Preliminary User Guide for AMSY: Estimating MSY-related fisheries reference points from abundance and resilience

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Introduction

AMSY is a new data-limited method that estimates fisheries reference points (Fmsy, F/Fmsy, B/Bmsy) from catch-per-unit-of-effort (CPUE) data combined with prior estimates of resilience, such as can be found in FishBase (www.fishbase.org) for fishes and in SealifeBase (www.sealifebase.org) for invertebrates. AMSY is meant for wide-ranging or migratory stocks where CPUE is known from surveys or from observers on some of the commercial boats, but where total catch is unknown or unreliable. It is also meant for bycatch species where CPUE may be available from surveys. In addition to CPUE and resilience, AMSY needs a prior for relative stock size (range of B/B0, between 0 and 1) for one of the years in the time series. For example, if current stock is known to be small compared to the beginning of the fishery, the B/B0 prior range can be set to 0.15 – 0.4 for the latest year with data (see Table 1). Alternatively, if the stock at the beginning of the CPUE time series was known to be very lightly exploited, the stock size was likely close to the unexploited size and the prior range for the first year with CPUE data could be set to a 0.75 – 1.0 (Table 1).

Table 1. Translation of qualitative stock size information into prior ranges of B/k.

B/k	**Lower limit**	**Upper limit**
Very small	0.01	0.2
Small	0.15	0.4
About half	0.35	0.65
More than half	0.5	0.85
Near unexploited	0.75	1.0

AMSY takes this information (CPUE, resilience prior, biomass prior) and tests a high number of combinations of productivity (the maximum intrinsic rate of population increase *r*) and unexploited stock size or carrying capacity (*k*) for their compatibility with these inputs. For example, *r-k* pairs that would predict negative catches or catches higher than the available biomass can be considered as incompatible with the inputs and can be excluded from the analysis. A detailed description of the theory and equations behind AMSY is given in a publication that is accepted for publication in the ICES Journal and expected to be published by the end of 2019.

The text below shows a screenshot of AMSY results for plaice in the western Baltic (*Pleuronectes platessa*). Note that kq is the CPUE that would be obtained in the unfished stock and MSYq is the maximum sustainable CPUE that would be obtained if the stock were at half of carrying capacity.

```
File EU_Stocks_ID_8.csv read successfully
-----------------------------------------------------------
AMSY Analysis, Wed Nov 13 17:16:45 2019
-----------------------------------------------------------
Stock ple-2123, Pleuronectes platessa, NA
CPUE data for years 1999 - 2015, CPUE range 4799 - 14159, smooth
= TRUE
Prior for r                    = Medium, 0.35 - 0.79
Used prior range for r         = 0.327 - 0.845
Prior for 1999 stock status    = Small, NA - NA
Used 1999 prior B/B0 range     = 0.15-0.4, prior B/Bmsy = 0.3-0.8
Used prior range for kq        = 12705 - 25383 [original range = 9
519 - 25383]
BSM r                          = 0.73 , 0.61 - 0.87
BSM k                          = 24600 , 20190 - 29980
BSM MSY                        = 4480 , 3740 - 5360
BSM last B/Bmsy                = 1.42 , 1.06 - 1.68
BSM last F/Fmsy                = 0.41 , 0.35 - 0.55
Comment: NA

Monte Carlo filtering of r-kq space with 50000 points and 30 erro
r patterns.
Viable r-kq pairs = 5004

 Results:
 viable r-kq pairs   = 5004
 median kq           = 18339, 13736 - 24592
 median MSYq         = 2531, 1807 - 3400
 r (4 MSYq/kq)       = 0.552, 0.377 - 0.795
 Fmsy (r/2)          = 0.276, 0.189 - 0.397
 F/Fmsy              = 0.369, 0.026 - 1.05 (2014)
 B/Bmsy              = 1.54, 0.856 - 2.8 (2015)
```

Figure 1 shows an example of the graphical output of AMSY for Western Baltic plaice. The bold curve in panel (a) presents the time series of CPUE data used in the analysis. A moving average was used to smooth the data, indicated by the thin black curve. The dotted horizontal lines show the prior bounds for the CPUE level that would correspond to B_{msy}, i.e., the CPUE corresponding to B_{msy} is expected to be somewhere between these lines. The blue vertical line with end bars shows the prior stock size B/B0, here provided as "About half" for 2003 and translated from Table 1 to 0.35 – 0.65.

The cloud of light grey dots in (b) indicates the r-k_q pairs that were tested by AMSY. The black dots represent 'viable' r-k_q pairs that passed the AMSY filters.

Figure 1c shows the magnified area occupied by the viable r-k_q pairs, shown again in black. The red cross indicates the most likely r-k_q pair at its center as median of the cloud of black dots, with approximate 95% confidence limits derived from the 2.5Th and 97.5th percentiles of r and k in log space.

The bold curve in (d) shows a time series of the median relative catch predicted by AMSY. The dotted curves are the approximate 95% confidence limits. The dashed horizontal line indicates the MSY-level. The blue curve are the official catch records relative to the official (proxy) estimate of MSY, shown here for comparison. Note that the "official" catches fall within the approximated 95% confidence limits for catch predicted by AMSY.

The bold curve in (e) represents the time series of fishing pressure F/F_{msy} predicted by AMSY. The dotted curves are the approximate 95% confidence limits. The dashed horizontal line indicates the $F=F_{msy}$ level. The blue curve shows the F/F_{msy} values estimated independently in the full assessment.

The bold curve in (f) shows the time series of CPUE expressed as B/B_{msy} in an MSY framework, as informed, smoothed and slightly modified by the AMSY filters. The dashed line indicates the $B=B_{msy}$ level as estimated by AMSY and the dotted lines indicate the corresponding approximate 95% confidence limits. The dashed red line indicates the stock size below which recruitment may be impaired. The blue dashed line shows the relative spawning stock biomass estimated in the full assessment, with the confidence limits given there, scaled by assuming $B_{msy}=2*B_{pa}$.

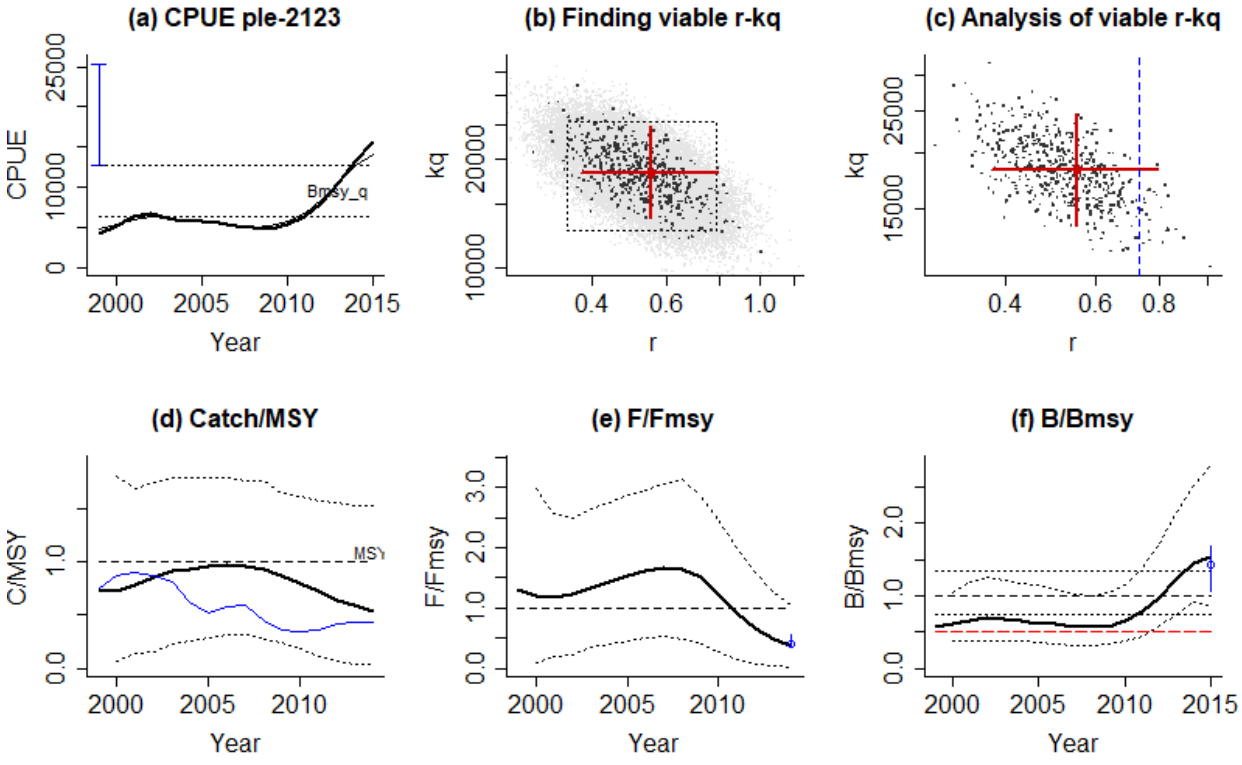

Figure 1. Example of graphical output of AMSY, here for Western Baltic plaice (Pleuronectus platessa).

Figure 2 shows a Kobe plot of stock status and exploitation for use by managers. In this case, Western Baltic plaice, recovered from too small stock size and substantial overfishing from 1999 to 2011 to large stock size and sustainable exploitation in 2015. In this year there is a 90.1% probability that the stock is in the green area, and only a 1.7% probability that the stock is still in the red area.

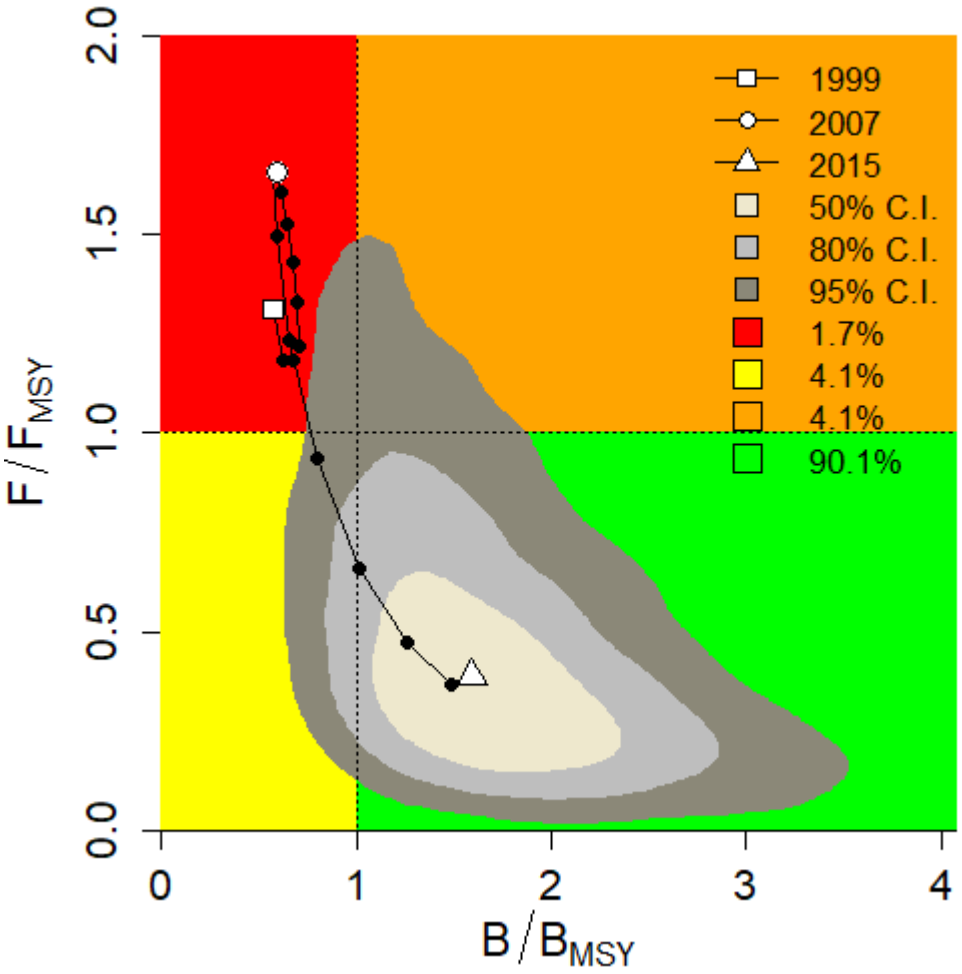

Figure 2. Kobe plot of stock status (X-axis) and exploitation (Y-axis) for use by managers.

Preparing the Input Data

AMSY requires two comma-delimited input files, one with the CPUE data (and independent assessment data if available for comparison) and one with the priors and settings for the analysis. The respective file names have to be indicated in the R-code, where 'cpue_file' is the data file and 'id_file' is the file with the settings for the analysis.

The data file has the columns: Stock, Year, CPUE, and optional F, FHi, FLow, BHi, Blow, and Catch. Use exactly these column names and remember that R is case-sensitive.

Stock : The abbreviation used for the stock, e.g. skj.iotc for Indian Ocean skipjack tuna, repeated for every year.

Year : The year to which the cpue data refer, e.g. 1995

CPUE : The cpue in any unit, such as 123 or 13.2

Catch : Catch as reported in independent assessments, for comparison (optional)

The ID file has the column names listed below. Use exactly these names and remember that R is case sensitive.

CPUE_File: The name of the data file, e.g. RealCPUE_3.csv

Stock : The abbreviation used for the stock, e.g. skj.iotc for Indian Ocean skipjack tuna, repeated for every year. Make sure the stock ID is exactly the same as used in the data file.

Name : The name used in the assessment, e.g. Skipjack

EnglishName: An official name, such as Indian Ocean skipjack tuna

ScientificName: e.g. Katsuwonus pelamis

StartYear: The first year to be used in the analysis

EndYear: The last year to be used in the analysis

Resilience: The resilience category derived from FishBase or SealifeBase, one out of Very low, Low, Medium, or High. Note mandatory first capital letter.

r.low : A numeric value for the prior lower bound of r, e.g. 0.3 (optional)

r.hi : A numeric value for the prior upper bound of r, e.g. 0.75 (optional)

Bk.yr : The year to which the prior for relative biomass B/B0 applies, e.g. 2003

Bk.pr : A qualitative statement about the relative stock size, such as Very small, Small, About half, More than half, or Near unexploited. Confirm allowed choices in Table 1 and note mandatory first capital letter.

Bk.pr.low: A numeric value for the lower bound of the biomass prior B/B0, e.g. 0.7 (optional)

Bk.pr.hi : A numeric value for the upper bound of the biomass prior B/B0, e.g. 1.0 (optional)

e.creep : An estimate for increase in catchability if cpue is from commercial fisheries. For example 2% entered as 2.0 is a reasonable default assumption in many fisheries. If cpue is from surveys, set to NA

Comment: Any comment that relates to the analysis, such as type of cpue or source of priors.

Source : Reference to source of cpue or assessment data, preferably as URL

true.r, true.kq, true.MSYq, true.Bk.end: These columns were used when results were compared against simulated data where true parameter values are known. These values will then be shown in the screen output.

MSY.BSM, MSY.BSM.lcl, MSY.BSM.lcl: Estimates of MSY from previous runs of the BSM model with catch and cpue, for comparison

r.BSM, r.BSM.lcl, r.BSM.lcl: Estimates of r from previous runs of the BSM model with catch and cpue, for comparison

k.BSM, k.BSM.lcl, k.BSM.lcl: Estimates of relative carrying capacity kq from previous runs of the BSM model with catch and cpue, for comparison when btype = biomass and q in the independent assessment is 1.0

B_Bmsy, B_Bmsy.lcl, B_Bmsy.ucl: Estimates of relative biomass B/Bmsy in the last year of the analysis from previous runs of the BSM model with catch and cpue, for comparison.

F_Fmsy, F_Fmsy.lcl, F_Fmsy.ucl: Estimates of relative biomass exploitation F/Fmsy from previous runs of the BSM model with catch and cpue, for comparison.

Some useful settings in the code

The code for AMSY is written in R and we recommend RStudio as user interface. You can find and download these programs for free from the internet. You will have to install several R libraries when you run the code for the first time. This should happen automatically at the first run, otherwise use RStudio, Tools -> Install Packages for this purpose.

This version of the User Guide refers to AMSY version 68x (AMSY_68x.R), the example data files are EU_Stocks_ID_8.csv and EU_Stocks_CPUE_1.csv. Copy source code, ID and data files into the same working directory. In the section of the code entitled “Required settings, file names” you have to specify the name of the ID file. If you do not provide directory information, use RStudio-Session-Set Working Directory-To Source File Location to make R find your files.

In the section “Stocks to be analyzed”, remove the comment-sign # from in front of, e.g., ‘ stocks <- “skj.iotc” ’ to analyze this stock. If you leave the # in place, all stocks in the ID file will be analyzed.

In the section “General settings for the analysis” you can determine whether the CPUE data should be smoothed, what the margins for process and observation error should be, the number of r-kq pairs to be tested, the number of random error scenarios to be tested per r-kq pair, the minimum number of viable r-kq pairs to accept a run, whether effort creep or other graphs should be plotted, and whether the results shall be written into a file. Normally the default settings should work fine.

The rest of the code should not be modified to avoid errors. It is in any case good practice to save the original version of the code and the example data in different place from your working directory and to rename the version you are working with. Thus, in case of unintentional changes to the code and resulting error messages, you can always go back to the original.

Enjoy using AMSY. If you have questions or suggestions, please contact

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