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TUMAS: A TOOL TO ALLOW ANALYSIS OF MANAGEMENT OPTIONS USING WCPFC STOCK ASSESSMENTS

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Introduction

Background to the Western and Central Pacific tuna fisheries

The tuna stocks in the western and central Pacific Ocean (WCPO) are the largest in the world, supporting annual catches of over 2 million metric tons since 2004 and providing around 60% of total world tuna catches (Williams and Terawasi 2010). These fisheries are managed under the Western and Central Pacific Fisheries Commission (WCPFC) which has 26 members, seven participating territories, and nine cooperating non-members[2]. The membership comprises some of the poorest countries in the world, but also some of the world's largest. A unique feature of the WCPO (compared to tuna fisheries in other ocean regions) is that a large proportion of catch is taken from the within the 200 mile exclusive economic zone (EEZs) boundaries around the Pacific Island countries. For some of these countries, revenues gained from tuna fishing activities can comprise a large proportion of total government revenues (Anon 2011).

Currently the four main tuna stocks considered by the WCPFC (South Pacific albacore tuna - *Thunnus alalunga*, bigeye tuna - *T. obesus*, skipjack tuna - *Katsuwonus pelamis*, and yellowfin tuna - *T. albacares*) are all estimated to be currently above the biomass level required to support the maximum sustainable yield (Harley et al. 2011). Nevertheless, increasing catches and high level of fishing mortality on bigeye tuna and yellowfin tuna (in the western equatorial region) have led the WCPFC to introduce conservation and management measures (CMMs) with aims of reducing (for bigeye) and not increasing (yellowfin tuna) fishing mortality levels.

The stock assessments for these stocks are undertaken by the Oceanic Fisheries Programme of the Secretariat of the Pacific Community (SPC-OFP) under a service agreement with the WCPFC. The assessments are some of the largest and most complex assessments undertaken for any stocks in the world – with the stock assessment model incorporating large scale movements within the waters of the WCPO, the characteristics of the many different fleets and fishing methods that are in operation, and the history of fishing back to the early 1950s. These assessments are undertaken using the stock assessment package MULTIFAN-CL (Hampton and Fournier 2001), a package specifically developed in the context of Pacific tuna fisheries to incorporate the key dynamics of the stocks and the fisheries that operate.

[2] www.wcpfc.int

In addition to undertaking the stock assessments, SPC-OFP have been increasingly called upon to undertake other analyses to help inform the WCPFCs development of CMMs, in particular undertaking "projections" whereby the abundance of the stock in the future is predicted for different potential management options (typically levels of catch or effort for fleets) (OFP 2011). The results from these analyses are also provided in electronic form to all WCPFC participants.

Increased transparency and information for fishery managers

The software used to undertake the assessment – including the input data and output files – is publicly available to ensure transparency in the stock assessment process[3]. Theoretically, any person can use these files to replicate both the SPC-OFP assessments and the projection analyses that are conducted. However, in practice MULTIFAN-CL is not for the faint hearted, presents a very steep learning curve to become familiar with, and is only used by a small handful of stock assessment scientists worldwide.

So while an emphasis is put on transparency, it is also fair to ask whether decision makers from small island developing states have enough information to confidently select management measures that will significantly affect the income of the entire country. On the same basis, can decision makers from those countries with major distant-water fleets confidently estimate the likely impact of proposed measures on their industries? Our experience working both within national fisheries administrations, and within Regional Fisheries Management Organizations (RFMOs) such as the WCPFC, Inter-American Tropical Tuna Commission (IATTC), and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), is that informed managers are more able to negotiate (with either industry or other countries) when they have a fuller understanding of the science and potential implications of future management measures.

It is these issues that motivated a funding proposal to the Pelagic Fisheries Research Program (PFRP[4]) to develop a simple user-friendly interface that would allow people to examine the results of the stock assessments, and undertake analysis of potential management options of particular interest to them. Best of all, they would not have to know MULTIFAN-CL or any of the related programming packages. Subsequently we were successful in receiving partial funding to support two years of development of TUMAS – the **TU**na **MA**nagement **S**imulator[5].

In the remainder of this paper we briefly describe the population / fisheries dynamics that underlie MULTIFAN-CL, in particular the assumptions made in the projection analyses. Then we step through the current features in TUMAS. Next we describe TUMAS, how it was developed, the software tools used and other basic information mostly of interest to software developers. We describe the approaches taken to testing TUMAS and the survey-based approach that we propose to use to get some indication of the success of TUMAS in leading to better-informed decision makers. Finally, we discuss the proposed additional development to be undertaken with the PFRP funding plus some additional thoughts if further funding can be obtained.

[3] http://www.spc.int/oceanfish/en/ofpsection/sam/sam
[4] http://www.soest.hawaii.edu/PFRP/
[5] http://www.tumas-project.org/

We note that all of this is taking place during a year when the WCPFC is seeking to renegotiate a revised CMM, which will cover the three tropical tunas (bigeye, skipjack, and yellowfin tuna) – a time when improved information will be critical.

TUMAS – the TUna MAnagement Simulator

Stock assessment and projection methodology

The foundation of TUMAS is the stock assessment software MULTIFAN-CL, an age-structured statistical catch-at-length model capable of modelling movement between regions, characterizing the practices of various fishing fleets, and integrating mark recapture data form large-scale tagging programmes (Hampton and Fournier 2001). Recent and future proposed developments of the MULTIFAN-CL software can be found in papers produced annually for the WCPFC Scientific Committee (e.g. Hoyle et al. 2009; Davies et al. 2010). In recent years there has been a particular focus in MULTIFAN-CL development in allowing the flexibility to examine the often-complex management measures of interest to WCPFC members.

In simple terms, all that is needed for a projection in MULTIFAN-CL is the stock assessment run that was used to determine current stock status, and a time series of either catch or effort for each fishery for some specified time into the future. As some fisheries are currently managed on output controls (e.g. catch limits) and others on input controls (e.g. effort limits and time area closures), it was important to allow a fishery to be projected on either catch or effort, but it is not possible to have a mix of catch and effort for a single fishery into the future. There are two types of projections currently implemented in MULTIFAN-CL 1) deterministic projections, and 2) stochastic projections. Only deterministic projections are implemented in TUMAS, since stochastic projections are too computationally intensive to incorporate at present.

Under deterministic projections the population is projected forward from the state (i.e. numbers at age and by region if appropriate) at the end of the estimation model. It is assumed that fishery parameters such as selectivity, and catchability (efficiency) remain constant into the future as do the key biological parameters of growth and natural mortality. Possibly the most important assumption in any projection analysis is the likely level of recruitment of young fish into the fishery. Within MULTIFAN-CL there are two options 1) that future recruitment will follow the prediction from the spawner recruitment curve; or 2) that recruitment will remain at the average level that was estimated for some defined period in the estimation model.

To run projections in MULTIFAN-CL one needs to manipulate the data input file to incorporate future catch or effort levels, and the parameter file that tells MULTIFAN-CL how many years to project forward, when to start, and whether fisheries are projected in catch or effort. This second task is more difficult than it sounds due to the difficulty of manipulating complex file structures containing estimates for thousands of parameters. Finally, we execute MULTIFAN-CL from either a DOS command line or within LINUX and view the results through a set of R functions. All of the steps above have been implemented within TUMAS, which protects the user from the large complex files, and removes the need to be familiar with any other piece of software.

TUMAS options and functionality

The basic options and structure of TUMAS are briefly described below, and Attachment 1 provides a range of screenshots. The TUMAS user manual provides a more detailed description[6].

The basic structure of TUMAS is set up around defining the parameters for a determinist projection of a WCPFC stock assessment model and then reviewing the results of that projection through a range of graphics.

Step 1: Set up the projection

- Choose the species and the model (typically the base or reference case model)
- Future recruitment levels:
    - the long-term average from the spawner-recruitment relationship; or
    - the recent average [default for recent period set to the past ten years]
- Length of the projection [default set to ten years]
- Whether or not to also project forward the biomass estimated to occur in the absence of fishing. This increases computation time by around 30%, but does provide important information about the non-equilibrium conditions that exist if one projects with recent average recruitment rather than long-term SRR levels.

Step 2: Setting up the fisheries management scenario

- In MULTIFAN-CL, fisheries are defined that characterize a method of fishing in a particular region. When different fleets use similar fishing methods, they can be either combined, or split into separate fisheries if they have different effects on the stock (e.g. catch different sized fish). There are currently three parameters that define the projection of a fishery:
    - Catch or effort: it is possible to project forward a fishery based on either catch or effort. Typically we project forward catch for longline fisheries and effort for other fisheries.
    - Baseline levels: the baseline level of catch or effort is defined by the first year and the number of years that the average is calculated over, e.g. a setting of 2004 and 3 would give the baseline as the average for the period 2004-2006.
    - Scalar: this is the multiplier of the baseline level of effort. A value of 1 projects catch or effort at the baseline level.
- With the scenario defined, it is then run using MULTIFAN-CL. Scripts within TUMAS first convert the options entered into the GUI into MULTIFAN-CL input files and command-line options, and then MULTIFAN-CL executes. On a high-end laptop computer with 4GB of memory, projections take less than one minute.

Step 3: Viewing the results

- Once the model run is complete TUMAS will transition to the graphics viewer. A range of graphics are produced that include projected catches, catch rates, and biomass and fishing mortality (including comparing these indicators to the MSY levels).

[6] http://www.tumas-project.org/documents/TUMAS%20user%20Manual.pdf

- These graphics can be exported as either png or pdf formats or the data behind the graphics can be exported to Excel.

It should be noted that TUMAS is designed to provide management option projection analyses only. A user can achieve much more in the way of fish stock assessment through direct use of MULTIFAN-CL, and TUMAS is not intended to be used for this purpose.

TUMAS development

TUMAS features a combination of Java and JavaFX Script code. As we wanted to make a more modern, RIA-like ('Rich Internet Application') web-enabled software, we investigated various solutions ranging from C# + Silverlight to Flash + ActionScript. In the end, we opted for Java because we wanted to capitalize on existing Java I/O code for reading and writing MULTIFAN-CL input and result files developed for MULTIFAN-CL Viewer and other projects. This also gave us the flexibility to provide TUMAS for the various platforms where MULTIFAN-CL has been ported without rewriting much of the code. In the current version of the software, the I/O operations and tasks scheduling layers are written in Java while the GUI, Charting and launch scripts are written in JavaFX Script. The provided MULTIFAN-CL is a native executable (from C++ code) that is the very same program currently being used by the scientists for stock assessments.

Preplanning and prototyping lasted from the end of 2009 to March 2010, and involved discussion about the feasibility of the projection algorithm, data packaging and distribution as well as early discussions about the graphical interface. TUMAS itself comprised of several independent entities, packages and packages such as the GUI run by the user, a setup manager that is run on the first launch and during software updates, a CD-ROM installer, a scenario editor, a launch script (which does several checks at the operating system level) and other utilities all regrouped under the TUMAS portmanteau name.

Several challenges arose during the main development, mainly due to the fact that both the JavaFX API and the JavaFX Script language were both in development at Sun's (now Oracle's). For example, release of JavaFX 1.3 led to drastic changes and simplifications in the way the GUI of the software works in late August 2010.

Porting the projection algorithm from the statistical software R to Java was mostly straightforward. Most of the existing MUTIFAN-CL related code was ported from Java 4 to Java 6 (and 7) without too much trouble. On the other hand, we had to be careful of the management of the various MULTIFAN-CL child processes that need to be spawned as external processes as well as the FRQ and PAR file reconstruction task for a single simulation to occur. Particular attention was also given to the file decompression and packaging routines as well as the backup of the temporary execution directory to be able to analyze and correct causes of crashes. Ongoing optimization is still being investigated in the parameters and memory configuration fed to MULTIFAN-CL, to try to minimize the memory footprint of the model (to help use on low-end computers).

While we always had planned for online installation and updates, we are not entirely happy with the current distribution model as Java Web Start, the distribution method we are using, does not seems to be always fully reliable. We recently acquired a digital certificate that will help managing the trust level between our software and our users.

Further work will be done later to add support for direct download of new scenarios from the web (vs. needing to repackage and republish a new version of TUMAS) and linking TUMAS directly to its website to get news feed such as release notes, etc. If the project continues, we expect more changes, optimizations and bug fixes in the future when switching to the JavaFX 2.0 API and rewriting part of the code that is currently in JavaFX Script in Java (or another programming language supported by the JVM).

Testing of TUMAS

Software testing is a critical aspect of software development and in the case of TUMAS testing is critical for addressing several matters:

1. Does the software actually work properly, e.g. are their bugs?
2. Does the software have the features that the users require?
3. Can the software feasibly run on the computing resources available to the target audience?
4. Can the software be downloaded and updated with the levels of bandwidth that are available in the region?

In the development of TUMAS we have sought to address these issues through a variety of approaches. To test the overall concept, early versions of TUMAS were demonstrated to fishery managers at several meetings including:

- Forum Fisheries Committee Management Options Consultation (Nov 2010)
- 31st Special Meeting of the Parties to the Nauru Agreement (Nov 2010)
- SPC Heads of Fisheries meeting (Feb 2011)
- SPC Pre-assessment workshop (April 2011)
- Forum Fisheries Committee Management Options Workshop (May 2011)

The main testing was achieved when TUMAS was put in the hands of users, and this was first done during the PRFP PI meeting in December 2010. In July 2011, TUMAS was used as the focus of the Stock Assessment training workshop (SAW) run by SPC. Eighteen fisheries officials representing the governments of 17 WCPFC member countries and territories used TUMAS over a period of three days to evaluate management options that would achieve pre-specified objectives, but also to examine the potential impact of management options on their own fisheries. None of these officials had previous experience with MULTIFAN-CL. and while they certainly found some bugs and suggested additional features, they were unanimous in their excitement at this new tool.

The biggest issue to address after the SAW testing was reducing the memory usage of TUMAS, so that it could run on some of the lower end machines. Based on some of the problems encountered, we have started examining a range of approaches to reduce the computational demands. The first release after the PAW used 50% less memory and moderately reduced processing time, but greater improvements might be expected in lower end machines.

The largest annual gathering of WCPFC member scientists is the Scientific Committee which is held over 10 days in August each year. During the meeting we will hold an special session introducing TUMAS to

the broader WCPFC membership[7], providing the most recent release, plus the templates required to use the 2011 stock assessments runs (completed only days before).

Not only will this provide another opportunity to test TUMAS, but it will be an important starting point for assessing the utility of the TUMAS software to the WCPFC decision making process. All participants at the PAW and the WCPFC Scientific Committee special TUMAS session will be contacted after the WCPF Commission annual session in December 2011 to see how useful TUMAS was in their preparation for, and negotiations at the annual meeting. We are interested in those who used TUMAS after our introductory session and particularly those who ran simulations to examine management options to inform their country's negotiating position.

This will also provide a final opportunity within the PFRP-funded implementation of the project to get feedback and potentially implement minor improvements to the software.

TUMAS – future developments

Currently development of TUMAS is funded by the PFRP through until early 2012, and as part of this funding and through the general support to the SPC membership, the following three major developments are planned over the next six months:

- Time/area closures for purse seine fishing effort: time/area closures have been an important part of the management restrictions used in the WCPO in recent years. We propose to implement in TUMAS the ability to examine the impact of seasonal closures of general areas within the equatorial region. Users will be able to select the regions and seasons for the closure. These will only be implemented for the three tropical tuna species;
- South Pacific albacore: this specifies is of critical importance to many countries and territories in the south Pacific. The stock assessment has two main features (i.e. a large number of defined fisheries to account for seasonal selectivity differences, and the modelling of the troll fishery at a different time step to the longline fisheries) which will require some modification to the algorithms used by TUMAS and MULTIFAN-CL; and
- Summaries of the size composition of projected catches: for many species the value of the catch can differ depending on the sizes of the individual fish. MULTIFAN-CL predicts catch at age for each fishery in the projection period, but we will look to summarize this into broader categories to reduce the volume of output.

In addition to these new features we will continue to address general issues of the software such as minimizing the memory use and running time for the projections, and improving the capacity for online updates.

Outside of what is currently funded we see scope for further development of TUMAS in the future. MULTIFAN-CL is used to assess tuna stocks in other oceans, and with some work it would be possible to allow TUMAS to support these other assessments. Finally, the outputs from projections should be able to support detailed bioeconomic analysis so we would like to work with fisheries economists to see how

[7] http://www.wcpfc.int/doc/wcpfc-sc7-2011-13/provisional-agenda-tutorial-session-tumas

we can better provide the information that they need to evaluate the costs and benefits of alternative management options.

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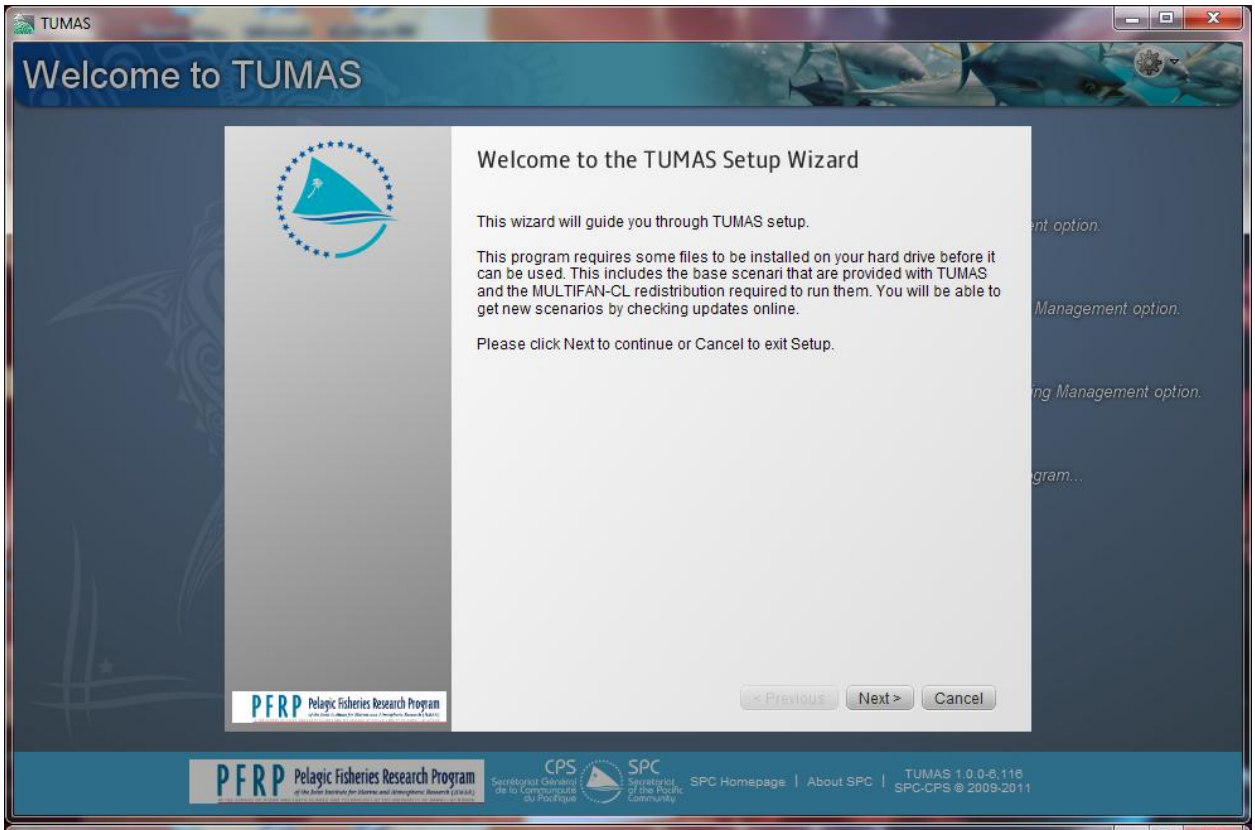
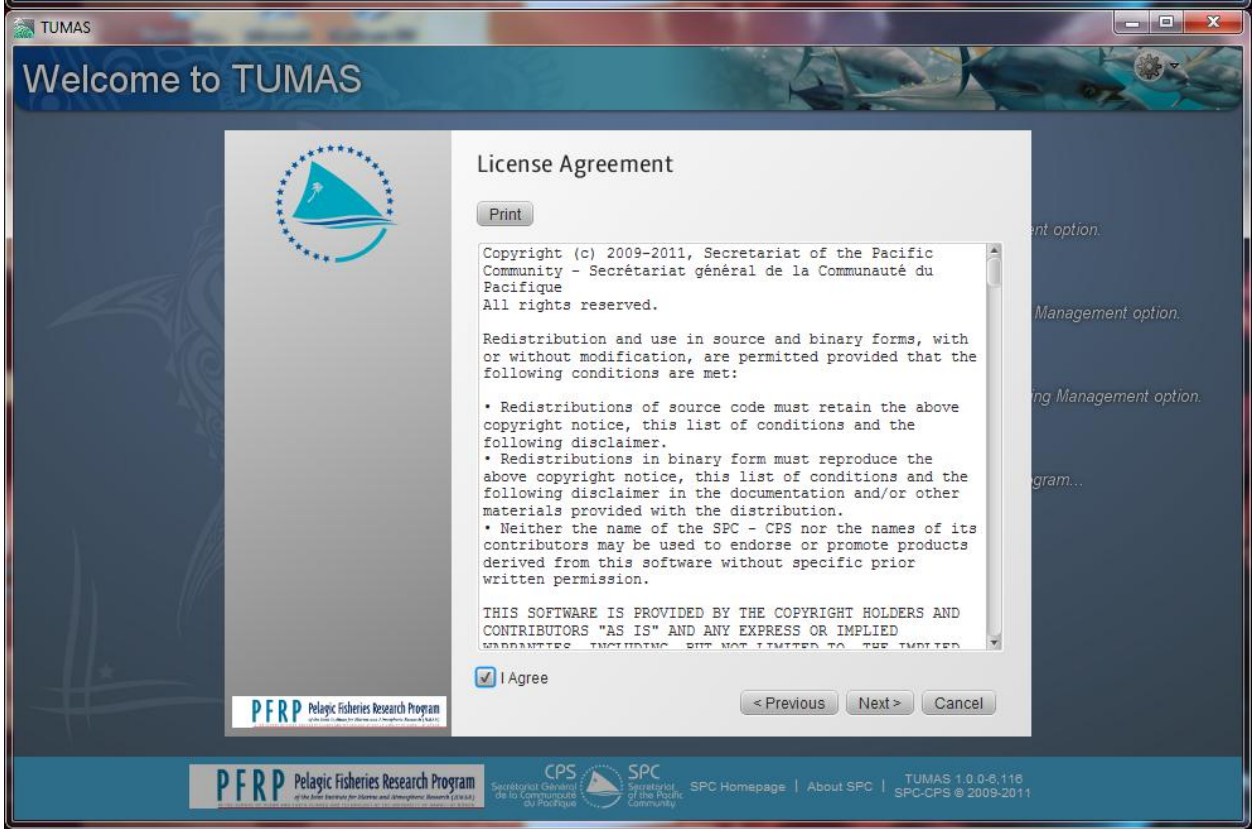
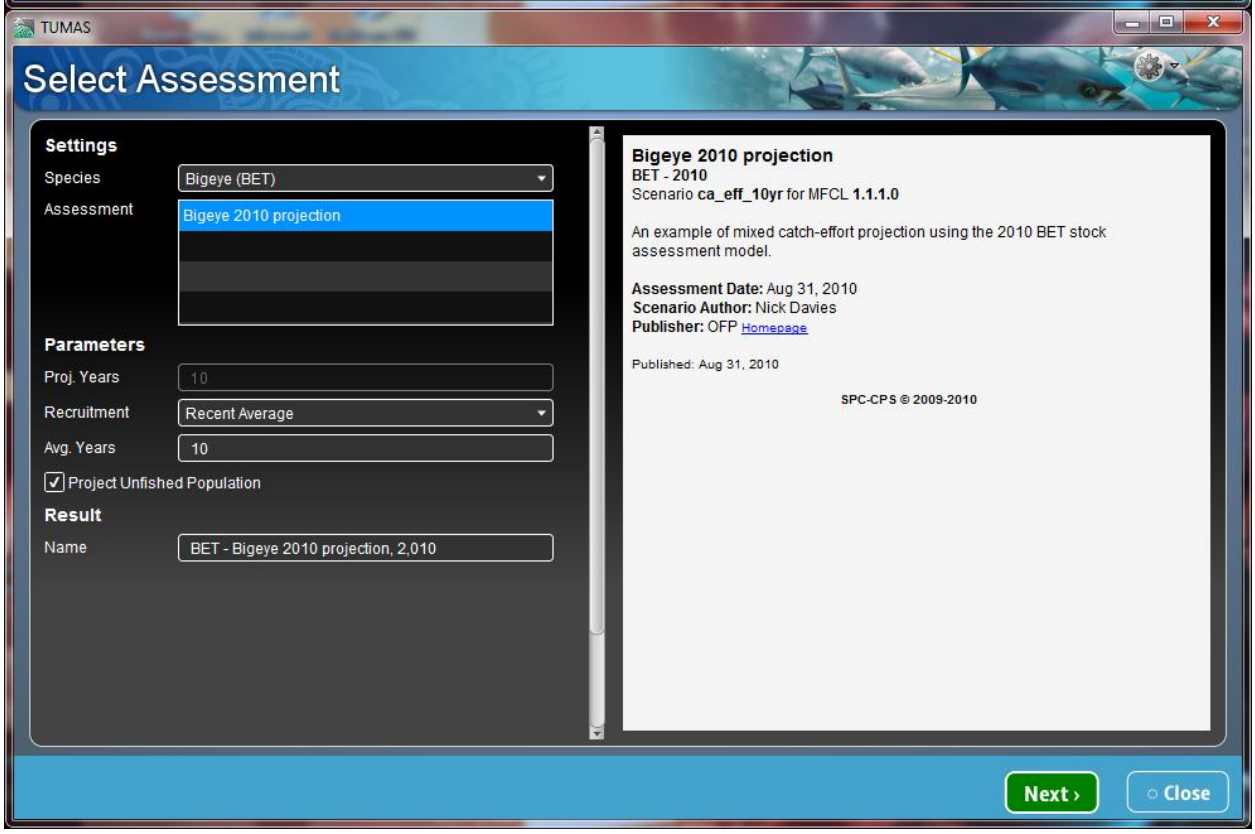
Annex 1: Screen shots of TUMAS






TUMAS
Welcome to TUMAS
New
Develop a new Management option.
Open
Open and modify existing Management option.
Review
View output from an existing Management option.
About
Information about this program...
Exit
Quit the program.
PFRP Pelagic Fisheries Research Program
CPS Secrétariat Général de la Communauté du Pacifique
SPC Secretariat of the Pacific Community
SPC Homepage | About SPC | TUMAS 1.0.0-6,116
SPC-CPS © 2009-2011


TUMAS
Select Assessment
Settings
Species
Bigeye (BET)
Assessment
Bigeye 2010 projection
Parameters
Proj. Years
10
Recruitment
Recent Average
Avg. Years
10
Project Unfished Population
Result
Name
BET - Bigeye 2010 projection, 2,010
Bigeye 2010 projection
BET - 2010
Scenario ca_eff_10yr for MFCL 1.1.1.0
An example of mixed catch-effort projection using the 2010 BET stock assessment model.
Assessment Date: Aug 31, 2010
Scenario Author: Nick Davies
Publisher: OFP Homepage
Published: Aug 31, 2010
SPC-CPS © 2009-2010
Next ›
Close

TUMAS

Projection Settings

Output

Name: BET - Bigeye 2010 projection, 2,010

Projections

#	Fishery	Type	Start Yr	N Years	Scalar
1	• LL ALL 1 (Regio...	Catch	2007	2	0.7
2	LL ALL 2 (Region 2)	Catch	2004	1	1.0
3	• LL HW 2 (Region...	Catch	2007	2	0.7
4	LL ALL 3 (Region 3)	Catch	2004	1	1.0
5	LL TW-CH 3 (Regio...	Catch	2004	1	1.0

► Tip: you can select multiple rows by holding down CTRL or SHIFT key.

Fishery: 1 - LL ALL 1 (Region 1)

Type: Catch

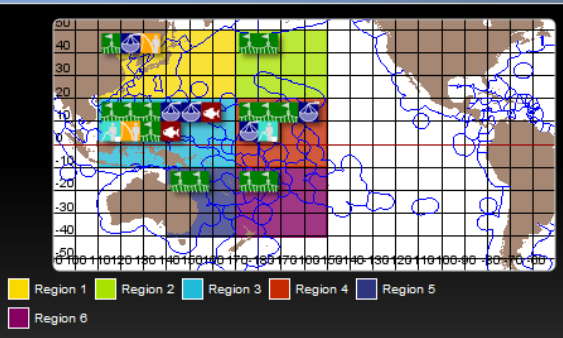
Start Yr: 2007

N Years: 2

Scalar: 0.7

► For selected fisheries, project catch at average for the year range [2007 - 2008], multiplied by scalar 0.7.

Set | Set To Selection



‹ Previous | Run » | ○ Close

TUMAS

Please Wait...

```
---------------------------------------------------------

input (.frq) file: bet.frq
 GRADSTACK_BUFFER_SIZE read in and set equal to 15000000
 CMPDIF_BUFFER_SIZE read in and set equal to 200000000
 array memblock size read in and set equal to 80000000
10
638
tag3.cpp 1
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
233 2 233 2
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233 2 233 2
233 2 233 2
```
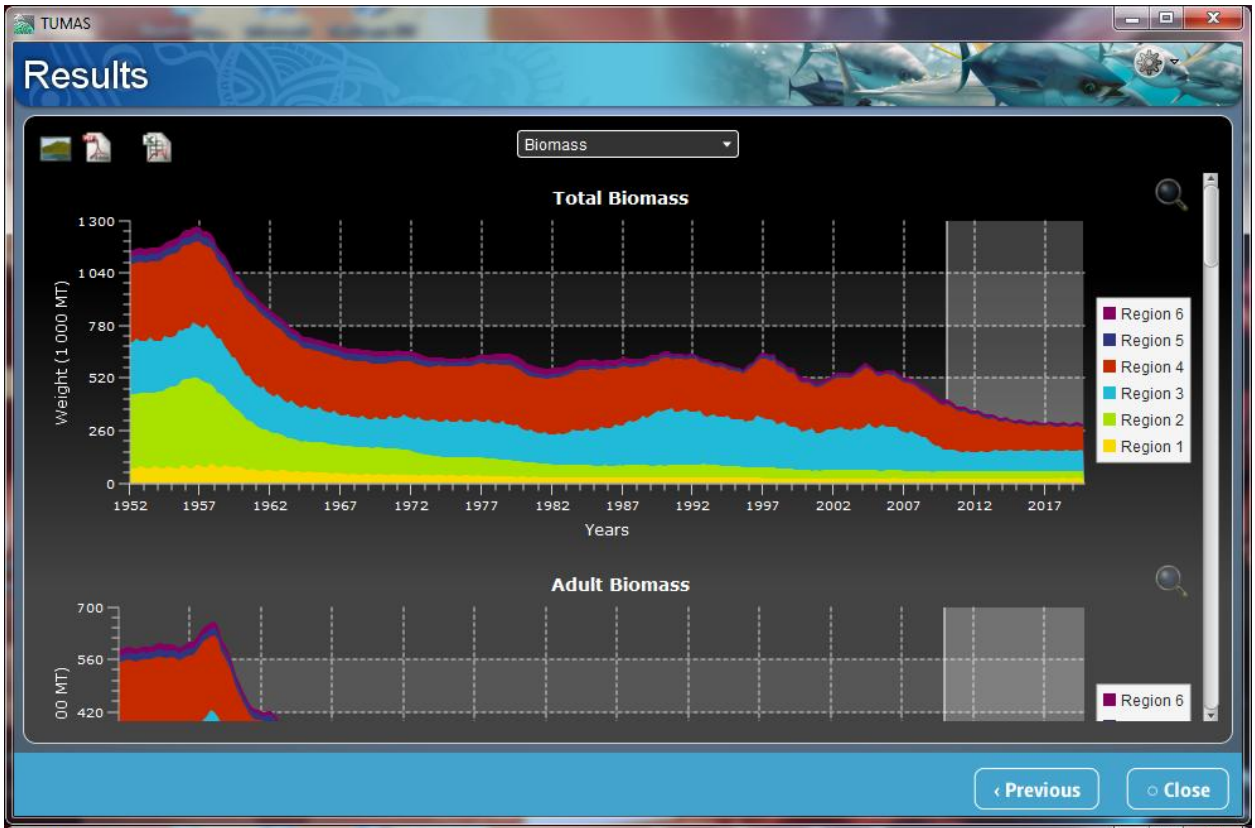
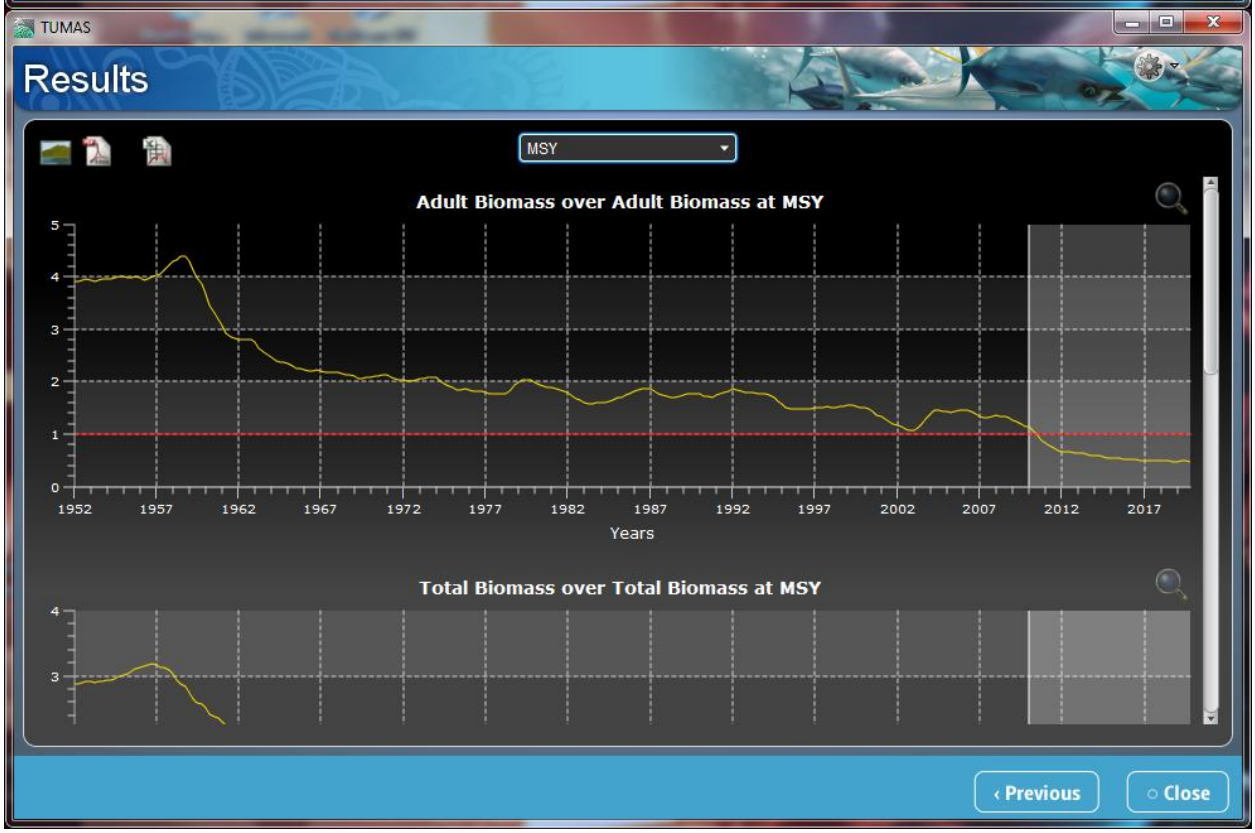
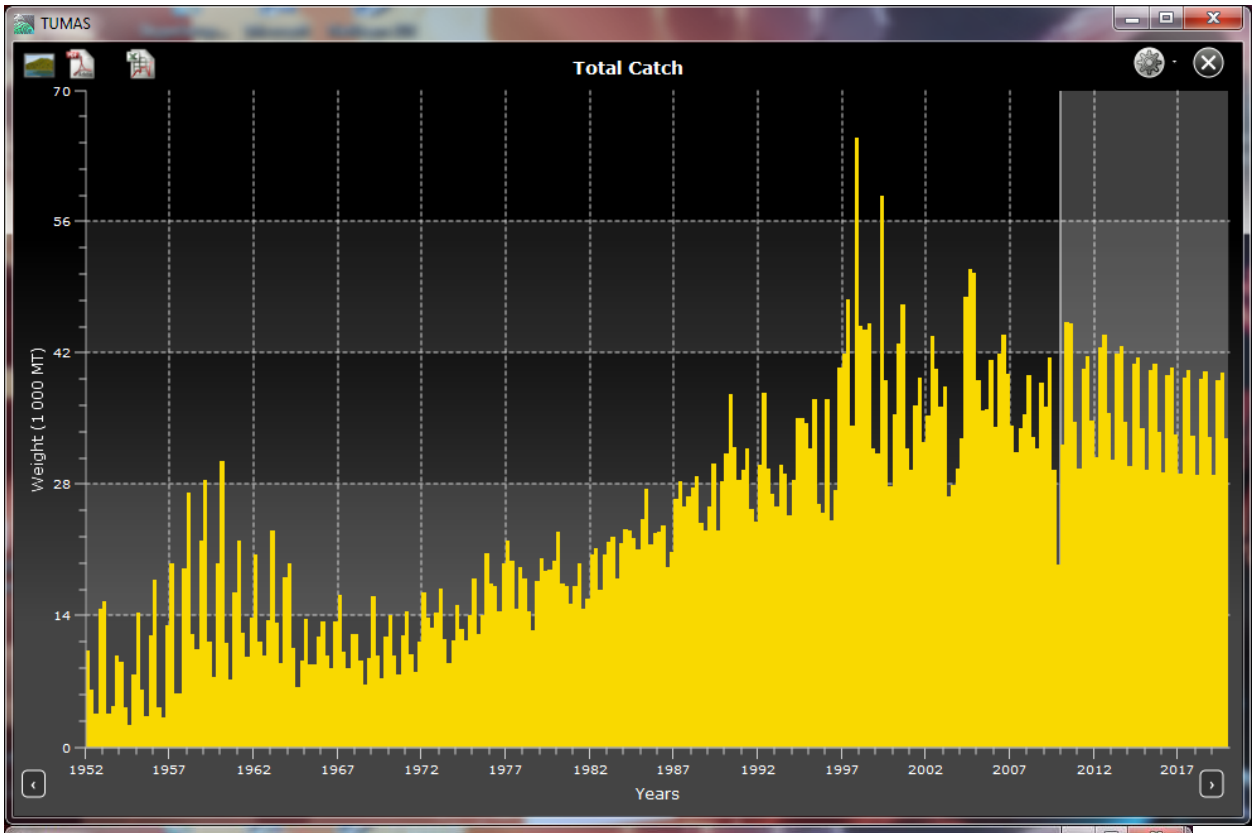
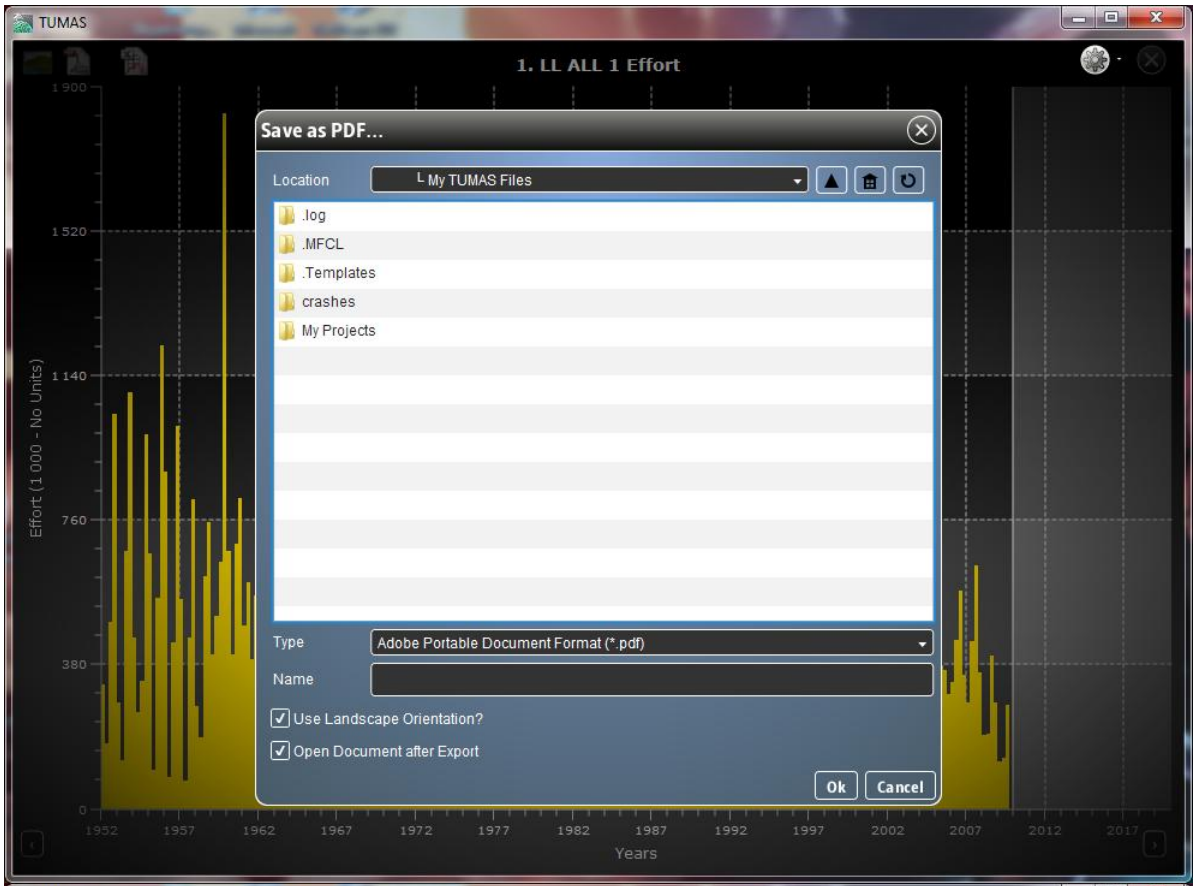
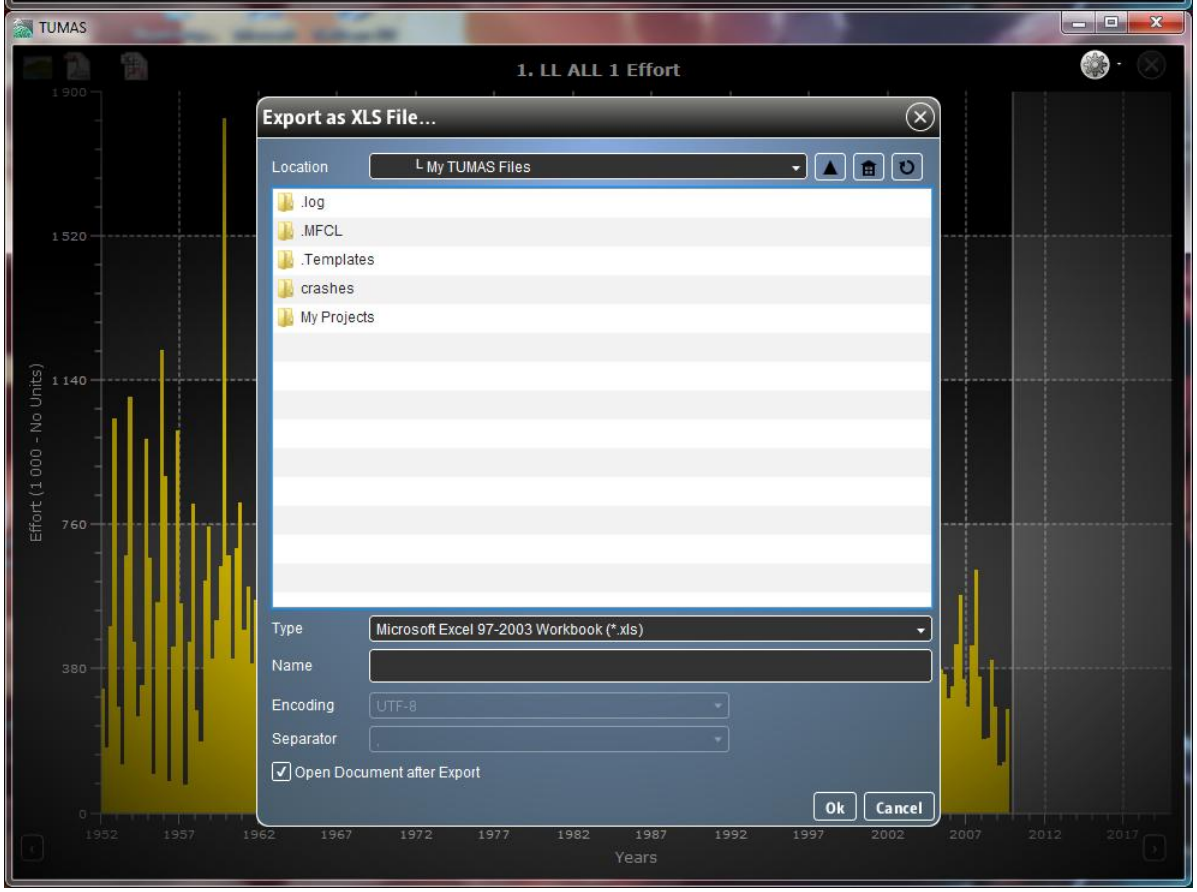


TUMAS
Results
Biomass
Total Biomass
Weight (1 000 MT)
1 300
1 040
780
520
260
0
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Years
Region 6
Region 5
Region 4
Region 3
Region 2
Region 1
Adult Biomass
700
560
420
Region 6
‹ Previous
○ Close


TUMAS
Results
MSY
Adult Biomass over Adult Biomass at MSY
5
4
3
2
1
0
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Years
Total Biomass over Total Biomass at MSY
4
3
‹ Previous
○ Close


TUMAS
Total Catch
Weight (1 000 MT)
70
56
42
28
14
0
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012
2017
Years


TUMAS
1. LL ALL 1 Effort
Effort (1 000 - No Units)
1 900
1 520
1 140
760
380
0
Years
Export as Image...
Location
My TUMAS Files
.log
.MFCL
.Templates
crashes
My Projects
Type
png Images (*.png)
Name
1.png
Width
800
Pixel(s)
Lock
Aspect Ratio
1.0
Height
800
Pixel(s)
Compress
100%
Ok
Cancel


TUMAS
1. LL ALL 1 Effort
Save as PDF...
Location
My TUMAS Files
.log
.MFCL
.Templates
crashes
My Projects
Type
Adobe Portable Document Format (*.pdf)
Name
Use Landscape Orientation?
Open Document after Export
Ok
Cancel
Effort (1 000 - No Units)
Years


TUMAS
1. LL ALL 1 Effort
Export as XLS File...
Location
My TUMAS Files
.log
.MFCL
.Templates
crashes
My Projects
Type
Microsoft Excel 97-2003 Workbook (*.xls)
Name
Encoding
UTF-8
Separator
Open Document after Export
Ok
Cancel
Effort (1 000 - No Units)
Years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Help
TUMAS
Tuna Management Simulator
Software to support
WCPFC fishery management
The Tuna Management Simulator
TUMAS is being developed to:
Simulate what might happen to the stock in the future.
Predict benefits and costs of management options.
The purpose of TUMAS is to help fishery managers and advisers make decisions and negotiate.
With TUMAS, you can manage tuna populations on your computer. More...
Download & Updates
The first release of the software allows the user to work with bigeye, yellowfin, and skipjack tuna. It uses the latest full stock assessment for each stock.
Future versions will permit more flexible definitions of management options, including spatial and temporal closures.
They will also provide a wider range of outputs.
Software updates will be available via this website. More...
Secretariat of the Pacific Community | Oceanic Fishery Program | Pelagic Fisheries Research Program | WCPFC
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