An online tool to easily run stock assessment models, using SS3 and SWO as an example

Anne-Elise Nieblas[1], Sylvain Bonhommeau[2], Taha Imzilen[3], Dan Fu[4], Fabio Fiorellato[4], Julien Barde[5]

[1]IRD, UMR MARBEC (IRD/Ifremer/Univ.Montpellier/CNRS), IRD Réunion, 97744 St Denis, La Réunion, France

[2] IFREMER- DOI, rue Jean Bertho, 97822 LE PORT CEDEX, France.

[3] IRD, UMR MARBEC (IRD/Ifremer/Univ.Montpellier/CNRS), IRD Sète, 34200, France.

[4] IOTC, Le Chantier Mall, Victoria Mahé, Seychelles

[5] IRD, UMR MARBEC (IRD/Ifremer/Univ.Montpellier/CNRS), IOC, Rue de l'Institut, Ebène, Maurice

Stock assessment models are developed to provide scientific advice to managers about exploited populations. Stock assessment software are complex and advanced technical skills are required to develop the models. Producing output becomes time-intensive and even more complex as thousands of simulations must be run on supercomputers in order to include the multiple sources of uncertainty in assessment results. As very few stock assessment participants have the specific technical skills required to reproduce these outputs, our aim has been to develop a Virtual Research Environment (VRE) that enables any user to easily parameterize and execute various steps of the stock assessment workflow using SS3 (a widely-used statistical catch-at-age model). We will repackage SS3 codes used for large pelagic species and provided by the Indian Ocean Tuna Commission and their consultants so that they can be parameterized, executed and edited online by anybody from a simple web page, with standardized data outputs. The VRE will provide various collaborative web services, including: (i) a workspace to share documents or data, (ii) webpages or an RStudio server to process data online, and (iii) an automated reporting service to dynamically generate documents to package these results. Here, we will show a mock-up of the VRE, using the last stock assessment of swordfish (SWO) as an example. Using an R-shiny application, we will explain the procedure of inputting new data, changing parameters, and quickly and automatically viewing the results of these changes on the graphical interface as well as through the automated reporting service. A collaborative environment such as the VRE uses simple tools to enable the storage and access of the data and source codes necessary to replicate past results or to try new parameterizations of the model. Increasing access to this complex model will bring more transparency and collaboration within working groups by providing "non-modelers" with a possibility to test hypotheses for the stock assessment. This will also increase the number of users of various levels of expertise: from experts, to managers, to even wider audiences with the potential applications of these tools to serious games.

This preliminary paper outlines the aims of the SS3 Bluebridge project. This work is currently in progress and finalised results will be presented at the WPB15. A final draft of the accompanying paper will be received by the Secretariat several days before the meeting.

INTRODUCTION

Several different types of stock assessment models are used to provide scientific advice to managers about exploited populations. Of the assessment models, Stock Synthesis 3 (SS3) is a statistical catch-at-age model that is used widely [1], including several stocks under the management of the Indian Ocean Tuna Commission (IOTC). SS3 is flexible in terms of data inputs and complexity, making it possible to run for even data-poor stocks. It can use a diverse array of fishery and survey data, including both age and size structure of the population.

SS3 is based on ADMB C++ software that maximises the goodness-of-fit of a set of parameter values, and then calculates the variance of these parameters using inverse Hessian and MCMC methods. This software is complex and advanced technical skills are required to develop the models. The developers of SS3 have provided a Graphical User Interface (GUI) for Microsoft operating systems to aid in the set up and parameterisation of complex assessment models. However, the GUI is limited in operating systems that support it, and the production of outputs can be time-intensive and complex when thousands of simulations are needed to include the multiple sources of uncertainty in the assessment results.

As very few stock assessment participants have the specific technical skills required to reproduce these outputs, our aim is to develop a Virtual Research Environment (VRE), using BlueBridge infrastructure (European Project number XXX), that enables any user to easily parameterise and execute various steps of the stock assessment workflow using SS3. In collaboration with the IOTC and the FAO, IRD and Ifremer would like to develop this VRE to facilitate the use and the visualization of the results of SS3 to users with varying levels of expertise, following a similar approach as that of BFT-E with ICCAT [2]. The end goal is to allow participants of stock assessments to use the SS3 VRE interactively at working groups to explore input parameters and results.

The first part of the work consists of testing the feasibility of reproducing past IOTC SS3 stock assessment models used for tropical tunas and billfish (provided by the IOTC and related consultants). We will then repackage the SS3 codes so that they can be parametrized, executed and edited online from a simple web page, with standardized data outputs. The VRE will provide various collaborative web services, including: (i) a workspace to share documents, codes or data, (ii) webpages or an RStudio server to process data and codes online, (iii) visualisation services with an interactive interface to select model runs, and (iv) automated reporting to dynamically generate documents of results. A collaborative environment such as this uses simple interfaces to facilitate the storage and access of the data and source codes necessary to replicate past results or to explore new parametrizations of the model.

Expected scenarios of use

If successful with the latest version of SS3, then we will be able to set up a VRE for working group participants to parametrize the work flow. It is expected that this tool will be used to replicate past stock assessments and attempt to develop and investigate new stock assessments (see Table 1 for expected scenarios of use). Improving the ease of use of this complex model will bring more transparency and collaboration within working groups by providing “non-modelers” with a possibility to test hypotheses and explore uncertainty for stock assessment. Technical performance, document production, and harmonization of content are expected to be enhanced due to this increased participation.

Table 1 : Scenarios of expected use of the VRE for the stock assessment. For one simulation of an IOTC example code on laptop: ~1.5 hours with uncertainty calculations, ~20 min without (complies with consultant’s methodology). For one simulation of an IOTC example on Rstudio online: 4.3 hours with uncertainty calculations, ~1.1 hours without

ID	Summary	CPUs required:
Scenario 1	A consultant developing a model and running sensitivity analyses before the stock assessment (10,000 iterations). Results required within 1 day for a total of 3 days (i.e. allowing for 3 major modifications to the model).	(20*10000)/ (3*24*60) = ~ 47 CPUs
Scenario 2	A consultant making modifications on the model during the stock assessment (1,000 iterations). Results required in 1 hour for 1 day of the meeting.	(20*1000)/60 = ~ 334 CPUs
Scenario 3	Meeting participants individually exploring parameters	
Scenario 3a	One simulation per user, approximately 30 users. Available for the full duration of the meeting, e.g. 5 days.	30 CPUs available throughout meeting
Scenario 3b	Each user allowed 10 iterations. Results required immediately (i.e., duration of single run). Schedule could be specified for a period of time within a single day.	30*10 = 300 CPUs

Users

We foresee an increase in the number of and technical capacity of users of various levels of expertise: from experts, to managers, to even wider audiences with the potential applications of these tools to serious games.

Users would mainly be scientists / experts involved with stock assessment, and would require an account to access the VRE. Currently, SS3 is available to researchers with an NOAA VLab account, but we have confirmed that it is acceptable to the developers and maintainers of SS3 that we make the software available to users in the format of the VRE.

METHODS and RESULTS

SS3 model codes (Linux versions 3.24 and 3.3) were provided by the NOAA/SS3 team and were successfully compiled on the BlueBridge infrastructure, which is Linux-based with Rstudio online. A single run of NOAA's simple stock assessment model example was executed in 2.5 minutes.

Model codes (including NOAA examples and past stock assessment codes for bigeye tuna, yellowfin tuna, and swordfish provided by the IOTC and its consultants) were then split into R functions to produce the four files that define the model parameterisations and are required to run SS3 : starter.ss, forecast.ss, control.ctl, and data.dat. Input are read from a csv table, within which input data tables are nested (see Table 2 for example of the input file).

A single run is executed by running these functions through the BlueBridge Rstudio online infrastructure. A single run of the 2015 SWO SS3 model, used here as an example (Table 2) is completed in 1.5 hours. The outputs of this run are read using the SS_output function of the r4ss R package [3], which are then converted to a standardised netcdf format.

At the WPB15, we hope to present examples of a single run on the VRE parameterised by a user. We will show an example of the outputs displays in the form of figures and tables, as well as an example of the generation of an autoreport.

FUTURE WORK

The single-run structure will be converted to a web processing service such that individual users can parameterise aspects of the model. This WPS version will be parallelised within the FAO supercomputing resources, such that multiple iterations can be executed simultaneously, thus incorporating uncertainty.

We will package and display the results of the SS3 runs within the VRE with output visualisations readily available for each parameterisation scenario and an automated report of the stock assessment. This automated report will allow users to quickly update the stock assessment and incorporate scientific advice during the meeting.

Potential after the project

The aim of the BlueBridge project is to facilitate stock assessment development by easily incorporating changes and scientific advice such that different parameterisations can be achieved within the scope of working parties. The VRE will be a tool to enable many more users to participate in the development of the stock assessment model. The VRE will be used to keep track of stock assessment development and results such that stock assessments can be replicated to aid to reference and comprehend past decisions as well as for creating new assessments.

Table 2 : An example of the input table, using SWO's 2015 stock assessment inputs.

STARTER.SS		
variables	SWO	
version	3.21	
filename	../test_SWO/starter.ss	
comments	starter.ss made using writeSS324Starter.R	
model	SWO	
init_vals		0
display_deets		1
age_str_rep		1
checkup		0
param_trace		0
cum_report		1
full_priors		0
soft_bounds		1
num_data_out		1
turn_off_est		10
MCMCburn		10
MCMCthin		2
jitter		0
sdrep_start		-1
sdrep_end		-2
n_sd_yrs		0
sd_yr_vector	#	
final_conv	0.0001	
retro_yr		0
minage_sumbio		1
dep_basis		1
frac_depden	0.25	
SPR_rep_basis		4
F_rep_units		1
F4_age_range		
F_rep_basis		0
endfile_val		999

FORECAST.SS		
variable	SWO	
version	3.24	
comments	forecast.ss made using writeSS324Forecast.R	
filename	../test_SWO/forecast.ss	
benchmarks		1
MSY		2
first_yr_avg_recF		
end_yr_avg_recF		
F_mult		
SPR_target	0.4	
biomass_target	0.4	
bmark_yrs	rep(0,6)	

bmark_relF_basis		2
forecast		2
n_forecast_yrs		10
F_scalar	0.2	
Fcast_yrs	c(2015,2015,0,0)	
control_rule		0
control_rule_uplim	0.4	
control_rule_lowlim	0.1	
control_rule_buff	0.75	
n_fcast_loops		3
first_fcast_loop		3
fcast_loop_ctl3		0
fcast_loop_ctl4		0
fcast_loop_ctl5		0
first_yr_capsall		2500
imp_err	0.	
rebuilder		0
rebuilder_Ydecl		1999
rebuilder_Yinit		-1
fleet_relF		1
fcast_catch_basis		2
fishery_names	FISHERY1 FISHERY2 FISHERY3	
fishseas_F		1
max_total_catch_fleet	rbind(rep(-1,4),rep(-1,4),rep(-1,4))	
max_total_catch_area	rep(-1,4)	
fleet_assignment	rbind(rep(0,4),rep(0,4),rep(0,4))	
allocation_fractions		
n_forecast_catch		0
Fcast_basis		2
endfile_val		999

SWO.CTL		
Variable	SWO	
version	3.21e	
model	SWO	
n_growthpatterns		1
n_submorphs		1
submorph_growthvar		
morph_dist		
n_seasons_peryear		1
n_areas		4
n_recrassign		4
recr_inter		0
recr_assign_tab	read.csv('../input/recr_assign_tab_SWO.csv',sep=',',header =F)	
n_move_defs		8
age_firstmove	0.6	
movement_def	read.csv('../input/movement_def_SWO.csv',sep=',',header=F)	

Table 2 (cont'd)

n_block_patterns		0
n_blocks_per_pattern		
yr_range_Nblockpatterns		
frac_female	0.5	
natM_opt		0
n_brk_pts		
age_brk_pts		
Lorenzen_ref_age		
agespec_M		
growth_mod		1
growth_amin	0.01	
growth_amax		999
agespec_K_amin		
agespec_K_amax		
sd_add_to_laa		0
cv_patt		0
mat_opt		3
agespec_MatFec	read.csv('../input/agespec_MatFec_SWO.csv',sep=',',header=F)	
lengthspec_Mat		
first_mat_age		1
fec_opt		1
hermaph_opt		0
hermaph_seas		
include_males		
offset_method		1
time_var_adj		1
growth_param	read.csv('../input/growth_param_SWO.csv',sep=',',header=F)	
movement_param	read.csv('../input/movement_param_SWO.csv',sep=',',header=F)	
mg_env		0
mg_env_param		
mg_block		0
mg_block_param		
param_seasonality	rep(0,10)	
seasonal_param		
mg_ann_dev_phase		4
sr_fun		3
sr_param	read.csv('../input/sr_param_SWO.csv',sep=',',header=F)	
sr_env_link		0
sr_env_target		0
do_recr_dev		1
recr_dev_begin_yr		1950
recr_dev_end_yr		2013
recr_dev_phase		6
adv_opt		1
recr_dev_early_start		0
recr_dev_early_phase		-5
forecast_recr_phase		5
lambda_fcast_recr		1

Table 2 (cont'd)

last_yr_nobias		1970
first_yr_nobias		1971
last_yr_fullbias		2001
first_rec_nobias		2002
max_bias_adj		1
recr_cycle_period		0
min_recr_dev		-6
max_recr_dev		6
n_recr_devs		0
n_recr_cycles		
recr_cycle_param		
recr_dev		
f_ballpark	0.2	
f_ballpark_yr		2003
f_method		3
max_f		4
f_start_val		
f_phase		
n_f_inputs		
n_tuning		2
f_param		
initF_param	read.csv('../input/initF_param_SWO.csv',sep=',',header=F)	
Q_tab	read.csv('../input/q_tab_SWO.csv',sep=',',header=F)	
Q_param	read.csv('../input/q_param_SWO.csv',sep=',',header=F)	
size_select_tab	read.csv('../input/size_select_tab_SWO.csv',sep=',',header=F)	
age_select_tab	read.csv('../input/age_select_tab_SWO.csv',sep=',',header=F)	
size_select_param	read.csv('../input/size_select_param_SWO.csv',sep=',',header=F)	
age_select_param		
do_tag		0
tag_param		
tag_param_rep		
tag_param_decay		
var_adj_factor		1
var_adj_tab	read.csv('../input/var_adj_tab_SWO.csv',sep=',',header=F)	
max_lambda_phase		4
sd_offset		1
n_changes_lambda		44
like_comp_tab	read.csv('../input/like_comp_tab_SWO.csv',sep=',',header=F)	
read_specs		0
var_control		
selex_std_bin		
growth_std_bin		
NatAge_std_bin		
endfile_val		999

Table 2 (cont'd)

SWO.DAT		
Variable	SWO	
model	SWO	
version	3.24	
start_yr		1950
end_yr		2015
n_seasons_peryear		1
n_months_perseason		12
spawning_season		1
n_fleets		12
n_surveys		10
n_areas		4
fishsurvey_names	GI_NE%LL_NE%GI_NW%LL_NW%GI_SE%LL_SE %ALGI_SW%EUEL_SW%ISEL_SW%JPLL_SW %TWFL_SW%TWLL_SW%UJPLL_NW%UJPLL_NE %UJPLL_SW%UJPLL_SE%UTWLL_NW%UTWLL_NE %UTWLL_SW%UTWLL_SE%UPOR_SW%UESP_SW	
sample_timing	rep(0.5,22)	
fleet_area	c(2,2,1,1,4,4,rep(3,6),1,2,3,4,1,2,3,4,3,3)	
catch_units	rep(1,12)	
se_logcatch	rep(0.01,12)	
n_genders		2
n_ages		30
init_equil_catch	rep(0,12)	
n_catch_obs		66
catch=catch.csv	read.csv('../input/catch_SWO.csv',sep=',',header=F)	
n_cpue_obs		285
cpue_units=cpue_units.csv	read.csv('../input/cpue_units_SWO.csv',sep=',',header=F)	
cpue=cpue.csv	read.csv('../input/cpue_SWO.csv',sep=',',header=F)	
n_fleets_w_discards		0
n_discard_obs		0
discard_units=discard_units.csv		
discards=discards.csv		
n_mnbodywt_obs		0
df_mnbodywt		30
mnbodywt=mnbodywt.csv		
lengthbin_method		1
binwidth		
pop_minsize		
pop_maxsize		
n_popbins		
lowedge_popbin		
comp_tail		0
add_to_comp	0.01	
bin_to_combine_genders		0
n_lengthbins		25
lowedge_lenbin	c(15,45,54,63,72,81,90,99,108,117,126,135,144,153,162,171,180,189,198,207,216,225,234,243,252)	
n_length_obs		274
length_comp=length_comp.csv	read.csv('../input/length_comp_SWO.csv',sep=',',header=F)	
n_agebins		0
lowedge_agebins		
n_ageerr_defs		0
age_matrix=age_matrix.csv		

Table 2 (cont'd)

n_age_obs	0
Lbin_method	0
agebin_combine_genders	0
age_comp=age_comp.csv	
n_mnsizeage_obs	0
mn_size_at_age=mn_size_at_age.csv	
n_envvar	0
n_env_obs	0
env_data=env_data.csv	
n_sizefreq_methods	0
nbins_per_method	
sizefreq_units	
sizefreq_scale	
sizefreq_mincomp	
n_sizefreq_obs	
lowedge_sizefreq_bins	
sizefreq=sizefreq.csv	
do_tags	0
n_tag_groups	
n_recap_events	
mix_period	
max_tracking	
release=release.csv	
recapture=recapture.csv	
do_morphcomp	0
n_stockcomp	
n_stocks	
mincomp	
stockcomp=stockcomp.csv	
endfile value	999

REFERENCES

1 R.D. Methot Jr., C.R. Wetzel, Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management, Fisheries Research 142 (2013) 86– 99.

2 T. Imzilen, S. Bonhommeau, T. Rouyer, L. T. Kell, J. Barde, Online collaborative enviroment to run the eastern bluefin tuna stock assessment workflow, Collect. Vol. Sci. Pap. ICCAT, 73(7) (2017) 2528-2534.

3 Taylor, I.G., Stewart, I.J., Hicks, A., Garrison, T.M., Punt, A.E., Wallace, J.R., Wetzel, C.R., r4ss: R code for Stock Synthesis. R package version 1.16. (2011) http://R-Forge.R-project.org/projects/r4ss/.