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

This guide is complementary to the CMSY user guide that can be found at https://github.com/SISTA16/cmsy

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 lightly exploited, the stock size was likely more than half of the unexploited size and the prior range for the first year with CPUE data could be set to a 0.5 – 0.85 (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

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 currently in preparation but is expected to be published by the end of 2019.

Figure 1 shows a screenshot of AMSY results for North Sea herring (*Clupea harengus*) based on CPUE from surveys (DATRAS) and resilience from FishBase. Note that the AMSY estimates (Fmsy = 0.46, F/Fmsy = 1.51, B/Bmsy = 0.55) are reasonably close to the official estimates of the independent full ICES stock assessment (Fmsy = 0.33, F/Fmsy = 1.48, B/Bmsy = 0.88).

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AMSY Analysis, Tue Apr 16 15:40:59 2019
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Stock her.27.3a47d , Clupea harengus , North Sea herring
CPUE data for years 1975 - 2018 , CPUE range 7.56 - 93.6 , smooth = TRUE
Prior for r                  = Medium , 0.3 - 0.68
Used prior range for r       = 0.281 - 0.72
Prior for 2003 stock status  = About half , NA - NA
Used 2003 prior B/B0 range   = 0.35 - 0.65 , prior B/Bmsy = 0.7 - 1.3
Used prior range for kq      = 123 - 246 [ original range = 123 - 228 ]
Assessment Fmsy              = 0.26
Assessment F/Fmsy            = 0.808 , 0.62 - 1  ( 2017 )
Assessment proxy Bmsy        = 2800000
Assessment proxy B/Bmsy      = 0.546 , NA - NA  ( 2018 )
Source: http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/he
r.27.3a47d.pdf
Comment: DATRAS areas 1-10, all Quarters, min length 24 cm, a=0.0059, b=3.09,
min of 10 length classes. Outliers in 1999 and 2004 replaced with mean of
adjacent years. Proxy Bmsy=2*BmsyTrigger.

Monte Carlo filtering of r-kq space with 10000 points and 30 error patterns
Viable r-kq pairs = 1569

 Results:
 selected r-kq pairs = 1489
 median kq           = 186 , 130 - 260
 median MSYq         = 23.4 , 14.8 - 37.7
 r (4 MSYq/kq)       = 0.505 , 0.353 - 0.708
 Fmsy (r/2)          = 0.252 , 0.177 - 0.354
 F/Fmsy              = 2.05 , 0.838 - 3.57 ( 2017 )
 B/Bmsy              = 0.495 , 0.302 - 0.692 ( 2018 )
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Figure 1. Screenshot of results reported by an AMSY run for North Sea herring. Note that kq is the CPUE that would be obtained in the unfished stock and MSYq is the maximum sustainable relative catch obtained if the stock were at half of carrying capacity.

Figure 2 shows an example of the graphical output of AMSY for North Sea herring. The bold curve in panel Figure 2a 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 grey dots in Figure 2b indicate the r-k_q pairs that were tested by AMSY. The black dots represent 'viable' r-k_q pairs that passed the AMSY filters. Because a numerical prior was provided for r (from FishBase), the distribution of r is assumed to be log-normal rather than uniform.

Figure 2c shows the magnified area occupied by the viable r-k_q pairs, shown again in black. The diagonal black line indicates all r-k_q pairs that result in the same MSY_q value as the overall median MSY_q. Light red dots are r-k_q pairs that result in an MSY_q estimate within the approximate 95% confidence levels of MSY_q. The dark red cross indicates the most likely r-k_q pair at its center, with confidence limits as estimated by AMSY.

The bold curve in Figure 2d 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 Figure 2e 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 Figure 2f 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 $B_{msy}=2*B_{pa}$.

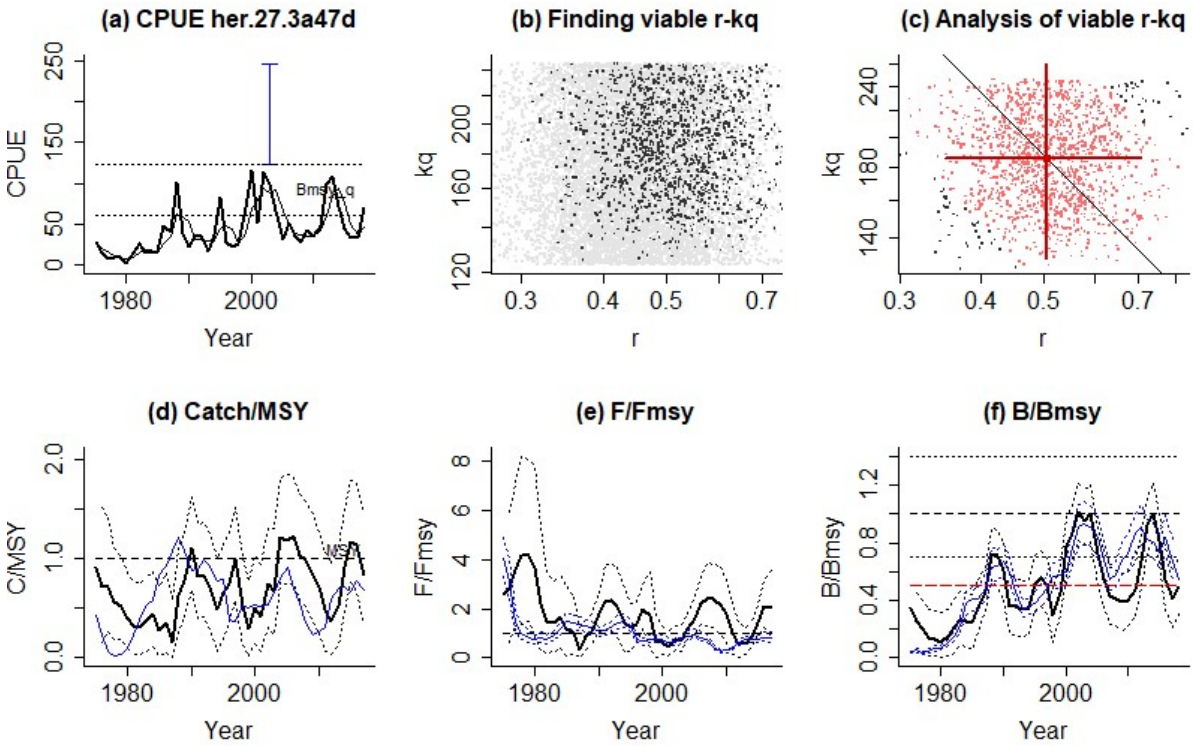

Figure 2. Example of graphical output of AMSY, here for North Sea herring (Clupea harengus).

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 rows 21 and 22 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, yr, cpue, and optional F, FHi, FLow, BHi, Blow. 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

F : The fishing mortality as estimated independently, for comparison (optional, not used in anaylsis)

FHi : The upper bound of the independent F estimate (optional)

FLow : The lower bound of the independent F estimate (optional)

BHi : The upper bound of the independent biomass B estimate (optional)

BLow : The lower bound of the independent biomass B estimate (optional)

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 or More than half. See 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.

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.

Fmsy.ass, Bmsy.ass: Independent estimates of Fmsy and Bmsy, if e.g. full assessments are available for comparison. These values will then be shown in the screen output.

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

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. In RStudio, use Tools-Install Packages for this purpose.

This version of the User Guide refers to AMSY version 52 (AMSY_52.R), the example data files are RealCPUE_ID_7.csv and RealCPUE_3.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 (3 years running average), 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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