Introduction to CMSY/BSM Stock Assessment

13 January 2017
G.S. Khush Hall, IRRI Los Baños, Laguna, Philippines

Contents

Foreword

Fisheries stock assessment characterizes the past and current status of a fish population and allows scientists to predict how it will respond to management actions. Maximum Sustainable Yield (MSY), the largest catch that can be taken from a stock over an indefinite period, is the parameter used in fisheries stock assessments. Several methods based on various biological parameters have been used to estimate MSY, most with intensive data requirements. Recently, Rainer Froese and colleagues introduced a method that can estimate MSY in data-poor situations, for example in countries like the Philippines where aging of fish is problematic and abundance data are scarce..

A workshop introducing this new methodology was organized by the FishBase Information and Research Group (FIN) in collaboration with Philippine Bureau of Fisheries and Aquatics Resources - National Fisheries Research and Development Institute (BFAR-NFRDI) on 13 January 2017 at FIN headquarters in Los Baños, Laguna, Philippines. Data on catch and relative abundance from the Natonal Stock Assessment Program (NSAP) of NFRDI; reconstructed catches and catch per unit effort (CPUE) from the Sea Around Us (Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, Canada); and Bayesian priors for biological parameters from FishBase were used.

The main objective of the workshop was to introduce to the NSAP regional personnel the application of this stock assessment tool to data they gathered from their regions. Participants were also shown that such tools can be misused, for example when using data that are not representative of the stock.

Overall, this workshop succeeded in its objective in making NSAP members aware that MSY, stock status and exploitation level can be estimated even with only a 10-year time series of catch data. The positive feedback from the NSAP participants indicated to us that there might be future collaborations between FIN and NFRDI on further training workshops like this and possible consultations on the interpretation of results from these workshops.

The Workshop Organizers:

- Maria Lourdes D. Palomares, FIN Associate Scientific Director
- Mary Ann Bimbao, FIN Executive Director

Workshop Programme

08:00   Welcome, Introduction of participants[1]
(Chair: Dr. Maria Lourdes Palomares, Institute for the Oceans and Fisheries, University of British Colombia, Canada)

08:15   Introduction to CMSY/BSM
(Resource Person: Dr. Rainer Froese, GEOMAR, Helmholtz-Centre for Ocean Research, Germany)

10:00   Coffee Break, setting up of participant computers, connecting to WLAN

10:30   Installing RStudio, R, libraries, JAGS, CMSY

11:00   Getting participants data into CMSY format

11:30   Getting priors from FishBase

12:00   Lunch

13:00   Running analyses

15:00   Coffee break

15:30   Presenting results (participants)

16:30   Discussing usefulness of CMSY/BSM

17:00   Closing Remarks
(Executive Director: Dr. Mary Ann Bimbao, FishBase Information and Research Group)

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[1] See list of participants in Annex A.

Introduction to Data-Limited Stock Assessment Using CMSY / BSM

Lecture by Rainer Froese

This study presents a Monte Carlo method (CMSY) for estimating fisheries reference points from catch, resilience, and qualitative stock status information on data-limited stocks. It also presents a Bayesian state-space implementation of the Schaefer production model (BSM), fitted to catch and biomass or catch per unit of effort (CPUE) data. Special emphasis was given to derive informative priors for productivity, unexploited stock size, catchability, and biomass from population dynamics theory. Both models gave good predictions of the maximum intrinsic rate of population increase r, unexploited stock size k and maximum sustainable yield MSY when validated against simulated data with known parameter values. CMSY provided, in addition, reasonable predictions of relative biomass and exploitation rate. Both models were evaluated against 128 real stocks, where estimates of biomass were available from full stock assessments. BSM estimates of r, k, and MSY were used as benchmarks for the respective CMSY estimates and were not significantly different in 76% of the stocks. A similar test against 28 data-limited stocks, where CPUE instead of biomass was available, showed that BSM and CMSY estimates of r, k, and MSY were not significantly different in 89% of the stocks. Both CMSY and BSM combine the production model with a simple stock-recruitment model, accounting for reduced recruitment at severely depleted stock sizes.[2]

Rainer Froese is a Senior Scientist at the GEOMAR Helmholtz Center for Ocean Research in Kiel, formerly the Leibniz Institute of Marine Sciences, and a Pew Fellow in Marine Conservation.

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[2] Rainer Froese, Nazli Demirel, Gianpaolo Coro, Kristin M. Kleisner, Henning Winker. *Abstract*. In Rainer Froese, Nazli Demirel, Gianpaolo Coro, Kristin M. Kleisner, Henning Winker. Estimating fisheries reference points from catch and resilience. Fish and Fisheries. DOI 10.1111/faf.12190. (2016)

Introduction to Data-Limited Stock Assessment using CMSY/BSM

Rainer Froese, GEOMAR

Stock Assessment Workshop organized by FIN

13 January 2017, IRRI, Los Baños, Laguna, Philippines

Overview

- Too many stocks, too few data
- Reminder of surplus production modelling
- Getting priors for resilience
- Estimating fisheries reference points from catch and resilience
- Conclusions

Too many stocks, too few data

- New legislation in the US and in Europe (and presumably also in the Philippines) requires management of all exploited stocks
- In Europe, of about 400 exploited stocks, only 100 have sufficient data for traditional age-structured stock assessment
- New approches are needed to get reasonable assessments with less data
- New data-light but computation-heavy methods come to the rescue

Thomas Robert Malthus

(1766 – 1834, English Economist)

An Essay on the Principle of Population (1798)

$$N_t = N_0 e^{r_{max}t}$$

where N_t is the population number at time t, N_0 is the number at start, and r_{max} is the maximum intrinsic rate of population increase, the Malthusian parameter.

The equation describes unlimited, exponential growth.

World Population Growth

"The power of population is indefinitely greater than the power in the earth to produce subsistence for man"
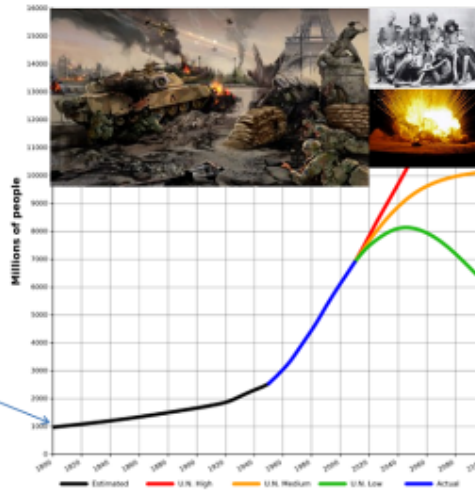
Pierre François Verhulst
(1804 – 1849, Belgian Mathematician)

The logistic equation (1844)
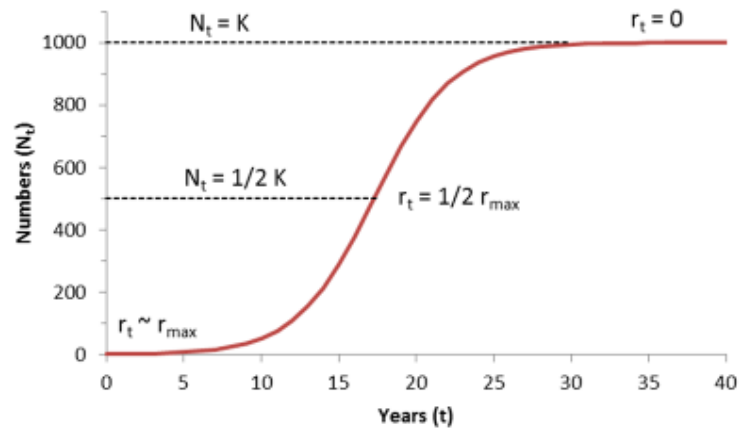
$$\frac{dN}{dt} = r_{max} N_t (1 - \frac{N_t}{K})$$

$$N_t = \frac{K}{1 + e^{-r_{max}t}} = \frac{K N_0 e^{r_{max} t}}{K + N_0(e^{r_{max} t} - 1)}$$

where K represents the carrying capacity, i.e., the maximum number of individuals that a given environment can support.

Logistic Curve Properties

BioDivPopGrowthMSY.xls

Milner Baily Schaefer
(1912 – 1970, US Fisheries Scientist)

Some aspects of the dynamis of populations important to the management of the commercial marine fisheries (1954)
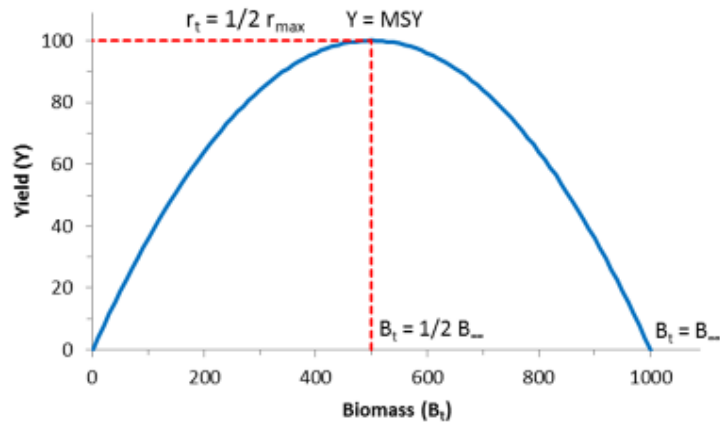
The **Schaefer model** builds on the logistic curve, replaces population numbers with biomass, defines surplus production as yield, and establishes the *MSY* concept of **m**aximum **s**ustainable **y**ield.

$$Y = r_{max} B_t (1 - \frac{B_t}{B_\infty})$$

$$MSY = \frac{r_{max}}{2} \frac{B_\infty}{2} = \frac{r_{max} B_\infty}{4}$$

where *Y* is the surplus production or yield, B_t is the biomass at time t, and B_∞ is the carrying capacity of the ecosystem for this population.

The Schaefer Model

Life History Correlates of r_{max}

$r_{max} = 2\ F_{msy}$ (Schaefer 1954)

$r_{max} \sim 2\ M$ because $M \sim F_{msy}$ (Gulland 1971)

$r_{max} \sim 3\ k$ because $k \sim 2/3\ M$ (Jensen 1996)

$r_{max} \sim 9/t_{max}$ because $t_{max} \sim 3/k$ (Taylor 1958)

$r_{max} \sim 3.3/t_{gen}$ because $t_{gen} \sim 1/k$ (Roff 1984)

$r_{max} = f(\text{Fecundity} < 1000)$ (Musick 1999)

These relations were used to predict r_{max} in FishBase for currently close to 1000 species:

Merluccius merluccius (Linnaeus, 1758)
European hake

Upload your photos and videos
Pictures | Stamps, Coins | Google image

Add your observation in Fish Watcher
Native range | Point map | Year 2100
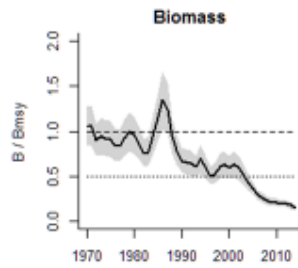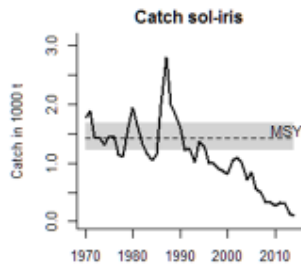
Merluccius merluccius
Picture by Svensen, R.
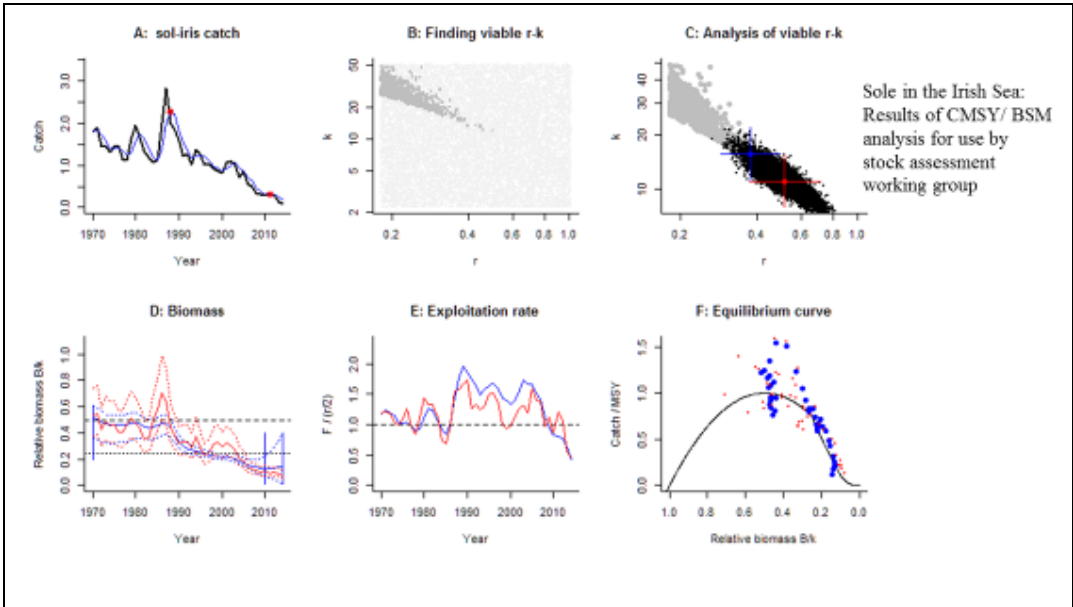
Herkentus merluccius   AquaMaps   Data sources: GBIF OBIS

Estimates of some properties based on models

Resilience (Ref. 69278): Medium, minimum population doubling time 1.4 - 4.4 years (K=0.07-0.3; tmax=20; Fecundity=7 million)

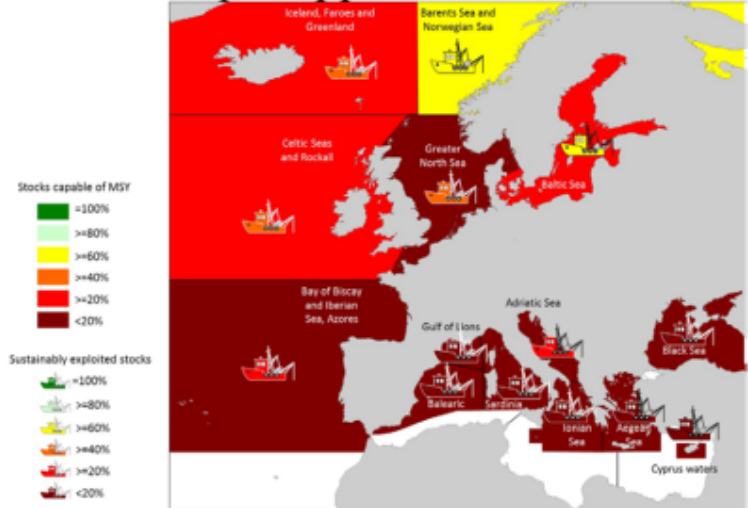Prior r = 0.46, 2 SD range = 0.22 - 0.95, log(r) = -0.78, SD log(r) = 0.37, Based on: 3 M, 76 K, 24 tgen, 7 tmax, 38 Fec records
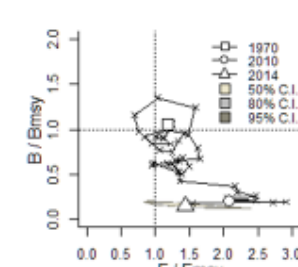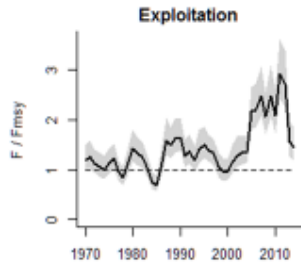
Sole in the Irish Sea: Graphical results of CMSY / BSM analysis for use by management

A: sol-iris catch
B: Finding viable r-k
C: Analysis of viable r-k

Sole in the Irish Sea:
Results of CMSY/ BSM
analysis for use by
stock assessment
working group

D: Biomass
E: Exploitation rate
F: Equilibrium curve

Proof of Concept: Application to 400 Stocks

Conclusions

- For most commercially exploited stocks, data are lacking to do traditional age-structured stock assessments
- New computation-intensive methods can estimated fisheries reference points and stock status from catch and resilience
- However, there is no silver bullet here: garbage in garbage out remains true

Using CMSY/BSM[3]

Challenges encountered in installing CMSY software

- Installation of software on Mac Os.

- Errors on loading packages on Rstudio and running the program on some units where older versions of R and Rstudio have been installed.

Questions and clarifications during hands-on exercise

1. What are the minimum data requirements (i.e., number of records) for the tool to work?

   A minimum of 10 consecutive years of catch data is required.

2. Can you use catch data from different years?

   Yes, as long as the data is continuous for 10 years or more. In cases where data is missing for some in between years, a reconstruction of that data would be necessary. For this exercise, reconstruction was done by interpolating data between years. Methods of catch data reconstruction are available via the work of the Sea Around Us (Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, Canada).

3. Can you use abundance data from different years?

   Yes, even if the abundance data is not continuous for 10 years it can be used. A minimum of three data points is needed for this to be of value to the analysis.

4. Can the data be assessed per gear used?

   If catch data is available for multiple gears, data with the gear that represents most of the catches in the area would be used.

5. Can this method be used for bays?

   If the data for a bay is representative of the whole stock, that is including the part of the stock that goes in and out of the bays, then that data can be used for the analysis. However, in most cases, such data only represents a part of the stock, and would therefore lead to an incomplete picture of the state of the stock. Ideally, the total catch for the complete distribution area of the stock is used.

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[3] Based on CMSY User Guide in Annex B.

Data used and results of analyses during hands on exercise

In order to demonstrate the CMSY method to participants, four data sets (*Decapterus macrosoma*, *Katsuwonus pelamis*, *Rastrelliger brachysoma*, and *Sardinella fimbriata*) were rendered in the required format using the results of Palomares and Pauly (2016)[4], downloaded from the Sea Around Us database (www.seaaroundus.org, version of 12 January 2017). This reconstructed data include catches by Philippines fishers and catches of fishers from other countries within the Philippine EEZ. The reconstruction of the data set involved, i.e., a) estimating the subsistence and artisanal catches from catch per unit of effort per fisher and multiplying this to the number of fishers; b) estimating the recreational catches from catches reported by game fishers via tournament websites; c) estimating the catch of tuna and large pelagic species from outside the Philippine EEZ and subtracting this from the reported industrial fisheries catches. Abundance estimates based on catch per unit of effort (CPUE) from independent studies used in the various contributions in Palomares and Pauly (2014)[5] were used. Priors for the instantaneous rate of population increase (rmax) and resilience were obtained from FishBase (www.fishbase.org, consulted on 13 January 2017).

Results of these analyses are shown in Figures 1-4, which suggest that all of these four stocks are exploited above their MSY levels, are currently below the level that can produce MSY,,but not reaching the critical point of half BMSY where recruitment may be impaired, and are being exploited at high levels (F/FMSY>1). If management options are to be based on these results, short term fishery restrictions (like closure of the fisheries at spawning or migration time or in certain areas) might need to be put in place in order to let these stocks recover at levels that can produce maximum yields.

The participants applied the CMSY method to their own data, i.e., three marine (*Decapterus macrosoma*, *Encrasicholina punctifer*, *Katsuwonus pelamis*) and one freshwater (*Sardinella tawilis)* stock. These data sets were gathered by NSAP personnel in order to establish baseline parameters for stock assessment. The NSAP program was created by the Philippine Department of Agriculture under BFAR in 1997 in response to "*the lack of standardized and continuous information on fishery resources which is fundamental to fishery management and the apparent institutional incapacity of the Regional Field Units to conduct resource assessment studies in their respective areas of jurisdiction*"[6]. The participants' data represented fishing areas in Central Luzon, including Tayabas Bay and Taal Lake, spanning the period 1996-2016.

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[4] Ma. Lourdes Palomares and Daniel Pauly. *Philippines*. In Daniel Pauly and Demirel Zeller (eds.). Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts. (Washington D.C.: Island Press, 2016), 367.

[5] Ma. Lourdes Palomares and Daniel Pauly. *Philippine Marine Fisheries Catches: A Bottom-up Reconstruction, 1950 to 2010.* Fisheries Centre Research Report 22, (Vancouver, BC: Fisheries Centre, University of British Columbia, 2014).

[6] Quoted from a description of NSAP by Francisco Torres, Jr. available at http://nsap.weebly.com/about-us.html, consulted on 25 January 2017.

Figures 5-8 show the results of the analyses of NSAP data, which suggest that the three marine stocks are being exploited above MSY in recent years. In addition, the results for the Taal Lake sardine (Figure 8) suggest that it has now crashed to dangerously low levels due to the high exploitation since the late 1990s. It is interesting to note that although the data is only representative of Central Luzon marine fishing areas, the results for *K. pelamis* (Figure 6), though with a wider range of uncertainties, concur with those of the reconstructed data (Figure 2). This suggests that this stock is indeed being fished above MSY levels and that if nothing is done to stop the high exploitation levels in recent years, this stock might continue the downward trend as suggested in Figure 2. Finally, the more optimistic results of *D. macrosoma* from Tayabas Bay (Figure 5) is due to the fact that this stock has a wider distribution range within Philippine waters. Thus, the Tayabas Bay data might be too 'local' and thus not representative of the stock.

These eight data sets, which were analyzed in a 6-hour workshop, provided insights to the status of these highly important fish stocks in Philippine waters. The participants were impressed at the ease of use of the CMSY method and saw its usefulness in NSAP. This led to discussions on organizing a training module within NSAP that focuses on the application of the CMSY method to national data. The results of which will be used to validate existing MSY estimation methods.
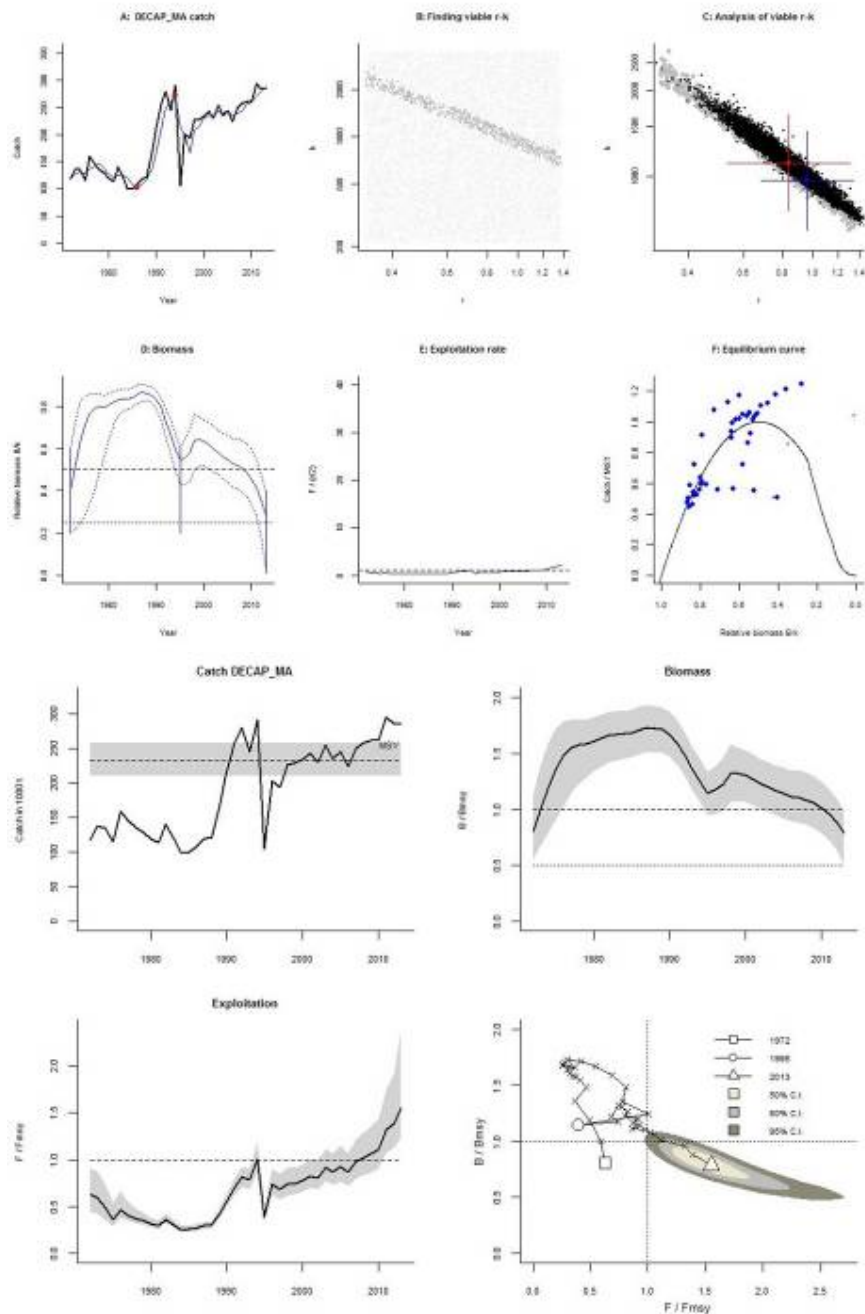
Figure 1. Analysis of *Decapterus macrosoma* stock from the Sea Around Us reconstructed catch data of Western Central Pacific, Philippines (downloaded January 12, 2017 from www.seaaroundus.org). The input catch data was available for 1950-2013. The CMSY analysis was based on the period 1972-2013. Abundance was based on independent estimates of catch per unit of effort data for 1972, 1996 and 2003 (see contributions in Palomares and Pauly, 2014).
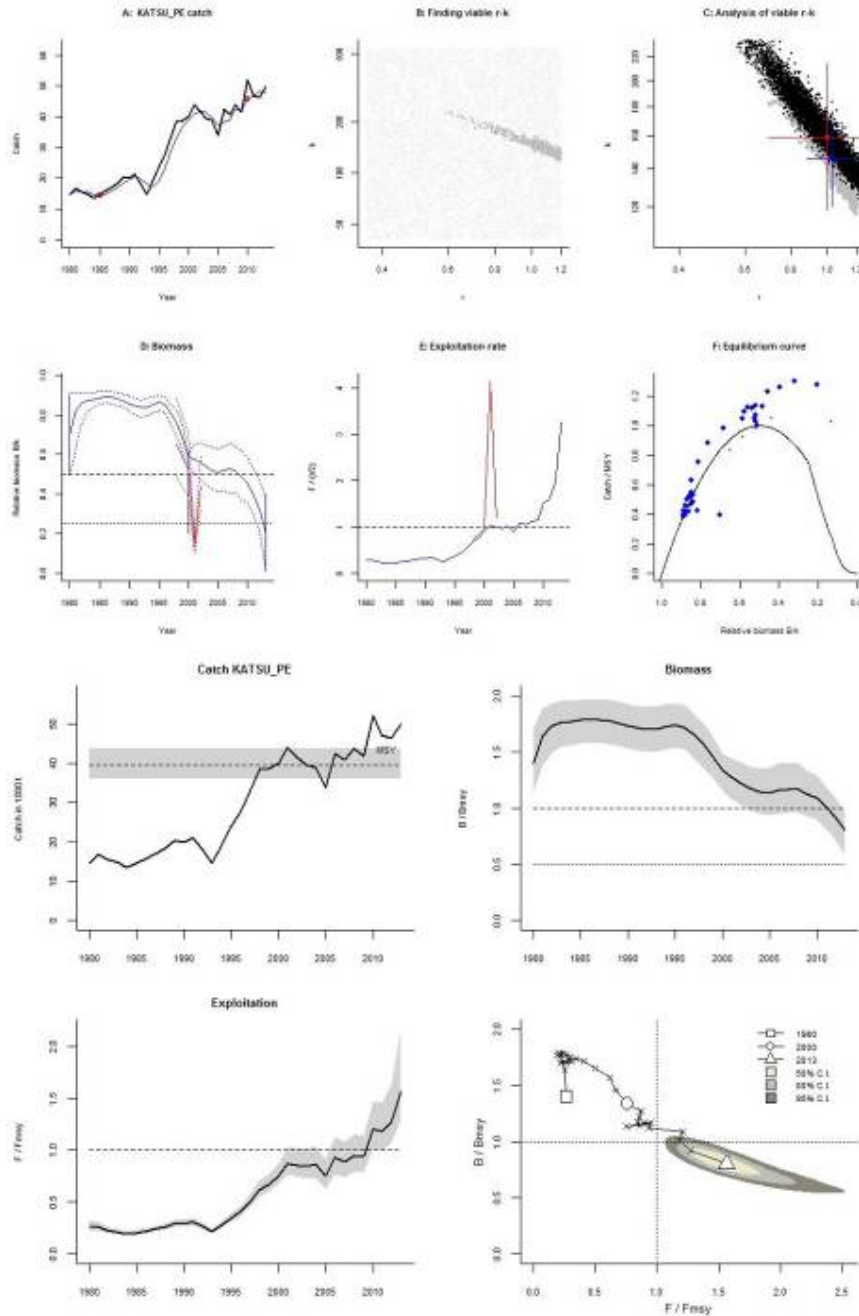
Figure 2. Analysis of *Katsuwonus pelamis* stock from the Sea Around Us reconstructed catch data of Western Central Pacific, Philippines (downloaded January 12, 2017 from www.seaaroundus.org). The input catch data was available for 1950-2013. The CMSY analysis was based on the period 1980-2013. Abundance was based on independent estimates of catch per unit of effort data for 1998-2002 (see contributions in Palomares and Pauly, 2014).
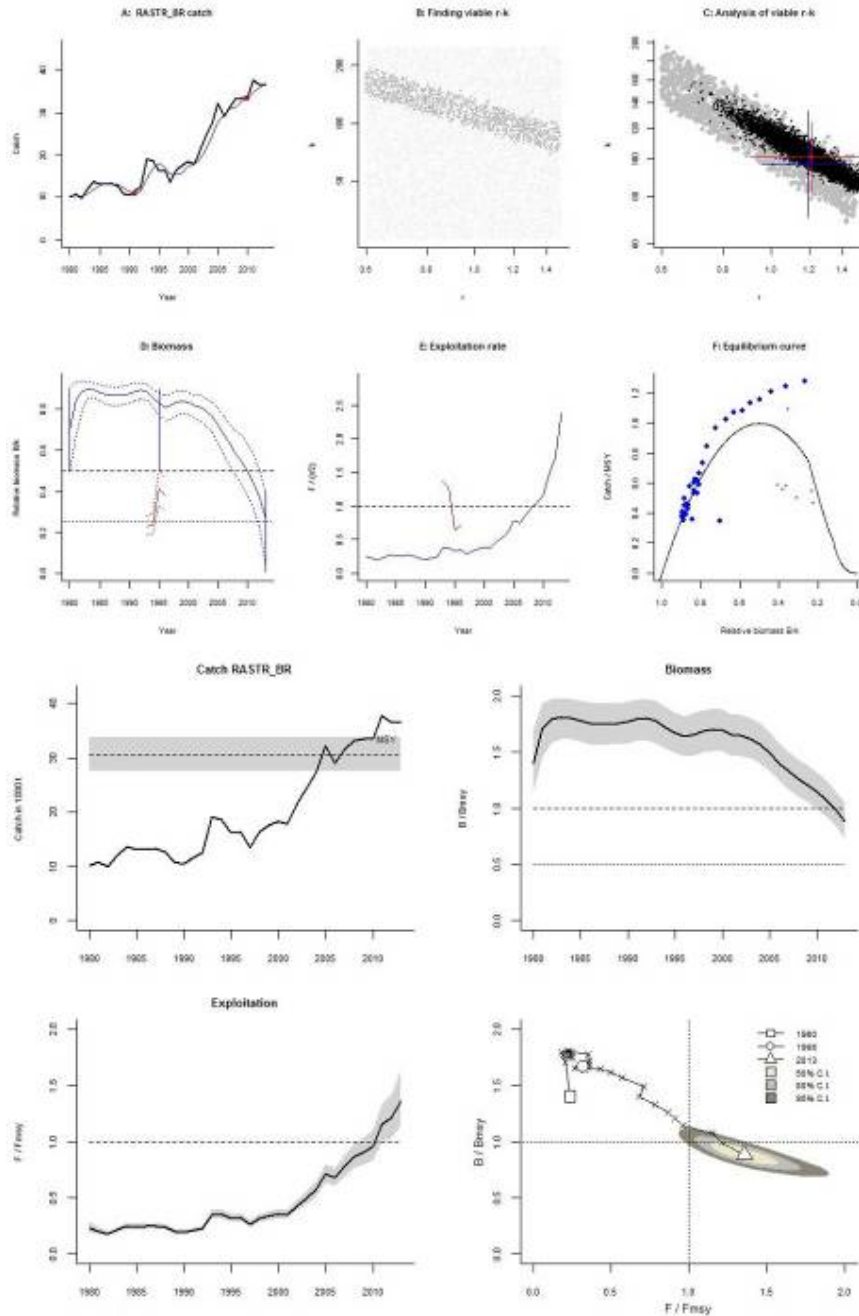
Figure 3. Analysis of *Rastrelliger brachysoma* stock from the Sea Around Us reconstructed catch data of Western Central Pacific, Philippines (downloaded January 12, 2017 from www.seaaroundus.org). The input catch data was available for 1950-2013. The CMSY analysis was based on the period 1980-2013. Abundance was based on independent estimates of catch per unit of effort data for 1993-1996, 1998-2001, 2010 (see contributions in Palomares and Pauly, 2014).
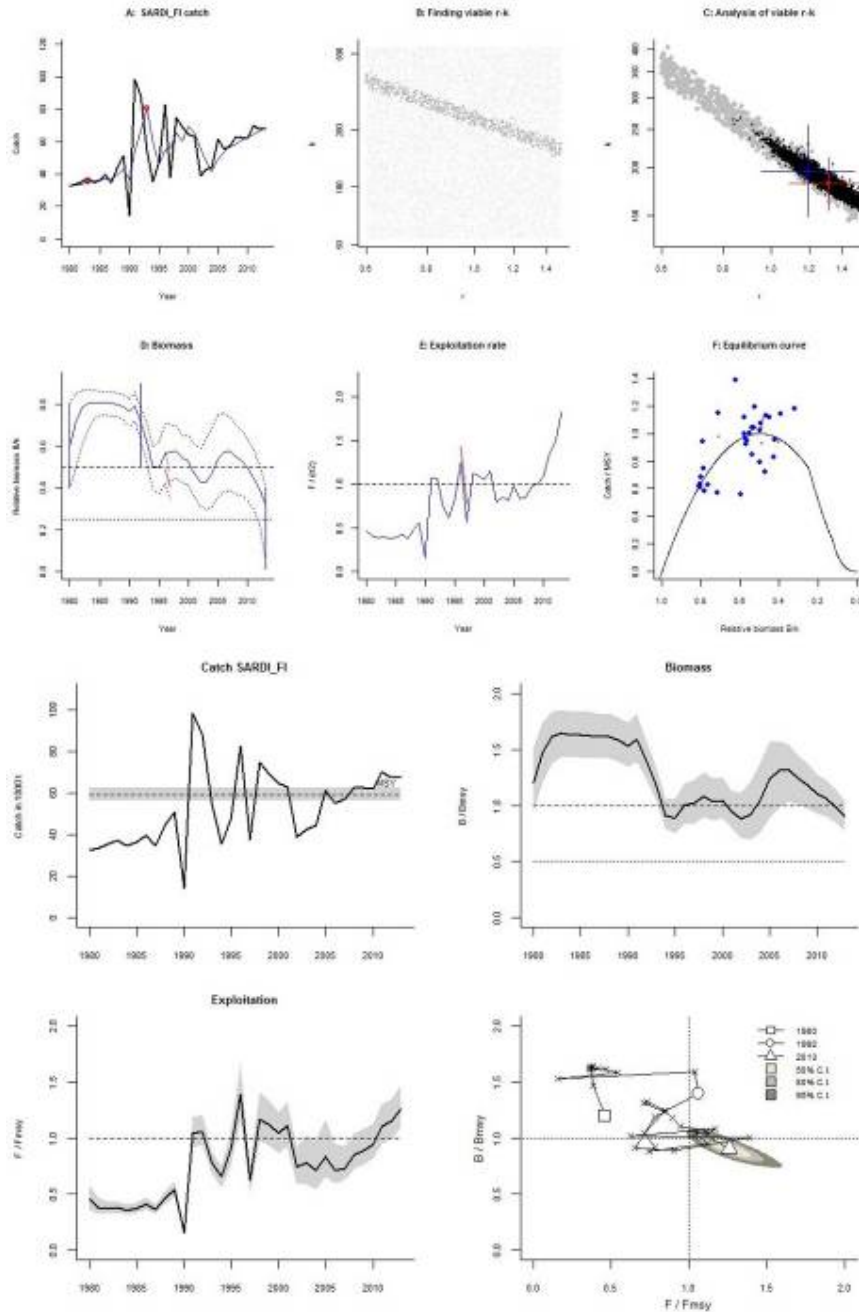
Figure 4. Analysis of *Sardinella fimbriata* stock from the Sea Around Us reconstructed catch data of Western Central Pacific, Philippines (downloaded January 12, 2017 from www.seaaroundus.org). The input catch data was available for 1950-2013. The CMSY analysis was based on the period 1980-2013. Abundance was based on independent estimates of catch per unit of effort data for 1996-1997, 2001, 2007, 2010 (see contributions in Palomares and Pauly, 2014).
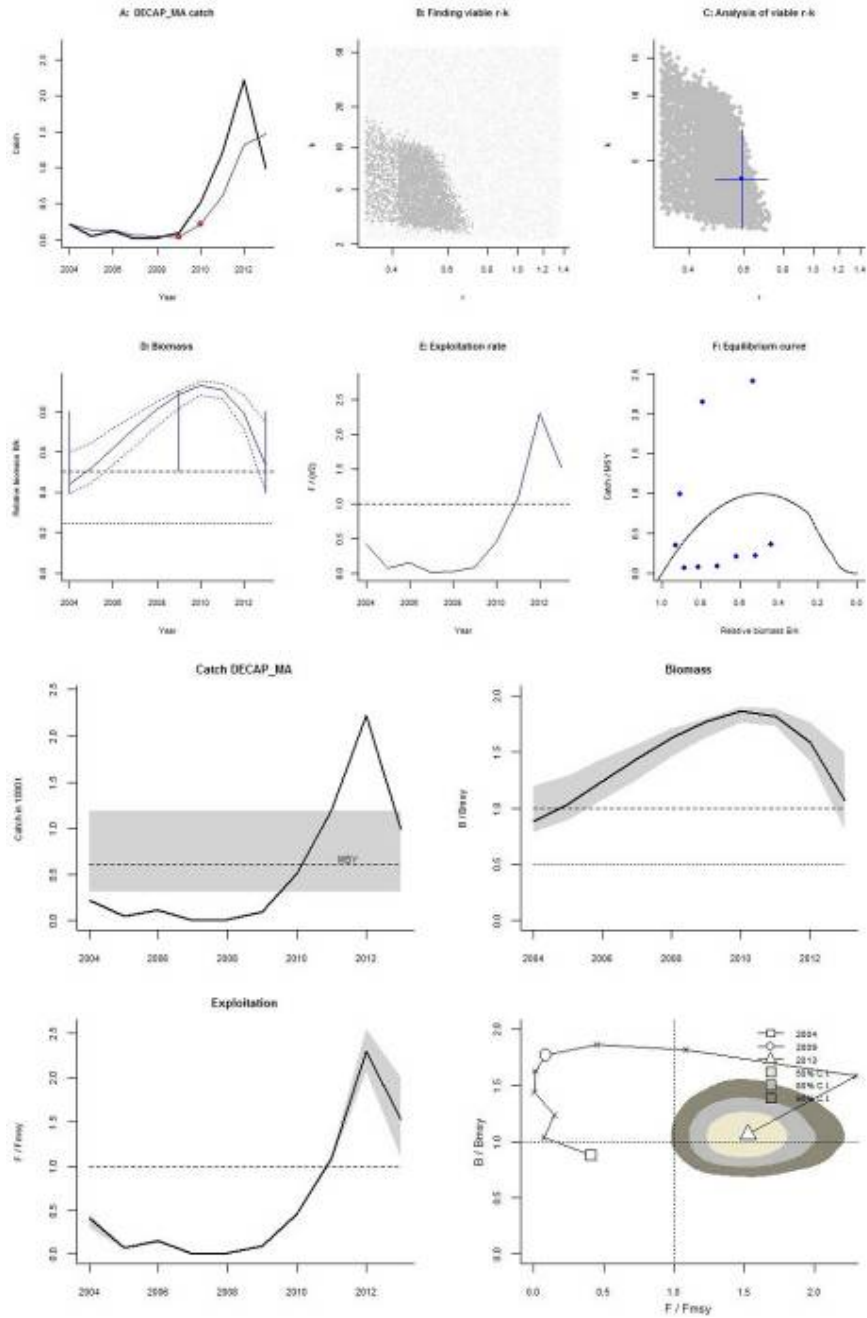
Figure 5. Analysis of *Decapterus macrosoma* stock from NSAP catch data of Tayabas Bay, Region IVA, Philippines. The CMSY analysis was based on the period 2004-2013. No abundance data was available for this analysis.
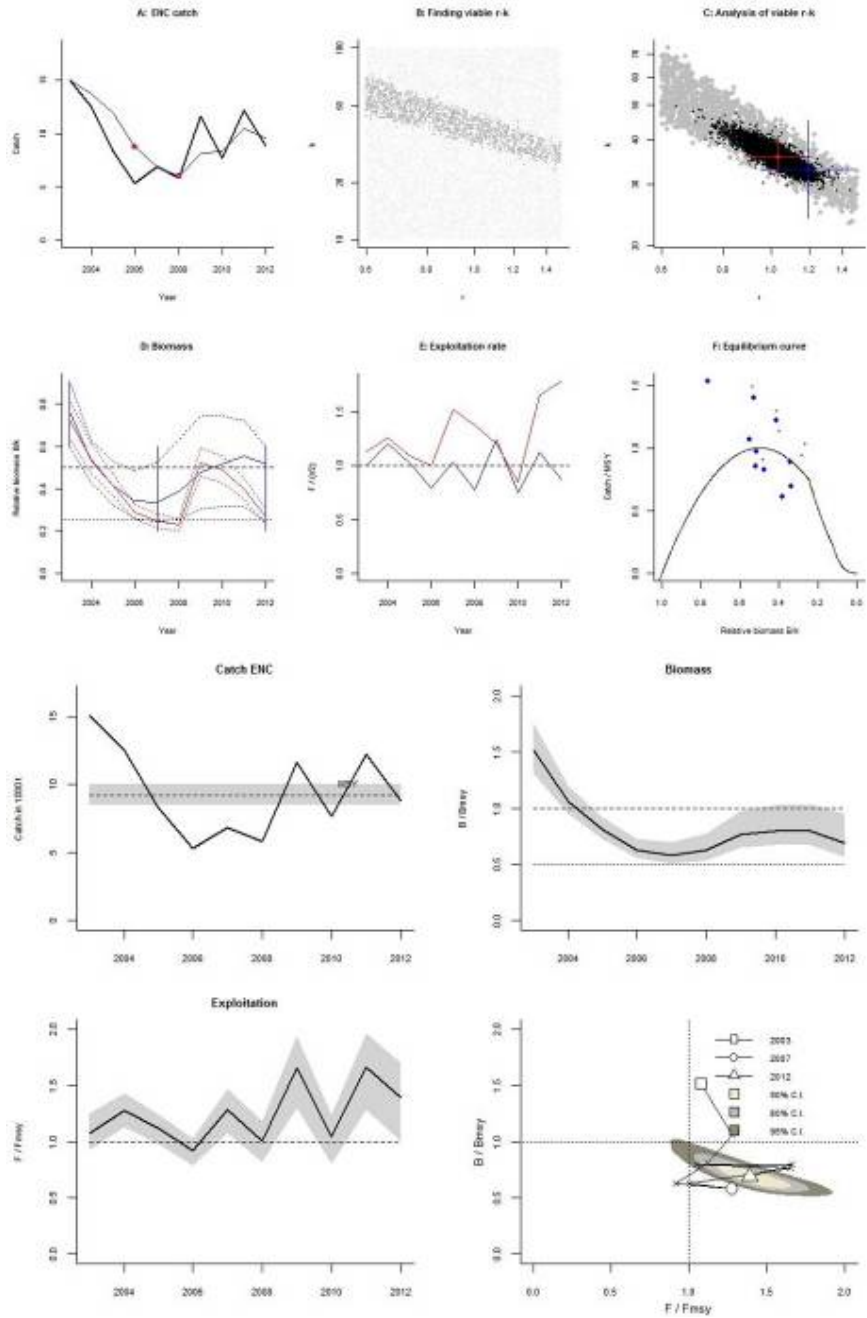
Figure 6. Analysis of *Encrasicholina punctifer* stock from NSAP catch data of Central Luzon, Philippines. The CMSY analysis was based on the period 2003-2012. Abundance was based on independent estimates of catch per unit of effort data for 2003-2012.
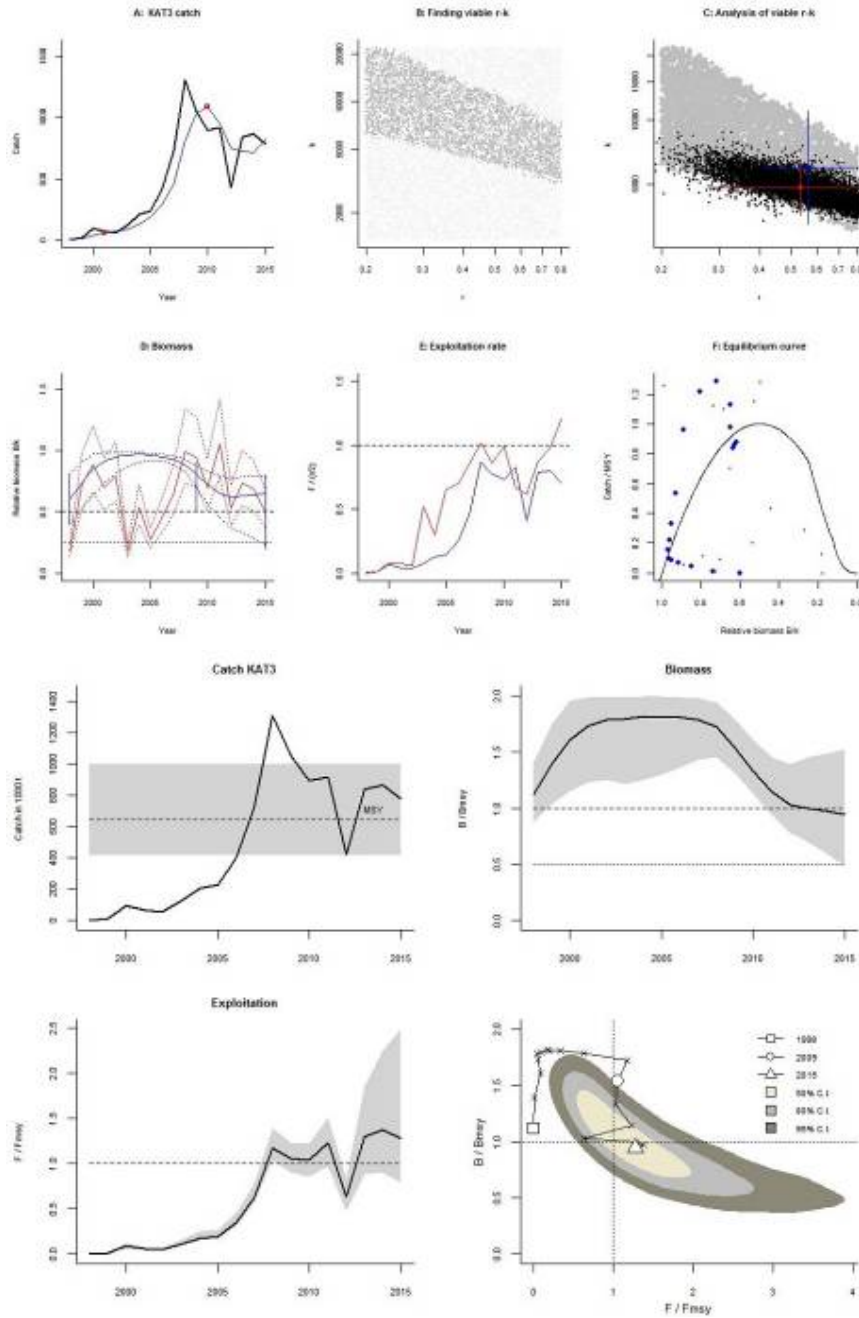
Figure 7. Analysis of *Katsuwonus pelamis* stock from NSAP catch data of Central Luzon, Philippines. The CMSY analysis was based on the period 1998-2015. Abundance was based on independent estimates of catch per unit of effort data for 1998-2015.
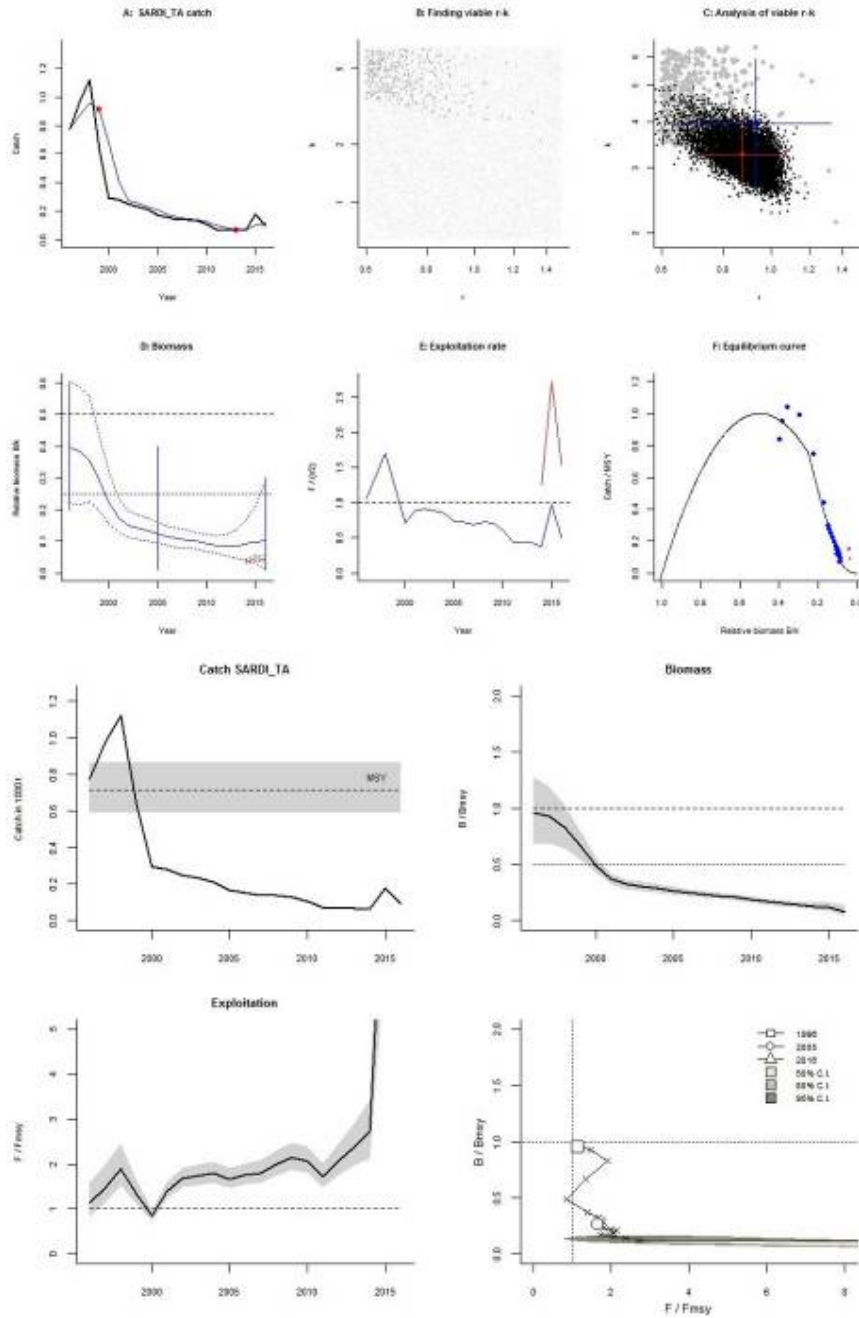
Figure 8. Analysis of *Sardinella tawilis* stock from NSAP catch data of Taal Lake, Luzon, Philippines. The CMSY analysis was based on the period 1996-2016. Abundance was based on independent estimates of catch per unit of effort data for 2014-2016.

Acknowledgements

Annex A
List of Participants

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Annex B

A Simple User Guide for CMSY and BSM (version "q")

R. Froese, N. Demirel, G. Coro, K. Kleisner and H. Winker
published online at http://oceanrep.geomar.de/33076/ on 27 October 2016

This is a copy of the accompanying document for Froese R., Demirel N., Coro G., Kleisner K.M., Winker, H. (2016). Estimating Fisheries Reference Points from Catch and Resilience. *Fish and Fisheries*, DOI: 10.1111/faf.12190. CMSY is a Monte-Carlo method that estimates fisheries reference points (*MSY*, *Fmsy*, *Bmsy*) as well as relative stock size (*B/Bmsy*) and exploitation (*F/Fmsy*) from catch data and broad priors for resilience or productivity (*r*) and for stock status (*B/k*) at the beginning and the end of the time series. Part of the CMSY package is an advanced Bayesian state-space implementation of the Schaefer surplus production model (BSM). The main advantage of BSM compared to other implementations of surplus production models is the focus on informative priors and the acceptance of short and incomplete (= fragmented) abundance data. This document provides a simple step-by-step guide for researchers who want to apply CMSY or BSM to their own data.

The CMSY version referred to in this guide (CMSY_O_7q.R) is newer than the one used in Froese et al. (2016). The main differences are faster execution because of parallel processing and more emphasis on management than on evaluating CMSY. Also, estimation of priors has been improved and some labels in the input files have changed, as indicated below.

The required R-code (CMSY_O_7q.R) and some example input files (O_Stocks_Catch_15_Med.csv and O_Stocks_ID_18_Med.csv) can be downloaded from http://oeanrep.geomar.de/33076/

Installation instructions

1) Install a recent version of R on your computer. CMSY was tested under R version 3.3.1, available from http://www.r-project.org/, but newer versions should also work.

2) We suggest using RStudio as an R development environment. RStudio is a free software that is available for several Operating Systems (Windows, OS, Linux) can be downloaded at http://www.rstudio.com/products/rstudio/download/.

3) Install the Gibbs sampler JAGS for your Operating System from the following web site: http://sourceforge.net/projects/mcmc-jags/files/JAGS/3.x/.

If you are using an Operating System different from MS Windows, please comment (#) all the lines in the code containing the windows(..) function.

4) In order to run the code, several R-packages are required. In the R Console execute the following commands (i.e. cut & paste into the Console window, then hit Enter and wait):

install.packages("R2jags")

install.packages("coda")

install.packages("lattice")

install.packages ("parallel")

install.packages ("foreach")

install.packages ("doParallel")

install.packages ("gplots")

(pay attention to possible required sub-packages, as alerted in warning/error messages form the R installer, and install missing packages if needed).

5) Two different data files are required by CMSY, which should be placed in the same directory as the script. The names of these files are specified in the code (lines 30 and 31). Examples are provided with the code and their structure is specified in next section.

6) Make sure that the source file and the downloaded R script are in the same directory.

7) Open the downloaded CMSY R script (CMSY_O_7p.R) in RStudio. Use the tab "Session" and select "Set Working Directory" -> "To Source File Location", so that the code will find the data files.

8) If you want to use your own input files, just change the file names in the *catch_file* and *id_file* variables in the "Required settings, File names" section of the code. If you create your own input files, make sure you use the same headers (case sensitive) as in the provided example files. Make sure you are using comma-delimited (.csv) files (look at the data in a simple text editor such as Notepad to check for consistent use of commas; semi-colons are not accepted).

9) The R-code can either analyze all stocks in the data files (default) or a single stock can be specified in the "Select stock to be analyzed" section of the code, according to the stock identification specified at line 42. To specify the stock to analyze just enter the unique fish stock name or identifier of the stock there (e.g. stocks <- "cod-scow"). To make the code run on all the stocks in the files, just comment out line 42 (put # in front). You can analyze the stocks in alphabetic order or in the sequence in the ID file or by Region or subregion, according to settings in lines 219 – 221. Uncomment (remove #) the code you want to use.

10) In RStudio, click on "Source" (or press Ctrl+A followed by Ctrl+R or Ctrl + Shift + S) to execute the code.

11) When the analysis is complete, results can be found in the console window as well as in the CMSY graphs window (which can be saved manually) and in an output .txt file (having the "Out_" prefix), whose name depends on the date of the execution. An output file in .csv format containing the results is also created in the same directory, which can be opened in Excel for example. The titles of the columns are in the same order as the results in the console.

Structure of the input files

Structure of the catch file (.csv)

For each stock, the following information must be specified (in the corresponding columns):

Stock: a unique fish stock name or identifier (e.g. "cod-2532"), repeated for each year

yr: the reporting year of the catch (e.g. 2004). One row for each year.

ct: catch value, in tonnes (e.g. 12345). One row for each year. Gaps with no entries are not accepted at the moment and must be filled by interpolating missing or incorrect values.

bt: the value of the biomass (in tonnes, e.g. 34567), or the value of the CPUE or stock size index (e.g. 0.123), or NA if there is no information. Gaps filled with NA are acceptable for bt, i.e., abundance data can be fewer than catch data.

Structure of ID file (.csv)

For each stock, the following information must be specified (in the corresponding columns):

Region: a string indicating the catch area, e.g. "Northeast Atlantic"

Subregion: a string indicating the subarea, e.g. "Baltic Sea"

Stock: a unique fish stock name or identifier (corresponding to the one in the 'Stock' column in the catch file)

Name: optional; a common name of the species, e.g. "Makala"

EnglishName: optional; a common English name of the species, e.g. "Greater forkbeard"

ScientificName: optional; the scientific name of the species, e.g. "Phycis blennoides"

SpecCode: optional; the code number used in FishBase for fish or SealifeBase for non-fish

Group: optional; the functional group that a species belongs to, e.g. "Large predators" or "Pelagic plankton feeders" or "Benthic organisms".

Source: optional; the source where the data were taken from, e.g. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2014/2014/gfb-comb.pdf

MinOfYear: the start year of the catch report

MaxOfYear: the last year of the catch report

StartYear: the start year of the catch time series to be used for the analysis (from when on the data are thought to be reliable)

EndYear: the end year of the catch time series to be used.

Flim, Fpa, Blim, Bpa, Bmsy, FMSY, MSYBtrigger, B40, M, Fofl, SSB: optional; fisheries reference points from assessments, for comparison, not used in the analysis

Resilience: prior estimate of resilience, corresponding to intrinsic growth rate ranges (see next section). Allowed values are "High", "Medium", "Low", "Very Low". Get default values from www.FishBase.org

r.low / r.hi: an optional pair of parameters to specify the range of intrinsic growth rate for the species. Set these to NA to use the range specified in Resilience. If values are given, the Resilience column will be ignored. Check www.FishBase.ca for prior estimates.

stb.low / stb.hi: the prior biomass range relative to the unexploited biomass (B/k) at the beginning of the catch time series (see next section).

int.yr: a year in the time series for an intermediate biomass level. Set it to NA to have it estimated by default rules.

intb.low / intb.hi: the estimated intermediate relative biomass range (see next section). Set it to NA to have it estimated from maximum or minimum catch, according to some simple rules (note: these may not be appropriate for your stock).

endb.low/ endb.hi: the prior relative biomass (B/k) range at the end of the catch time series (see next section). Set to NA if you want to use the defaults.

q.start / q.end: the start and end year for determining the catchabilitiy coefficient. Set to a recent period of at least 5 years where catch and abundance were relatively stable or had similar trends. If set to NA the default is last 5 years (or last 10 years in slow growing species).

btype: the type of information in the bt column of the catch file. Allowed values are "biomass" (when total biomass is reported), "CPUE" (when cpue or cpue index or SSB are reported) or "None" (if no abundance data are available).

force.cmsy: set to TRUE if the management analysis should use the CMSY results rather than available BSM results. Useful when the abundance data are deemed unreliable. Default is FALSE or F.

Comment: a comment on the stock or the quality of the analysis or special settings. This comment is shown in the output.

Remember that the files must be saved in "csv" (comma delimited) format. Double-check that indeed a comma (and not a semi-colon) is used as delimiter.

Suggestions for parameters settings

Table 1 reports a set of questions that can help to set the CMSY input parameters. Please note that priors can also be derived with other stock assessment tools, such as length frequency analysis or catch per unit of effort.

Table 1. Example of questions to be put to experts to establish priors for CMSY analysis.

Prior	Question to experts
Start year for catch time series	From what year onward are catch data deemed reliable?
Relative start and end biomass $B/B0$	What is the most likely stock status for the beginning and end of the time series: lightly fished, fully exploited, or overfished?
Relative intermediate biomass $B/B0$	Is there an intermediate year where biomass is considered to have been particular low or high, e.g., exploitation changed from light to full, or where an extraordinary large year class entered the fishery?
Resilience prior r	What is your best guess for the range of values including natural mortality of adults (M)? Consider the empirical relationship $r \approx 2\,M$
Resilience prior r	What is your best guess for the range of values including maximum sustainable fishing mortality ($Fmsy$)? Considering the relationship $r \approx 2\,Fmsy$ *Use this question to reinforce or change the answer to previous question*

Alternatively, you can get preliminary estimates of r from the following empirical relations:

$$r \approx 2\,M \approx 2\,Fmsy \approx 3\,K \approx 3.3/tgen \approx 9/tmax$$

where r is the intrinsic rate of population increase, M is the rate of natural mortality, $Fmsy$ is the maximum sustainable fishing mortality, K is the somatic growth rate (from the von Bertalanffy growth equation), $tgen$ is generation time, and $tmax$ is maximum age. If point estimates are very close to each other, assume a range of uncertainty of +/- 50%. Give more weight to traits giving low estimates of r, as these will act as bottle neck for population growth. Consider that low annual fecundity (<100) will further reduce r. This is already considered in prior r estimates available from FishBase.

Table 2 suggests ranges for relative biomass to be used as input parameters, depending on the depletion status of the stock.

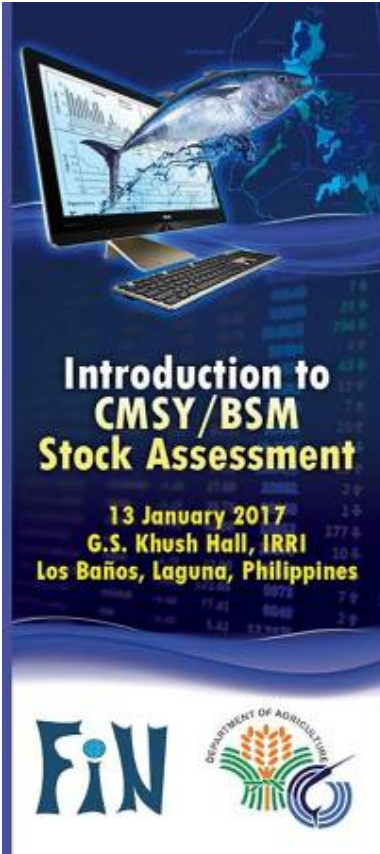**Table 2. Prior relative biomass (*B/k*) ranges for CMSY.**

Very strong depletion	Strong depletion	Medium depletion	Low depletion
0.01 – 0.2	0.01 – 0.4	0.2 – 0.6	0.4 – 0.8

Table 3 reports the *r* ranges automatically assigned by CMSY based on resilience categories.

Table 3. Prior ranges for parameter *r*, based on classification of resilience.	
Resilience	**prior *r* range**
High	0.6 – 1.5
Medium	0.2 – 0.8
Low	0.05 – 0.5
Very low	0.015 – 0.1

When setting an intermediate biomass, it often improves the CMSY analysis if the end of a period with low biomass is indicated by setting the intermediate year to the last year with low biomass, and indicating a respective relative range, e.g. as 0.01 – 0.3. Similarly, indicate a period of large biomass by setting the intermediate year to the last year with high biomass and indicate a respective range, e.g. as 0.4 – 0.8. In general, the width of relative biomass windows should not be less than 0.4, unless the stock is known to be very strongly depleted, in which case ranges of 0.01-0.3 or 0.01 – 0.2 are appropriate. Setting a range of 0 to 1 is also possible, and would indicate no information at all about stock status, which is, however, unlikely. If a stock is fished it must be smaller than 1. If it is delivering decent catches, it must be larger than 0.01. See Table 1 for guidance on how to get priors from interviews with fishers or experts (or yourself).

Note that if abundance information are provided, an additional surplus production analysis is performed with an advanced Bayesian state-space implementation of a Schaefer model (BSM). This analysis is then used for management advice, because it contains more information. If instead you want to use the CMSY results, set "force.cmsy" to TRUE in the ID file.