FIΣH IT 1.0-

STUDENT MANUAL

A TRAINING SYSTEM FOR AQUATIC RESOURCE MANAGERS

ABSTRACT

FIΣH IT is part of a family of multimedia coursework about the management of aquatic living resources. The focus of the training system is on the computation and utilization of diverse methods to assess the state and potential of resources, as well as to develop balanced harvesting strategies for the future; the aim of the course is the training and assisting of managers in realistic exploitation projects. The system includes many different training and learning tools, such as online media, Excel workbooks and more advanced simulation tools. This student manual can be used as the master document, provided all subject files are downloaded into the same directory. The individual files are otherwise self-explanatory and can be consulted independently.

Jorge Santos

Norwegian College of Fishery Science
University of Tromsø

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PREFACE

A manager is someone that makes decisions regarding the activities of others, and these are normally important income-related decisions. A living resource are organisms, wild or farmed, that can be exploited by mankind as food, or for any other purposes that imply its elimination. The two first questions that a population manager asks is how much wild living resource can be utilized without jeopardizing future yields (sustainability), and how to avoid conflict among resource users (harmony). The question of how much to take is obviously quantitative. It is also often related to another question: how much resource will be left un-exploited in the water. There are many solutions to this trade-off between leaving the resource in the water, where it can grow or die, or harvest it and make use of it right away. Ultimately, the decision has economic, social, ethical and political tones, all depending on the context of the industry. It is often the job of a population biologist to study the life-strategies, abundance and resilience of the resource, and to calculate the potential harvests for different levels of human input. In a fishery, this input comes in the form of fishing effort and fishing method. These calculations are the focus of the first chapters of this work.

A manager normally tries to avoid conflict among users. But, some of the users may not be immediately apparent, because the same resource may be targeted by many, in different places and times. Thus, some of these invisible competitors, which can be people or other wildlife, may easily be the loosing part, or, on the contrary, take the largest share. The managers or the agents have three ways to find acceptable yields and mitigate disputes. One would be to make use of some historical rules that have functioned adequately there or elsewhere for unknown reasons. A second solution would be experimentation: by trial and error the agents could find suitable solutions in the future, but they should be careful (conservative) along the way. With time one would learn something about the dynamics of the resource and user behaviour, even without fully understanding the underlying mechanisms. These two solutions require experience, common sense and, often, self-control to resist precipitation and all sorts of pressures. The third solution relies on some sort of quantitative prediction, also called a simulation model. With a fair mathematical description of the dynamics of the resource, one can try to predict future trends of yield and revenue. The advantage of these forecast models is that we can make an endless number of "experiments" with slight variations of the input, for instance of the fishing effort or season. We can quickly get a grasp of the consequences of our actions. Along our courses, we tend to discuss the two first types of solutions in class and in case-studies. The aim of the second part of this manual is to train in the utilization of these simulation models. These predictive models attempt to mimic fluctuating environments, uncertainty about many factors, as well as competing fleets and predators. Both deterministic and stochastic formulations of these computer models are used.

Quantitative methods are not immediately attractive or understandable to everybody. Here, an attempt is made to introduce some of the mathematical methods often used in

fishery biology in a gradual way. We start with simple statistics and statistical methods and proceed to more and more complex simulation models. This gradient reflects also the cost of information in real life: simple models are normally used where there is not much information available for research; complex models require large amounts of expensive information, and are thereby only utilized in some industrial fisheries. A fishery manager should be familiar with the different approaches, and be able to make suitable and conservative decisions even in the absence of complex science. The aim of the course is to train and assist managers to understand biological advice without being unduly distracted by the mathematical aspects. Teachers like Per Grotnes introduced me to the idea of learning serious matters with simple exercises, simulations and games. Fishery mathematicians with good pedagogical skills like Haddon, Hilborn, Pope and Punt were other important sources of knowledge and inspiration.

Contents

Chapter 1 - Introduction*

I developed much of the material in this training system between 1998 and 2005. My trainees had diverse disciplinary backgrounds (natural and social sciences) and were attending a multi-disciplinary program on International Fishery Management. Altogether, the time devoted to fish population dynamics and conservation management corresponded roughly to a one semester course. Given the wide background of the students and the purpose of the program, this training course was eminently practical. In the first part of the course we would have a classical progression, normally a lecture on a topic followed by a practical class. At later stages, problem-based approaches were more common.

Simulations and problem-solution often require intensive use of mathematics or computational tools. That is why this training system is mostly based on quantitative worksheets and software. I start this book (Chapter 2) with a simple test to the reporting and quantitative skills of the student, followed by some elementary training in the spreadsheet Excel. Spreadsheets have their limitations, but are low-threshold quantitative tools that are nearly free and available everywhere. These were definitively strong points with our batches of students that came from all over the world. Then, a simple refresher course in basic mathematics and statistics is made (Chapter 3), also in Excel, Later in the course, a soft introduction to a more powerful programming language, the R software, is made. This software is useful for i.a. simulation modelling.

This master document introduces the different topics in different chapters. Each chapter provides a hyperlink to one or several workbooks that are self-explanatory. The master document also provides links to internet sites that have relevant theoretical information for the topic. If working offline, the only practical requirement in order for the master document to link properly to the dependent workbooks is that they are installed in the same directory. Workbooks can otherwise be utilized independently from the master document or downloaded directly from the internet if working online. Some links to workbooks are inactive, particularly when they refer to material that must be collected in practical classes, such as e.g. research cruises, as in the original course in Tromsø.

This document and the dependent workbooks were inspired by co-workers and works from many other people. I will mention some of these sources of inspiration in the different chapters. I will also attempt to give a full reference list of the literature as well as of the photographic material, at the end of this master document. The books often used to cover part of this course were King (2005) and Cochrane & Garcia (Eds.) (2009), which are relatively easy reading for most students. On the next page is shown a list of logotypes:

* Santos, J. 2015. FISH IT 1.0 – Student Manual: A Training System for Aquatic Resource Managers. *Septentrio Educational 2015(3).* DOI: http://dx.doi.org/10.7557/se.2015.3 .

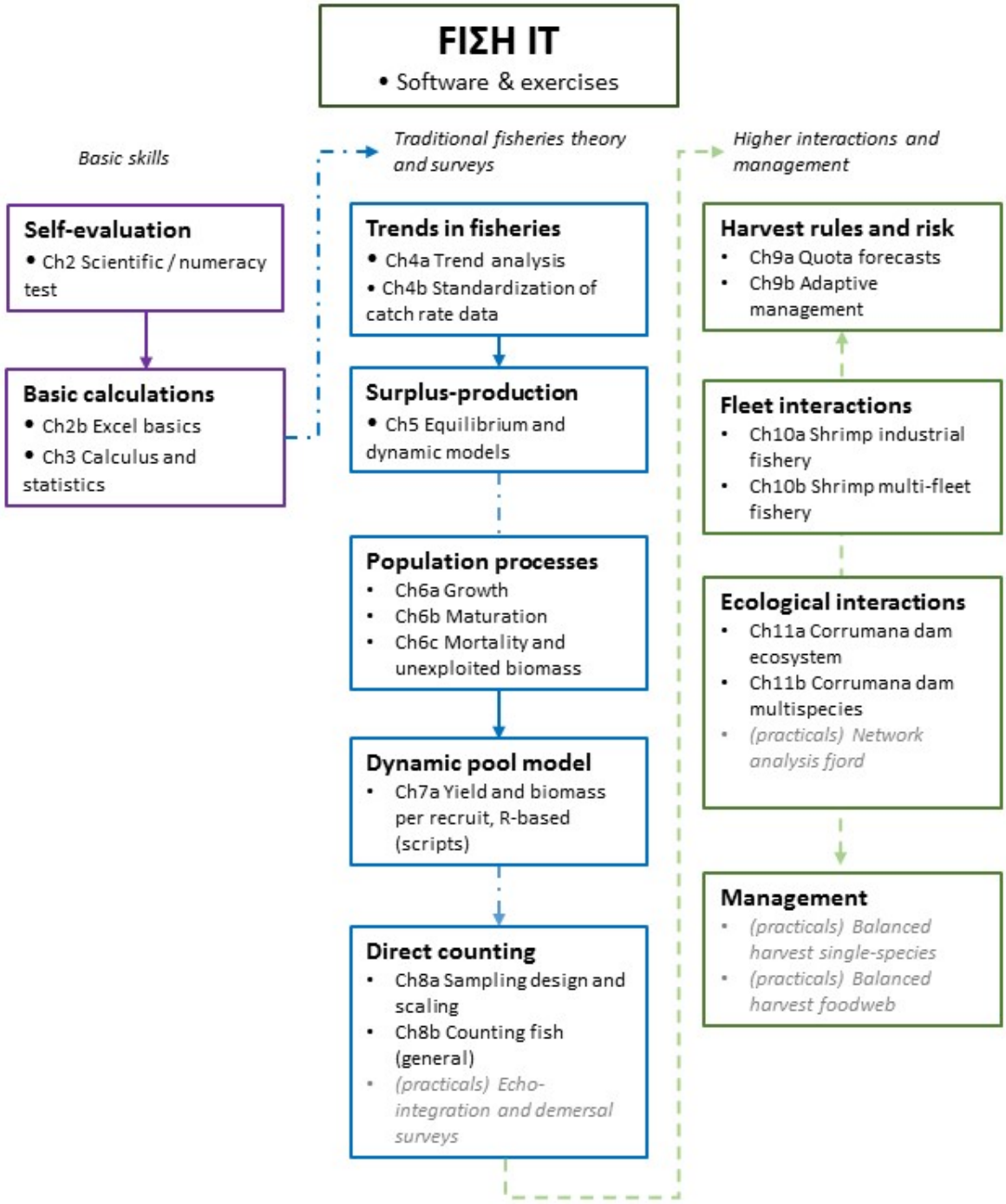
these logotypes make it easier to identify the source or type of external learning material used along the training system.

LOGOTYPES

Software

Online information

FISH IT: CHAPTERS, SOFTWARE AND MANAGEMENT SCALES



Chapter 2 – A self-assessment, and a tutorial in Excel*

QUESTIONS ASKED

- Am I aware of the basics of scientific writing required to write an informative report?
- Do I remember the basics of mathematics?
- How do I use statistics to plan and analyze my field or experimental data?
- How to lose the fear of using a spreadsheet?
- How to do basic repetitive calculations?
- How to present figures and reports in scientific style?
- How to efficiently select and summarize sub-groups of data?

BACKGROUND INFORMATION

- A fishery: Torbjordonso – Mackerel fishing in the North Sea

INFORMATION AND SOFTWARE

Chapter 2 of FISH IT contains a self-awareness test that takes less than 10 minutes to answer. In this simple and short form, it is a pen-and-paper test that will, hopefully, encourage students to review past knowledge at secondary school or college levels. In the 2nd part an introduction to Excel is made. Although most students claim to be familiar Excel, it is often the case that they are not acquainted with many of its useful capabilities (and limitations) for reporting and research work. It was in this spirit that this short lab was developed. These two sessions are extracts from the sister training package CONSERV IT 1.0. Additional multimedia material is contained in that package.

- Ch2a Test yourself
- Ch2b Excel basics JdS.xlsx

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SNAPSHOTS

Country	Total fish catch (MT)	Population (thousands)	Area km2	% of total catch	Catch pr capita	Catch pr km2
Bangladesh	1 047 170	125 000	144 000			
Cameroon	80 000	15 000	475 000			
China	25 721 740	1 222 000	9 600 000			
Colombia	146 407	37 000	1 140 000			
Eritrea	3 826	3 600	121 000			
Ghana	371 227	18 000	238 000			
India	4 324 235	967 000	3 300 000			
Namibia	285 980	1 700	825 000			
Nigeria	255 499	107 000	924 000			

Absolute reference used

Relative references

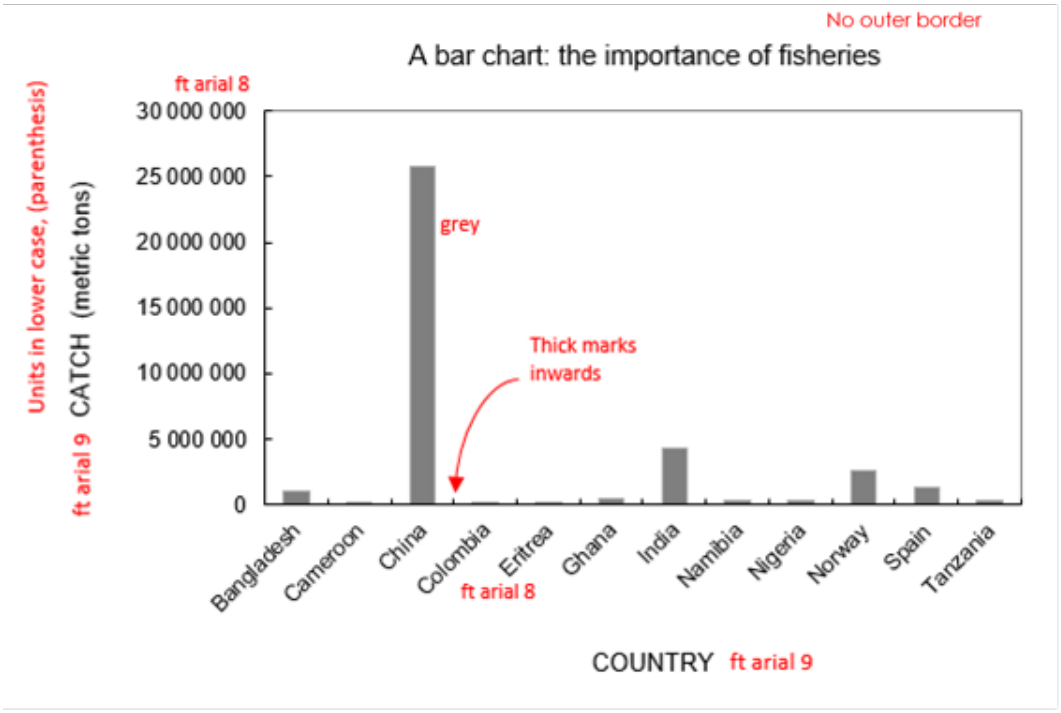

Figure Guidelines for Authors
African Journal of Marine Science

Chapter 3 – Basic calculus and statistics*

QUESTIONS ASKED

- Why rates, and why statistics?
- How to express such quantities in common speech?
- How to present much data in a concise and informative way?
- How to make predictions based on historical trends?

BACKGROUND INFORMATION

- Real statistics: Real statistics using Excel
- Simon Sez: Using simple statistical functions in Excel
- How Tech.Office: Add a trendline in Excel
- A fishery: Enpideguerra – Sea Bites – collecting goose barnacles Galicia

COVERAGE

- Rates
- Measures of tendency and dispersion
- Distributions and histograms
- Diverse trend lines and crude assessment of fit
- XY plots; extrapolation

INFORMATION AND SOFTWARE

The Chapter 3 of FISH IT is a refresher course for those that have some previous knowledge of statistics, but can easily be followed by those that do not have it. Emphasis is placed in the utilization of statistics in daily language and reports, in the summarization of large amounts of data, and in the application of trend lines to time-series data. This is a preparation to the next lab. One also deals with the assumptions of time-series analysis and the limits of extrapolation.

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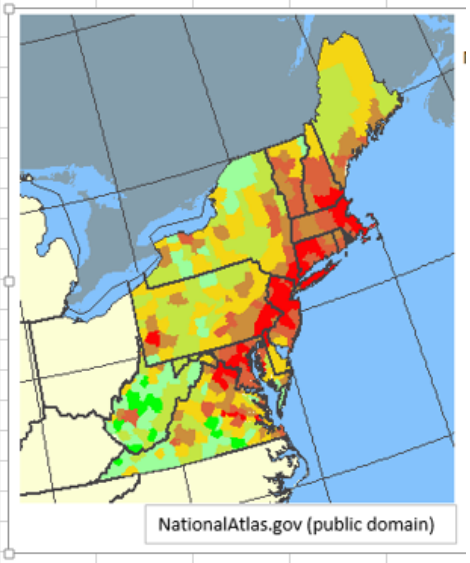
- Ch3 Statistics JdS.xlsx

SNAPSHOTS

TREND ANALYSIS JdS

The distribution of income per capita in households of different sizes.
Fit *all* the possible trendlines to the following set of data
1-Make a chart (x-y plot) of the data
2-Use the trendline option. Remember to choose the 'include equation' option.
3-Which trendline fits the observations better?
4-Using the chosen trendline, try to make an extrapolation for households of up to 35 people.

No. people	income pr. capita
1	0.60
2	0.34
3	0.60
4	0.18
5	0.12
6	0.17
7	0.11
8	0.13
9	0.11
10	0.10
11	0.06
12	0.06
13	0.06
14	0.06
15	0.06
16	0.06
17	0.42
18	0.05
19	0.09



Chapter 4 – Predict the future: trend analysis*

QUESTIONS ASKED

- How to assess the state of a fishery with a minimum of information?
- Where to obtain national and regional fishery data?
- How to interpret simple indicators of abundance?
- Do fisheries have typical cycles that can be recognized?
- How to compare and adjust the fishing power of different fleets?

BACKGROUND INFORMATION

- Wikipedia: Trend estimation
- PivotTableGuy: Excel Video 101-Forecasting Part 1

- A fishery: AZTI - Jigging for bonito in the Basque country

COVERAGE

- National and international databases
- Interpretation of cycles of catch, effort, cpue and relative rate of catch increase
- Typical cycles of a fishery
- Fitting more complex trend lines
- Simple linear standardization of cpue data between fleets

INFORMATION AND SOFTWARE

The Chapter 4 of FISH IT deals with the retrieval of data from databases of landings, the description of trends in time-series of data and their extrapolation to the future. The utilization of the Relative Rate of Catch Increase (Grainger & Garcia 1996) to make an early assessment of the state of a fishery is introduced. In the absence of other types of data, knowledge of the fishery and the cycles of the simplest fishery statistics can give good indications of the abundance of the stock and lead to conservative management measures. Simple linear standardization of catch rates to make data from different fleets comparable is introduced.

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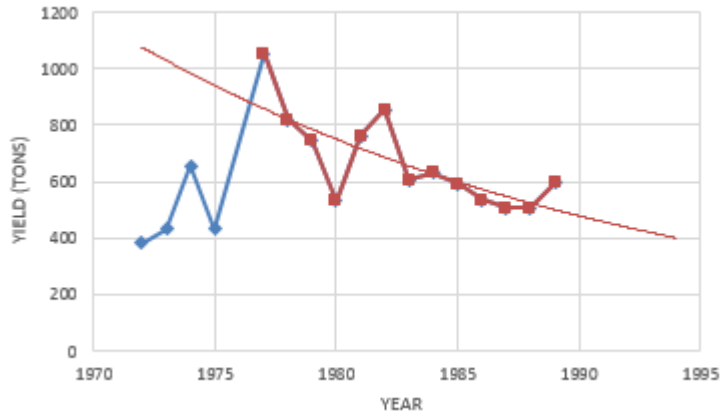
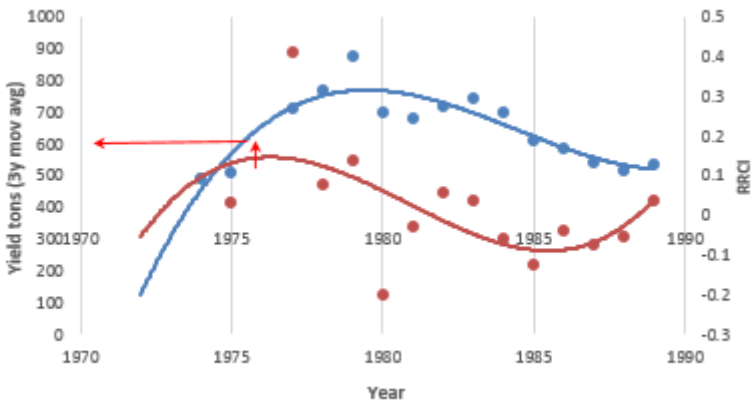
- Ch4a Trend analysis JdS.xlsx
- Ch4b Standardization of catch rates JdS.xlsx

SNAPSHOTS





Chapter 5 – Using simple data: surplus production models*

QUESTIONS ASKED

- How to assess the state of a fishery with a simple series of catch and effort?
- How is a fishery model different from a trend analysis?
- Do the assumptions of the model affect the management values of interest?
- How to word a management advice?

BACKGROUND INFORMATION

- Wikipedia: Population dynamics of fisheries
- Conservation Strategy Fund – Maximum Economic Yield
- A fishery: BBC – Underwater reef fishing in the Philippines

COVERAGE

- Equilibrium version of the Schaefer model: fit by hand and with computer
- Introduction to Solver, an optimization tool in Excel
- Dynamic version of the Schaefer model

INFORMATION AND SOFTWARE

The Chapter 5 of FISH IT deals with the provision of management advice using a simple fishery model that has a biological core. The equilibrium version of the Schaefer model is not utilized in serious fisheries stock assessment. But, since it can be fitted by hand, and is widely used in bio-economics, it is a good introduction to modelling. Then, the biodynamic version of the model, which does not rely on the assumption of equilibrium, is introduced. This part benefited from the recommendations from Punt & Hilborn (1996, 2001). The dataset utilized (King, 2005) is the same as in the previous chapter and allows an interesting comparison among the predictions made with the different methods.

- Ch5 Surplus production equilibrium and dynamic models JdS.xlsx

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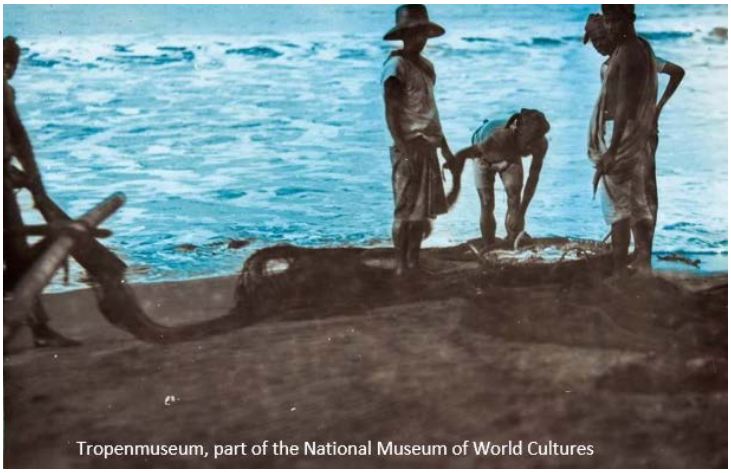
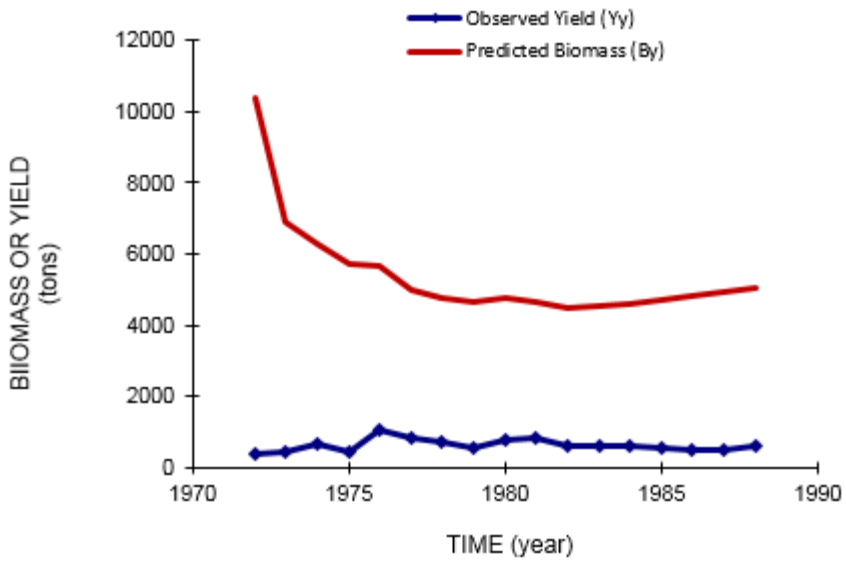
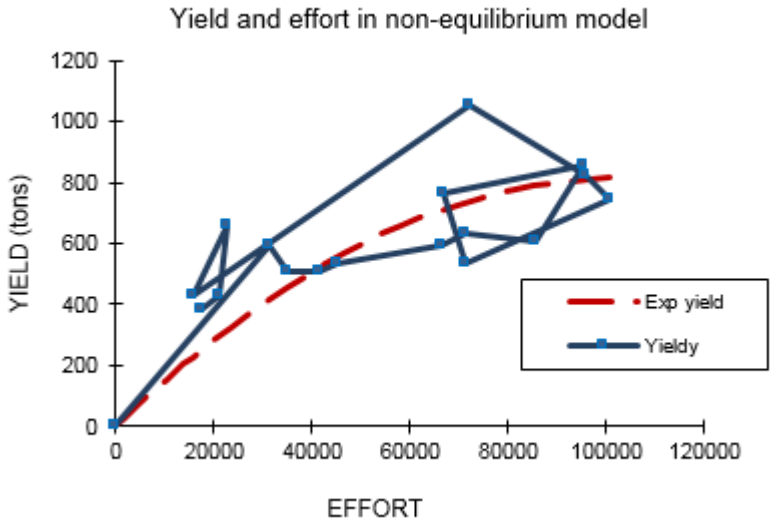
SNAPSHOTS


Tropenmuseum, part of the National Museum of World Cultures


Observed Yield (Yy)
Predicted Biomass (By)
BIIOMASS OR YIELD (tons)
12000
10000
8000
6000
4000
2000
0
1970
1975
1980
1985
1990
TIME (year)


Yield and effort in non-equilibrium model
YIELD (tons)
1200
1000
800
600
400
200
0
0
20000
40000
60000
80000
100000
120000
EFFORT
Exp yield
Yieldy

Chapter 6 – Fish it now or later? Population processes*

QUESTIONS ASKED

- How to describe the life of a cohort?
- How long to wait until we fish a cohort? The dilemma: catch it now or later?
- How to describe the sexual maturation and the recruitment processes in fish?

BACKGROUND INFORMATION

- FAO: Review of the State of the World Marine Resources 2011
- BBC: Reproduction in fish and birds

- Bozeman science: r and K selection
- A fishery: Sealord Story: Who caught your hoki?

COVERAGE

- Introduction to the mathematical treatment of growth and mortality
- Calculation of critical biomass for different life-histories
- The statistical treatment of the sexual maturation and recruitment processes.

INFORMATION AND SOFTWARE

The Chapter 6 of FISH IT deals with mathematical notation utilized in fisheries to describe growth and mortality of a cohort. The biomass development of an un-exploited cohort is calculated in a worksheet-like manner for two species with different life-histories. The logistic regression is introduced to make the fit of sexual maturation curves, and the spawning biomass of a stock is calculated. The Ricker and the Beverton & Holt recruitment functions are utilized and compared with the same set of spawning biomass and recruit data. The text by Haddon (2010) and the collaboration with Natalia Yaragina were very useful to develop the recruitment examples.

- Ch6a Pop processes Growth JdS.xlsx
- Ch6a Pop processes Mortality JdS.xlsx

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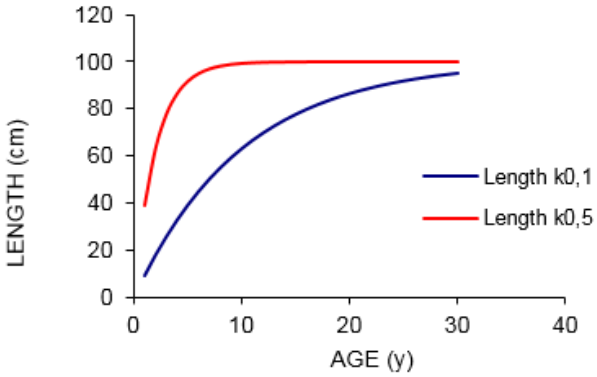
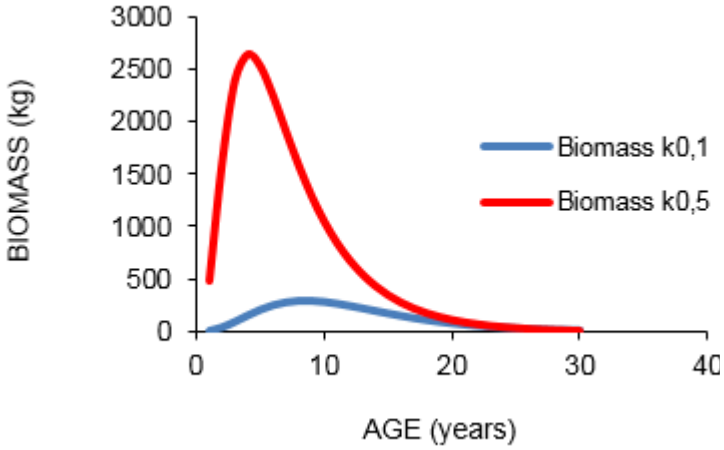
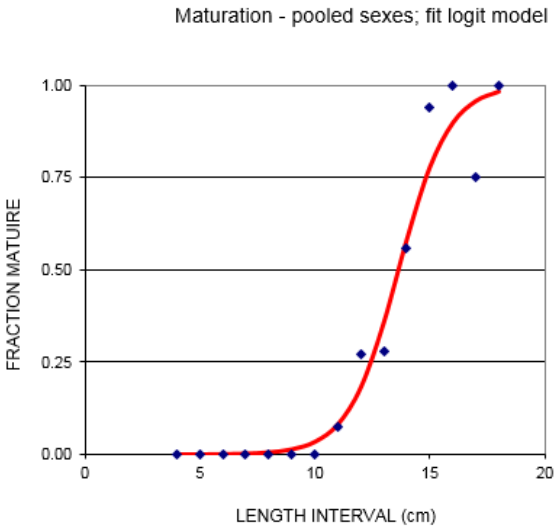
- Ch6a Pop processes Maturation JdS.xlsx
- Ch6d Pop processes Recruitment JdS.xlsx

SNAPSHOTS

Soumya Mukherjee 2012







Chapter 7 – Size and reproduction: yield per recruit model*

QUESTIONS ASKED

- What are the bases of the traditional regulations of effort and gear in fisheries?
- What are the trade-offs between fishing early or late on the reproductive potential of the stocks?
- How certain is the advice, and what are the risks?

BACKGROUND INFORMATION

- Compendium: Fishery Biology – Yield per recruit model
- tweedfoundation: Reading fish scales
- The Guardian: Who should have the right to catch fish?
- A fishery: UNESCO - Shrimp fishing on horseback

COVERAGE

- Yield per recruit and biomass per recruit
- Management advice in fisheries and aquaculture
- Study the uncertainty in the advice with Monte-Carlo methods

INFORMATION AND SOFTWARE

The Chapter 7 of FISH IT deals with the classical yield per recruit model developed by Beverton and Holt, which is described in many textbooks. Equipped with this model the students are expected to provide sound management advice. Although we tend to start this session with an Excel-based model, here only the R-based applications are given. They allow a quicker and more advanced treatment of the model (e.g. calculating isopleths automatically) as well as a study of risk. This requires only a preliminary introduction to the R software by the instructor.

- Ch7a Yield pr recruit R-based JdS.xlsx
- Ch7a R-script YR I PR by projection contour F tc JdS.R
- Ch7a R-script YR II PR by projection single tc (F and f based) JdS.R

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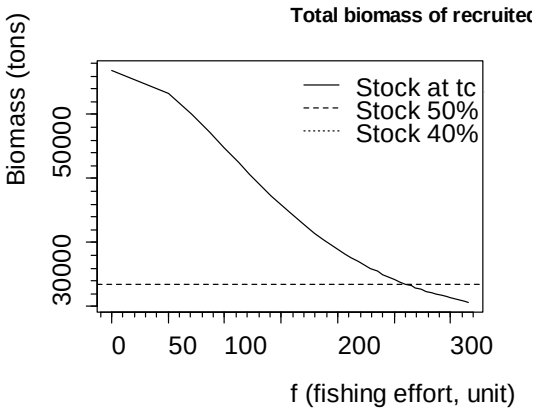
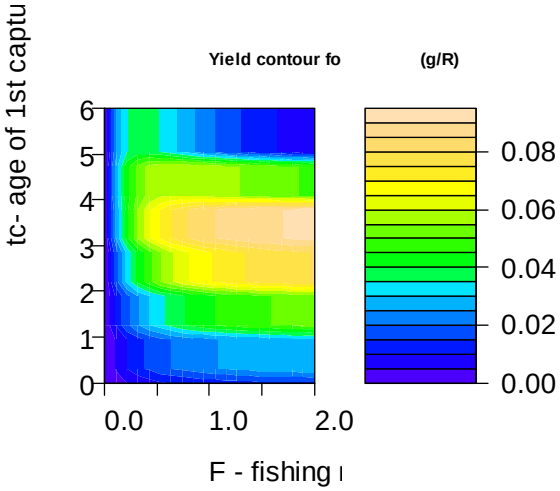
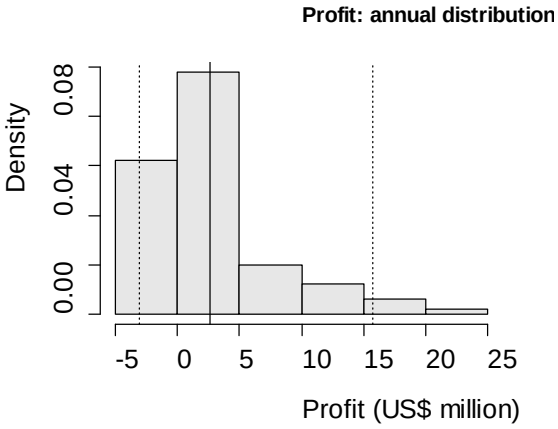
- Ch7a R-script YR III PR by projection Monte Carlo Risk single F tc JdS.R
- Ch7b Yield pr recruit Excel JdS.xlsx

SNAPSHOTS







Chapter 8 – Hands wet: counting the fish*

QUESTIONS ASKED

- How do biologists count organisms in the field?
- How do they design their sampling?
- How can one scale or extrapolate observations to other areas?

BACKGROUND INFORMATION

- UCSC: scientific diving – sampling methods
- Fisheries Research Australia: Tagging fish
- NOAA: Alaska Fisheries Science Center Longline Survey
- Ben Donnelly: Whale Aerial Survey

COVERAGE

- Sampling design: quadrats and distance sampling. Estimates and variance.
- Transects, tagging and depletion methods.
- Research cruises: echo-integration and swept-area surveys

INFORMATION AND SOFTWARE

The Chapter 8 of FISH IT deals with the field methods normally used by biologists to estimate the numbers of fish or sessile organisms in the sea, or on land. There is a great diversity of methods, but they rely on a few basic principles. A good knowledge of sampling design is required if any survey is going to be representative and unbiased. Surveys are normally very costly, and improvement of design increases precision for the same, or lower, cost. Some of these methods can be utilized onboard commercial boats; others are more suitably performed in research vessels. Some exercises deal with scaling of estimates in oceans and lakes. Sample estimates from echo-integration and swept-area surveys are dealt with in a practical lab during the cruise: for sampling strategy consult Galluci et al. (1995) and course manuals.

- Ch8a Sampling design scaling JdS.xlsx

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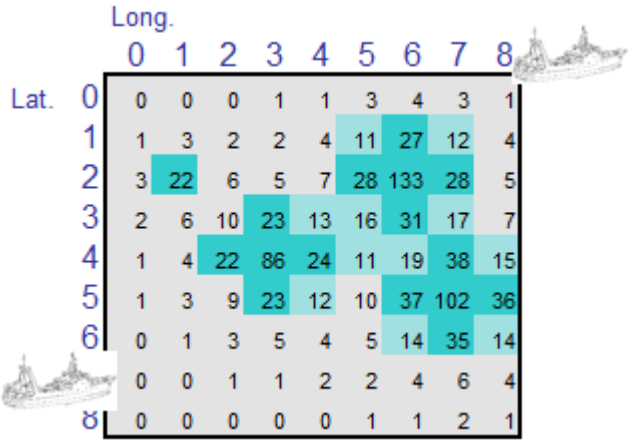
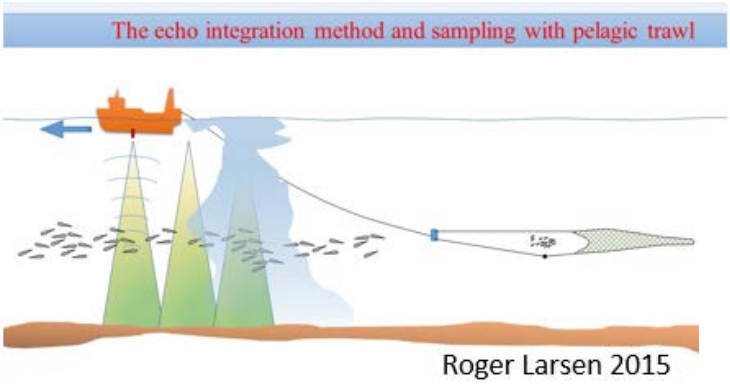
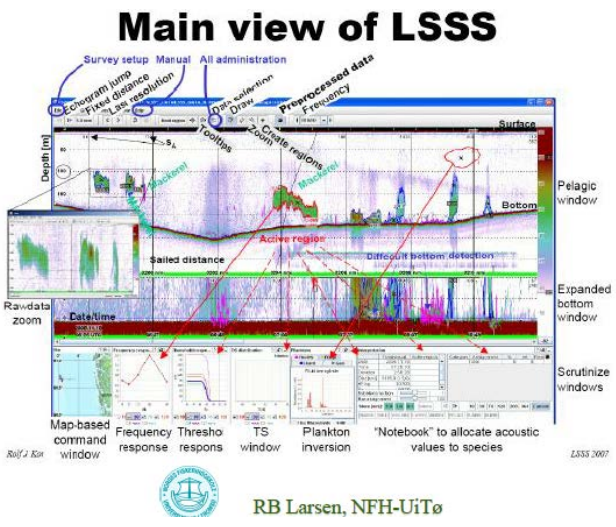
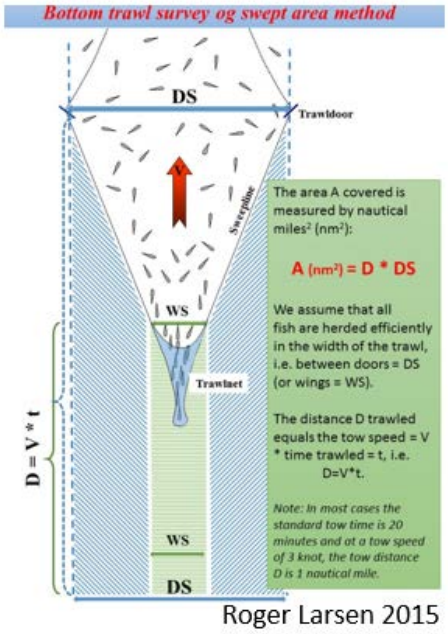
- Ch8b Direct counting (general) JdS
- Ch8c Echo-integration and demersal survey (practicals Tromsø) JdS.xlsx

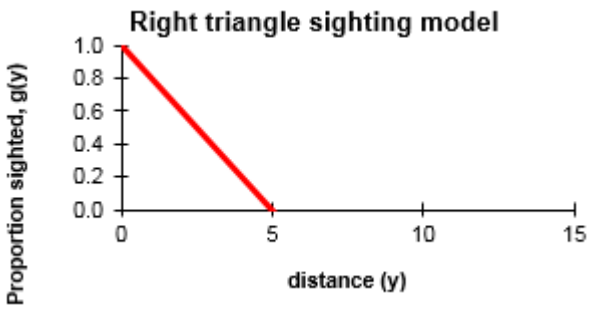
SNAPSHOTS











Chapter 9 – Rules for the future: forecasts and hindcasts*

QUESTIONS ASKED

- How do discuss and agree on fishery management plans for the future?
- Can we develop harvest rules in small-scale fisheries, without models?
- How can we express the probable costs of fishing too much or too little?

BACKGROUND INFORMATION

- Wikipedia: Adaptive management
- Wikipedia: Overfishing
- URIRC: Marine Fisheries Co-Management in Senegal

- A fishery: nanoe91 – Squid fishing Argentina

COVERAGE

- Harvest rules in a quota managed fishery using a model (parametric)
- Statements and calculations of risk
- Adaptive management in small-scale fisheries (non-parametric)

INFORMATION AND SOFTWARE

The Chapter 9 of FISH IT deals with different methods to design harvest rules for the future that can be understood and acceptable by the different agents in a fishery. These agents do not necessarily have deep understanding the dynamics of the stocks, but must be able to express and quantify their goals. The players are asked to formulate strategies, statements of risk and judge the achievements, sometimes in a cooperative way with the other agents in the fishery. The player must understand the socio-economic context of the fishery when developing these strategies. The models used to make forecasts have in-built forms of uncertainty, but are deterministic. This simplifies the calculations of risk by the players.

- Ch9a Forecasts and harvest rules - parametric quotas JdS.xlsx
- Ch9b Adaptive harvest rules - non-parametric JdS.xlsx

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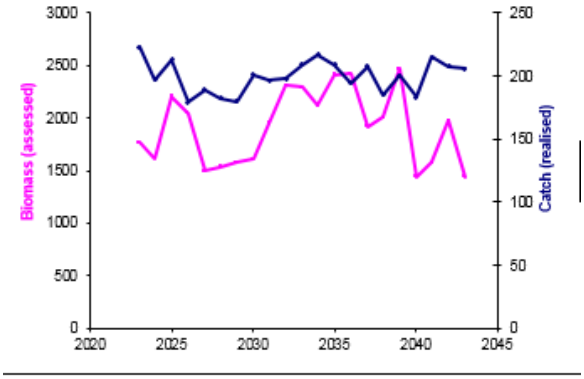
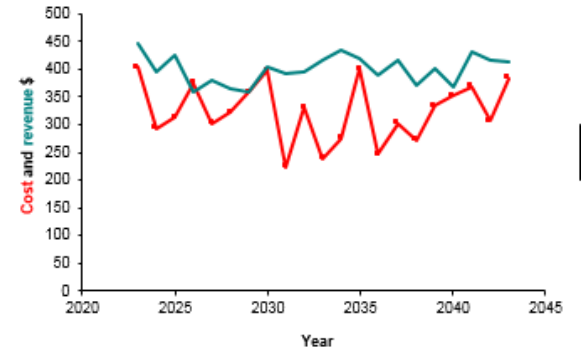
SNAPSHOTS


BH3321
Andrew Thomas

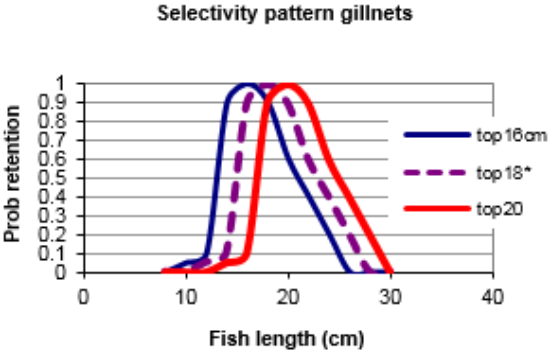

Van der Bank


Biomass (assessed)
Catch (realised)
3000
2500
2000
1500
1000
500
0
250
200
150
100
50
0
2020
2025
2030
2035
2040
2045


Cost and revenue $
500
450
400
350
300
250
200
150
100
50
0
2020
2025
2030
2035
2040
2045
Year


Rudolph.A.furtado


Faizul Latif Chowdhury


Selectivity pattern gillnets
Prob retention
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
Fish length (cm)
top16cm
top18*
top20

Chapter 10 – Catching the same fish: fleet interactions*

QUESTIONS ASKED

- How to apply different effort controls in a fishery?
- What does risk mean in fluctuating fisheries?
- Do we need information from all fleets involved in a fishery?

BACKGROUND INFORMATION

- ShrimpAlliance: How Does A Shrimp Boat Work?
- Global Fishing Watch: Technology Illuminating the global fleet
- Integrated project: IDPPE, Mozambique – Sofala Bank artisanal fisheries project

COVERAGE

- Simultaneous application of technical measures and closed seasons
- Dealing with competing fleets with different socio-economic profiles
- Further practice in the statement of development strategies and risk

INFORMATION AND SOFTWARE

The Chapter 10 of FISH IT deals with a very frequent situation in marine fisheries, which has received little formal treatment: a small-scale coastal fleet catches the same species that is targeted by an industrial fleet offshore. This raises dilemmas about the purpose of managing fisheries, and the players are forced to make clear statements about goals and positive and negative risks associated with the chosen strategies. The game invites to make experiments, but requires that the players devise simple and consistent strategies to be able to test their hypotheses. To increase realism, the simulations are stochastic, which forces the players to measure achievements in terms of probabilities and risk. This is an early version of this game, Sofala Shrimp Fishery v1.0. More advanced and realistic versions have been developed over the years, but this one has been often tested by students in the computer lab. Much of the background for this fishery is explained by de Sousa et al. (2006) and in special lectures. In the 2nd workbook the presence of the artisanal fleet is recognized and accounted for in the management of the fishery.

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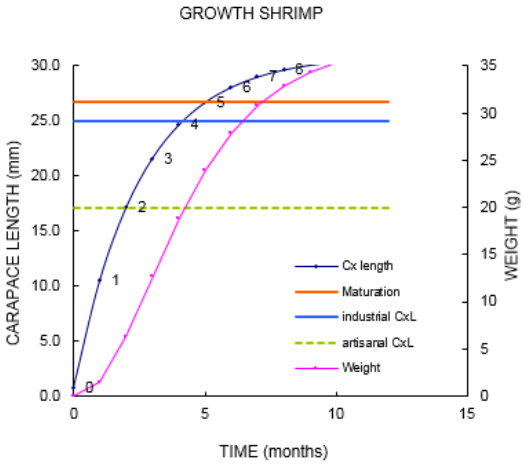
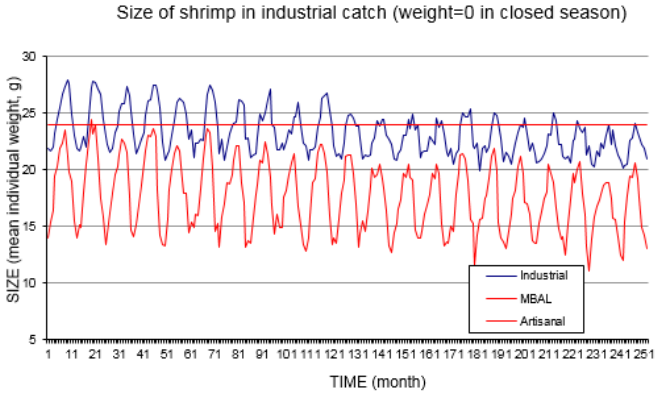
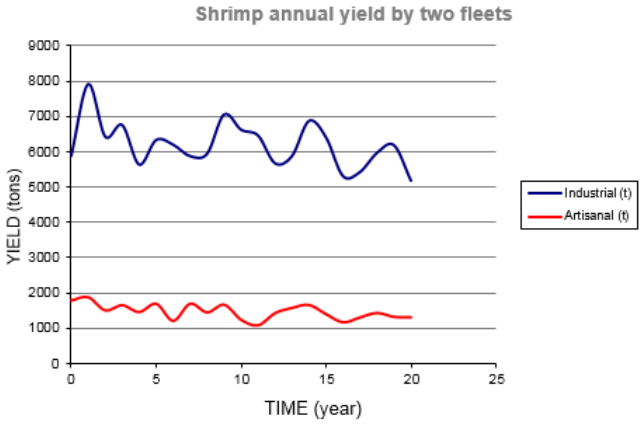
- Ch10a Shrimp industrial fishery JdS.xlsx
- Ch10b Shrimp multi-fleet fishery JdS.xlsx

SNAPSHOTS







Chapter 11 – Competing with predators: multispecies and stakeholder interactions in fluctuating environments*

QUESTIONS ASKED

- How does the climate influence a fishery?
- How to conciliate the interests of predators?
- How to conciliate the interests of different industries?

BACKGROUND INFORMATION

- Minnesota Sea Grant: Food web in Lake Superior
- USGS: Climate Change Effects on Fisheries in the Great Lakes
- UWASC: How Many Sport Fish Can Lake Michigan Support?
- A fishery: InDepthOutdoorsTV – Sports fishing trout in Lake Superior

COVERAGE

- A bottom-up controlled fishery in the absence of information on predators
- Seasonal cycles and control of predators
- Application of technical measures and closed seasons in complex settings

INFORMATION AND SOFTWARE

The Chapter 11 of FISH IT deals with environmental forcing and multispecies interactions in a relatively simple three-species fishery. As in the earlier chapter, the first workbook depicts a situation where management is performed in absence of full information. In the second workbook the information about predators is explicit and the players have to develop fishery strategies that reconcile the interests of different stakeholders. Environmental forcing can be modulated by the user to remove complexity. These examples and this game were suggested by the fishers of Corrumane dam who had themselves very sophisticated suggestions about the best population management strategies. The last example is a cruise + lab practical on the utilization of network analysis (Ecopath, Christensen et al. 2005) to describe the food web of a fjord.

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- Ch11a Corrumane dam ecosystem Mono JdS
- Ch11b Corrumane dam ecosystem Multi JdS
- Ch11c Balsfjord ecosystem with Ecopath (practicals Tromsø)

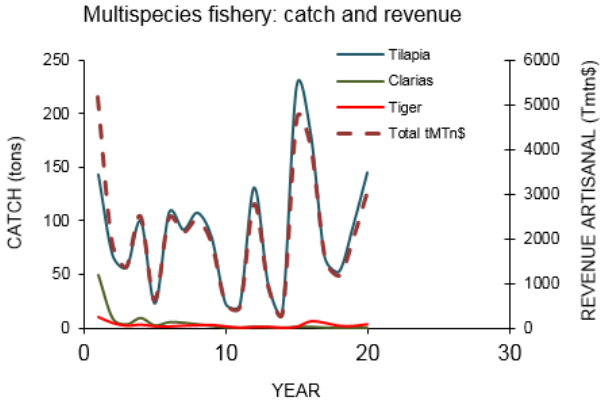
SNAPSHOTS

Ecological regime

Flow cycl	1	1=constant; 2=seasonal; 3=seasonal + annual

Food preference matrix

Prey	Tilapia	Clarias	Tiger
1ary prod	0.8	0.2	
2ary prod	0.2	0.6	0.2
Fish		0.2	0.8



Chapter 12 – In conclusion: how to manage fisheries? *

QUESTIONS ASKED

- What is the real state of fisheries around the world?
- What experiences have we on the assessment and management of different fish populations?
- When should we invest, or refrain from investing or intervening, in the fishing industry?

BACKGROUND INFORMATION

- Daniel Pauly - CIESM Panel on Fishery Governance
- Ray Hilborn Plenary, Seafood Summit 2011
- CLAW 14'- Group 3: Balanced Harvesting
- EUsem1 Sustainable Fishing Methods
- Costello et al. 2013 Status of the world's unassessed fisheries

COVERAGE

- Conflicting views about the state and management of marine fisheries
- Simple rules of the thumb for fishery and ecosystem management
- Challenges for the student

INFORMATION AND SOFTWARE

The Chapter 12 of FISH IT reveals that despite the large body of knowledge in fishery science, we are still far from agreeing on the best methods to manage or govern our fisheries. This is probably a challenge for the students who would expect more objective advice from science. With basis on their long professional experience, rather than complicated mathematics, Caddy & Gulland made in 1983 a very good, and still relevant, summary of the limitations of fishery science. They suggested possible strategies to handle and invest in different types of fisheries around the world. Students are otherwise challenged to address the policy of balanced harvesting (e.g. Garcia et al 2015), by discussing it, or by making simulations based on either some of the software distributed in this package or developed by their instructors (practicals in Tromsø). It should be

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recognized that changes in the way we exploit aquatic populations might require adaptation in the whole governance process and management procedures.

- Balanced harvest single-species
- Balanced harvest food web

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