated to South-America, at least the size-based migration patterns and the quantitative methods to represent this process. The outcomes from chapter 2 (see pag. ??) and the findings from embedded project abovementioned (see pag. 5) should shape the baseline to implement models and simulation methods in South-America. In this way, this chapter intended explore the potential impact that arise from a inadequate spatial specification of Patagonian Toothfish population model.

4.2 Methods

The core task in this chapter should be the extension and improve of the current model implemented in Chile to include the fishery data from Argentine, and also to incorporate the findings from Chapter 2 and those from embedded project. Consistently, a series of scenarios will be designed to try mimic the complex dynamics of Patagonian Toothfish in South-America and assess the impact on state variables such as unexploited biomass and depletion level.

The proponent of this PhD research plan already has access to the following sources:

- Chile:
  - Comprehensive industrial logbooks from longline fleet (1991-2013)
  - Length and biological samples database from industrial longline fleet (1991-2013)
  - Industrial longline landings (1989-2013)
  - Industrial longline standardized CPUE (1991-2013)
  - Catch at age matrix from industrial longline (1991-1992, 1995-2013) — include length at age keys
  - Weight at age matrix from industrial longline (1991-2013)
- Argentine:
  - Industrial trawl landings (1986-2012)
  - Industrial longline landings (1991-2012)
  - Industrial foreign landings (1987-2012)
  - Industrial longline standardized CPUE (1993-2012)

- Catch at age matrix from industrial trawl (1997-2012)
- Catch at age matrix from industrial longline (2003-2012)
- Weight at age matrix from industrial fleets (1997-2012)

However, the use of Argentine data has constraints as was noted in the Chapter 1 (see pag. 9). Also are available the Chilean artisanal logbooks and biological samples for the last 10 years, some of which have been used to explore illegal, unreported and unregulated (IUU) fishing in the main exploitation areas (Quiroz and Wiff, 2013).

The Chilean Patagonian Toothfish stock assessment have been carried out uniquely for the industrial fleet (south parallel 47^{o}S). An age-structured statistic model for both sexes that incorporates observation error in the catch-at-age, relative abundance index and landings was implemented in AD Model Builder (Quiroz, 2010). This model should be the baseline for most of the scenarios and simulations in this chapter.

4.2.1 Outcomes intended

Publishing type: *Peer-reviewed article*
Target journal: *ICES Journal of Marine Science (Oxford University Press, UK)*
Objectives addressed: *Objectives 2 & 3, see page 3*
Main milestone: *Manuscript submission by July, 2016*

4.3 Threat & Contingency

Delays or difficulties in use of Argentine data are dependent of an unsigned agreement between Chile and Argentine (see pag. 9).

Chapter 5

Bio-economic management strategy evaluation of Patagonian Toothfish (*Dissostichus eleginoides*) in southern & antarctic oceans

Submitted for publication as:

Quiroz, JC, Otros, N. .... *Plos One*.

5.1 Rationale

Previous studies highlight that Patagonian Toothfish is vulnerable to exploitation and make up one of the most major and valuable fishery in southern and antarctic regions (Constable et al., 2000; Norse et al., 2012). Therefore, fisheries management based on robust scientific knowledge should be highly desirable in southern and antarctic exploitation area, even more when modelling and management of Patagonian Toothfish population has added complexity related with population shared between nations (Candy et al., 2011).

Since the Patagonian Toothfish is managed by harvest strategy and control rules in CCAMLR's areas, and also explicit management objectives and reference points (e.i. bound to define harvest rules) have been recently proposed in South-America, the aim in this chapter is evaluate the robustness of these management procedures to a wide range of uncertainties, particularly the model error related to uncertainty about the spatial structure of Patagonian Toothfish population.

A second objective should be evaluate alternative or candidate management procedures which using optimal pathways try to accomplish the management objectives. Several research have shown that economic dimension is crucial to an adequate management system (Dichmont et al., 2010; Emery et al., 2014; Gardner, 2012; Gardner et al., 2013; Hilborn, 2012; Hoshino et al., 2014; Punt et al., 2013). Therefore, the management optimal pathways proposed in this chapter should include economic aspects together with the current biological and ecological dimension.

5.2 Methods

In this chapter, a Management Strategy Evaluation (MSE) is proposed to evaluate the consequences of alternative hypotheses in terms of achieving management objectives. The MSE is a simulation-base tool and has been applied in several fisheries, providing an appropriate simulation framework for evaluate management strategies and also compare alternative management options (Aranda and Motos, 2008; Hilborn, 2012; Milner-Gulland, 2011).

Since the MSE approach is wider in scope, for example, multiple evaluation criteria could be applied to process error, observation error, estimation error and implementation of harvest strategies error, the mathematical and statistical methods developed in this chapter should be bounded to outcomes of chapters 2 & 3 (see pag. **??** and **??**) and the findings from embedded project indicated in preceding chapters (see pag. 5).

5.2.1 Outcomes intended

Publishing type: *Peer-reviewed article*
Target journal: *ICES Journal of Marine Science (Oxford University Press, UK)*
Objectives addressed: *Objectives 3 & 4, see page 3*
Main milestone: *Manuscript submission by January, 2017*

5.3 Threat & Contingency

Because the MSE application depend of outcomes from chapters 2 & 3 as well as the embedded project, is impossible give major details about the candidates strategies or comparison methods through exploitation areas. Therefore, the MSE scope under this chapter could vary substantially.

Chapter 6

Discussion

6.1 Background

This chapter should presents a discussion of the thesis's key findings and conclusions, as well as suggestions about potential improvement in Patagonian Toothfish modelling, decision-making in Patagonian Toothfish fishery, and heterogeneity and the behaviour of harvest strategies for Patagonian Toothfish population. Finally, comprehensive details about limitations of this thesis and further research should be presented.

6.2 Patagonian Toothfish Management

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6.3 Outcomes intended

Publishing type: *Thesis Chapter*
Target journal: *n/a*
Objectives addressed: *Objective 1–4, see page 3*
Main milestone: *peer-review of chapters 2–4*

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Appendix A

How to install LaTeX

Windows OS

TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from https://www.tug.org/texlive/
2. Download WinCDEmu (if you don't have a virtual drive) from http://wincdemu.sysprogs.org/download/
3. To install Windows CD Emulator follow the instructions at http://wincdemu.sysprogs.org/tutorials/install/
4. Right click the iso and mount it using the WinCDEmu as shown in http://wincdemu.sysprogs.org/tutorials/mount/
5. Open your virtual drive and run setup.pl

or

Basic MikTeX - TeX distribution

1. Download Basic-MiKTeX(32bit or 64bit) from http://miktex.org/download
2. Run the installer
3. To add a new package go to Start » All Programs » MikTex » Maintenance (Admin) and choose Package Manager
4. Select or search for packages to install

TexStudio - TeX editor

1. Download TexStudio from
   http://texstudio.sourceforge.net/#downloads

2. Run the installer

Mac OS X

MacTeX - TeX distribution

1. Download the file from
   https://www.tug.org/mactex/

2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

TexStudio - TeX editor

1. Download TexStudio from
   http://texstudio.sourceforge.net/#downloads

2. Extract and Start

Unix/Linux

TeXLive - TeX distribution

Getting the distribution:

1. TexLive can be downloaded from
   http://www.tug.org/texlive/acquire-netinstall.html.

2. TexLive is provided by most operating system you can use (rpm,apt-get or yum) to get TexLive distributions

Installation

1. Mount the ISO file in the mnt directory

   ```
   mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
   ```

2. Install wget on your OS (use rpm, apt-get or yum install)
3. Run the installer script install-tl.

```
cd /your/download/directory
./install-tl
```

4. Enter command ‘i’ for installation
5. Post-Installation configuration:
   http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1
6. Set the path for the directory of TexLive binaries in your .bashrc file

For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

For 64bit OS

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

Fedora/RedHat/CentOS:

```
sudo yum install texlive
sudo yum install psutils
```

SUSE:

```
sudo zypper install texlive
```

Debian/Ubuntu:

```
sudo apt-get install texlive texlive-latex-extra
sudo apt-get install psutils
```

Appendix B

Installing the CUED class file

LaTeX.cls files can be accessed system-wide when they are placed in the <texmf>/tex/latex directory, where <texmf> is the root directory of the user's TeXinstallation. On systems that have a local texmf tree (<texmflocal>), which may be named "texmf-local" or "localtexmf", it may be advisable to install packages in <texmflocal>, rather than <texmf> as the contents of the former, unlike that of the latter, are preserved after the LaTeXsystem is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory <texmf>/tex/latex/CUED for all CUED related LaTeXclass and package files. On some LaTeXsystems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For TeXLive systems this is accomplished via executing "texhash" as root. MIKTeXusers can run "initexmf -u" to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in LaTeX.

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