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Fishery Management Decisions: Solutions using Computing tools

Mini K.G.
Fishery Resources Assessment Division
Central Marine Fisheries Research Institute
Cochin

Fisheries management is in the domain of political affairs, integrating social, economical and ecological factors to select an appropriate management plan. It relies on stock assessment to get an idea about the current stock status and the consequences of alternative harvest levels. The advances in the quantitative fishery management in the last thirty years are driven by the theoretical and analytical techniques in general. The progress was possible specifically by the development and availability of computers, programming languages and computational algorithms. The fishery surveys, satellite remote sensing, continuous ecosystem monitoring, large-scale sensor networks, digital imaging, fish genomes etc., have generated massive data and computational requirements continued to increase and it resulted in development of many computing environments. The computing tools for fishery management has advanced considerably starting with the classical programming languages (BASIC, FORTRAN, C, C++, Pascal, APL, Python, Visual Basic etc.) to development of spreadsheets (Lotus 123, Microsoft Excel), comprehensive statistical packages (SYSTAT, Minitab, SAS, SPSS, GAUSS, S-PLUS, R etc.) and customized stock assessment software (ADMB, WinBUGS, OpenBUGS, Stock Synthesis 2 (SS2), CASAL, Coleraine etc.). This lecture note will take a look at some of the computing frameworks which are used among fishery scientists and managers.

ARTFISH

ARTFISH stands for Approaches, Rules and Techniques for Fisheries statistical monitoring and this is a standardized tool adaptable to most fisheries in the developing countries. Its design was driven by the need to provide users with robust, user-friendly and error-free approaches with computer software, and achieve the implementation of cost-effective fishery statistical systems with minimal external assistance. The ARTFISH outputs consist of documents, guidelines, manuals, case studies, training kits and computer software. Its components are ARTBASIC for handling sample data and producing monthly

estimates and ARTSER for the integration of monthly estimates into annual databases. The basic variables involve catch, effort, CPUE, prices, values and average fish size. ARTFISH utilizes technology that increases user cognition and decreases training time. It also provides detailed statistical diagnostics on data quality and allows insights into the fisheries for which the data is being collected.

BEAM1 and 2 - Bioeconomic modeling of artisanal and industrial sequential shrimp fisheries

BEAM 1 and 2 are developed for bioeconomic modeling of artisanal and industrial sequential shrimp fisheries based on an age-structured Thompson and Bell yield per recruit model and a simple input-output microeconomic model. BEAM1 gives its simulated results by age groups. BEAM2 gives them by standard commercial categories as used in the shrimp fishing industry.The user interface of the program is like a spreadsheet which allows the users to simulate interactively various management options, changing the number of recruits, the size of the fishing fleets, the fishing regime (i.e., the age at first capture in the two sequential fisheries) and the economic parameters of the fleets and of the processing sector. The programs give their results in terms of biomass and catch, in numbers, weight and value.

BEAM4 - Analytical Bioeconomic Simulation of Space structured Multispecies and Multifleets Fisheries

BEAM4 (BioEconomic Analytical Model) is a software designed to predict yield, value and a series of measures of economic performance as a function of fishery management measures such as fishing effort control, closed season, closed areas and minimum mesh size regulation. It is a versatile tool for the rational management of exploited living aquatic resources. It can deal with a fishery system of several stocks, several fleets, several fishing grounds and several processing plants and can account for migration of the animals as well as seasonality of recruitment. BEAM4 depends on an age structured cohort based fish stock assessment model combined with an economic model of both harvesting and processing sectors. The measures of economic performance calculated by the economic submodel include private profit, profitability, gross value added, net value added, national net value added, resource rent, employment, costs in foreign exchange and foreign exchange earnings. Though BEAM4 was primarily designed for the analysis of tropical mixed fisheries with penaeid shrimps as the target and finfish as the by catch, it can be used to analyze any fishery. Also, it is suitable for the analysis of resources shared between artisanal and industrial fisheries.

CLIMPROD

CLIMPROD is designed to fit surplus production models using catch and effort data as well as including environmental variable into the model. CLIMPROD requires annual dataseries on catch and effort of a fishery on a single stock, and annual (or seasonal) data series on an environmental variable known to influence the abundance or the catchability of this stock. At least 12 years observations are required. The software offers a statistical and

graphical description of the dataset and then allows an appropriate model to be chosen, fitting it using a nonlinear regression routine and trying to assess the fit with parametric and nonparametric tests before presenting the tables and graphs of the results. These results may explain how environment and fishing effort governed the yields of the fishery during the period under study. Based on an estimate of the next two years' data on effort and environmental regime, an exploratory prediction is proposed for catches per unit of effort (CPUE), and a graph gives variations in "maximum sustainable yields (MSY)" and "optimal fishing efforts (fmax)" according to different environmental regimes.

FAST

The Fishing Activity Simulation Tool, called FAST has been developed as an extension for the ESRI ArcView GIS Software (v.3.1) in combination with the Spatial Analyst v. 1.0 extension. It is based on two models, one of them based on the concept called `friction of distance´ and the other one based on a deductive model on the use of space. Both models are developed in FAST giving values to a set of variables taking part in the spatial distribution of effort ('scoring function'). These values are distributed as percentage of the total effort exerted for every variable considered.

FiSAT

The FAO-ICLARM Stock Assessment Tools (FiSAT) is a package consisting of robust methodologies to formulate management options for fisheries, especially in data-sparse, tropical contexts. FiSAT is resulted from merging of LFSA (Length based Fish Stock Assessment) developed at FAO and the ELEFAN (Electronic Length Frequency Analysis) package developed at ICLARM.

FishStatJ

FishStatJ provides users with access to Fishery Statistics of various sorts. Any data having time series structure can potentially be stored and processed by FishStatJ. The system consists of a main module and the datasets. Currently one set of data is included within the set up module, while other sets are provided separately.

NANSIS

NANSIS is a software for Fishery Survey Data Logging and Analysis. This is a Survey Information System for logging, editing and analysis of scientific trawl survey data (trawl/catch data and length/frequency data).

SPATIAL - Space time Dynamics in Marine Fisheries

SPATIAL is a simulation package developed to model the space-time distribution of fishing intensity using alternative approaches. Three models were built with different input data requirements and output possibilities. ALLOC is a shortrun spatial bieconomic model that represents the interdependencies of smallscale and industrial fleets from different ports of origin, harvesting a target species over several fishing grounds. Model YAREA

introduces geographically contiguous unit areas, and the realism of age structure. It generates a virgin stock by stochastic patch distribution of recruitment, constrained by a user provided maximum species biomass spatially distributed in the corresponding grid. Model CHART was designed to represent the short and longrun spatial dynamics of demersal fisheries as a result of interacting biological, economic, and geographic characteristics. It is an age structured model like YAREA, but incorporates distance from different ports of origin and the shortrun bioeconomic elements of ALLOC. The location of fishing sites are specified in geographic coordinates. When data are available, CHART seems to provide the most comprehensive representation of the space-time distribution of fishing intensity.

Ecopath with Ecosim (EwE) is a free ecological/ecosystem modeling software suite. EwE has three main components: *Ecopath* - a static, mass-balanced snapshot of the system; *Ecosim* - a time dynamic simulation module for policy exploration; and *Ecospace* - a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. The Ecopath software package

can be used toAddress ecological questions;Evaluate ecosystem effects of fishing;Explore management policy options;Analyze impact and placement of marine protected areas; Predict movement and accumulation of contaminants and tracers (Ecotracer);Model effect of environmental changes.
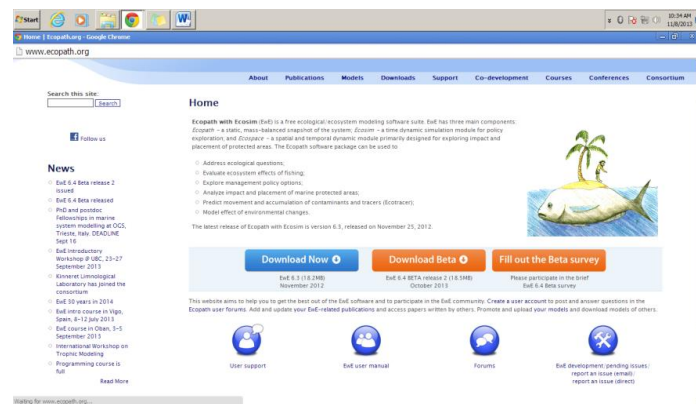
LFDA

The Length Frequency Distribution Analysis (LFDA) package is designed for estimating growth parameters and mortality rates from fish length frequency distributions. LFDA includes methods for estimating the parameters of both non-seasonal and seasonal versions of the von Bertalanffy growth curve. The package includes Shepherd's Length Composition Analysis (SLCA) method, the projection matrix (PROJMAT) method, and a version of the Elefan method for estimating growth parameters. In addition to methods for estimating growth parameters, the package also includes three methods for estimating the total mortality rate, given estimates of the von Bertalanffy parameters. A function allowing simulation of length frequency data under a variety of assumptions is also included.

CEDA

The Catch Effort Data Analysis package (CEDA) is for analysing catch, effort and abundance index data. CEDA allows calculation of estimates of current and unexploited stock sizes, catchability and associated population dynamics parameters. Both depletion and several types of stock production (biomass dynamic) models can be fitted, using one of three

different assumptions about the distribution of residuals. Both point estimates and bootstrap confidence intervals for the estimated parameters can be calculated. CEDA also includes the facility to do projections of stock size into the future under various scenarios of catch or effort levels, so that different management strategies can be investigated.

Yield

Yield is a program for calculating fishery yields and stock biomasses, on an absolute or per-recruit basis, and for calculating biological reference points associated with these. On starting the program, users are asked to enter values of biological parameters (e.g. growth, mortality, age at maturity and stock-recruitment relationship) and fishery parameters (e.g. length at first capture, fishing season). For each parameter, either a single value can be entered, or a probability distribution can be specified to allow for uncertainty. When calculating yields and yields per recruit, the program takes explicit account of specified parameter uncertainties, presenting results in terms of histograms. Transient projection and reference point calculations can also be made, once the extent of stochastic recruitment variability has been specified

ParFish

Participatory Fisheries Stock Assessment (ParFish) Software uses Bayesian Statistics and Decision Theory to assess the state of a fishery stock and estimate limit and target control levels. The ParFish software is based on the logistical biomass growth model and requires information on four parameters: Current Biomass, Unexploited Biomass, Catchabilty and Growth rate. Interview data from fishers are used to construct 'priors' for the model parameters which can be combined with other available information to provide best estimates. This information is then used, together with preference data from fishermen, to calculate the current stock level and the control levels that will provide the most preferred catch rates for fishers. The programme takes explicit account of uncertainty in the data, presenting results as probability density functions.

SAS

The SAS System provides a powerful framework for statistical analysis. In addition to statistical analysis, it also allows programmers to perform report writing, graphics, business planning, forecasting, quality improvement, project management, and more. SAS is a good program for the intermediate and advanced user because it is very powerful, can be used with extremely large data sets, and can perform complex and advanced analyses. SAS is run largely by programming syntax rather than point-and-click menus, so some knowledge of the programming language is required. For a new user, learning how to write code and run the appropriate procedures can be daunting. Enterprise Guide enables you to get answers without having to write programs, through a point-and-click interface making selections from a series of menus. As a benefit even for experienced SAS programmers, EG provides a framework within which to organize the data, tasks, and results involved in

performing a statistical analysis, through the creation and maintenance of "projects". The web site at http://www.sas.com/, gives complete information about SAS. SAS is fully supported on Windows and on UNIX/Linux, and is fully up to date on these two operating systems.

IBM SPSS Statistics

SPSS, is the one among the popular data management and analysis product used in various fields of research. Originally named Statistical Package for the Social Sciences, later modified to Statistical Product and Service Solutions to reflect the diversity of the userbase. Now it is acquired by IBM in 2009, and current versions are officially named IBM SPSS Statistics. Companion products in the same family are used for survey authoring and deployment (IBM SPSS Data Collection), data mining (IBM SPSS Modeler), text analytics, and collaboration and deployment (batch and automated scoring services). The IBM SPSS Statistics offers the core statistical procedures which business managers and analysts need to address fundamental business and research questions. The software provides tools that allow users to quickly view data, formulate hypotheses for additional testing, and carry out procedures to clarify relationships between variables, create clusters, identify trends and make predictions.

STATA

Stata is a full-featured statistical programming language that runs on a variety of platforms such as Windows, Mac OS X, Unix and Linux. It can be used for both simple and complex statistical analyses. STATA uses a point-and-click interface as well as command syntax, which makes it easy to use. STATA also make it easy to generate graphs and plots of data and results. Analysis in STATA is centered around four windows: the command window, the review window, the result window, and the variable window. Analysis commands are entered into the command window and the review window records those commands. The variables window lists the variables that are available in the current data set along with the variable labels, and the results window is where the results appear.

The following are packages developed using R computing framework which are useful for performing specific fisheries related analyses.

FSA: Fisheries Stock Assessment

A wide variety of functions used to perform traditional stock assessment methods — e.g., population, growth, mortality, etc. estimates. Also includes functions for visualizing the effect of violating assumptions in common stock assessment models. Originally developed as a teaching tool, FSA has been expanded to be a useful analytical tool.

FLR: Fisheries Library in R

A collection of tools in the R statistical language that facilitates the construction of bio-economic simulation models of fisheries and ecological sytems. It is a generic toolbox, but is specifically suited for the construction of simulation models for the evaluation of fisheries management strategies. The FLR library is under development by researchers accross a number of laboratories and universities in various countries.

Fishmethods: Fisheries Methods and Models in R

Fishmethods is a comprehensive collection of functions written in R to perform Fishery methods and models from Quinn and Deriso (1999), Haddon(2001), and the literature.

ADMB – Automatic Differentiation Model Builder

ADMB-based computer models are used globally to monitor populations of many endangered and commercially valuable species, to develop place-based resource management policies, and to reconstruct movements of animals tracked with electronic tags. ADMB-based stock assessments are critical to the management of commercially important fisheries stocks.

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