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PROJECT 62: SEAPODYM WORKING PROGRESS AND APPLICATIONS TO PACIFIC TUNA AND BILLFISH POPULATIONS AND FISHERIES.

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1 Introduction

SEAPODYM is a model developed for investigating spatial tuna population dynamics, under the influence of both fishing and environmental effects. The project is affiliated as an independently funded project in the SC's programme of work (Project 62).

2 Recent and ongoing code developments

Since the previous SC meeting (SC7), the code of SEAPODYM has been enhanced both to improve the skills of the model and to facilitate its use by non-developers colleagues.

The main changes include:

1. Increased efficiency of the code, especially for optimization simulations. This is a key issue to use higher spatial resolution and more data (e.g tagging) in the Maximum Likelihood Estimation (MLE). The code was enhanced by:
    a. avoiding Input/Output during optimization runs
    b. reducing the gradient stack (memory required to save variables to compute gradients) by 15%.
2. Flexibility was added into model mechanisms such as cannibalism on juveniles by adults, the modulation of mortality through food requirement index for young and adults and environment for juveniles.
3. Parameters for seasonal switch controlling the spawning migration can be estimated with optimization.
4. More diagnostic routines were developed to facilitate the analysis and validation of simulation outputs (e.g., mean mortality, diffusion and displacement weighted by cohorts, larvae distribution in relation to SST…).
5. Preliminary work on the code was conducted to compute biomass transfers between regions.

Ongoing key developments are concerning two major objectives:

1. ***The optimization of the energy transfer coefficients for the Mid-Trophic Level component (tuna forage) of the model*** (PFRP project "Assimilating *in situ* bioacoustic data in a mid-trophic level model"). Optimization experiments are conducted using acoustic data provided by Réka Domokos and Rudy Kloser.

2. ***The use of tagging data in the optimization approach of tuna population dynamic*** (PFRP project "Integrating conventional and electronic tagging data into SEAPODYM"). Substantial changes in the code structure are required to use both conventional and electronic tagging data in the MLE (Senina et al 2012). Thanks to the enhancement of code efficiency, it is now possible to use an approach similar to the one developed by Sibert and co-authors (1999). The tagging dataset is split into several cohorts by the size of the tagged fish. The position at recapture is used to fit habitats and movements parameters through the minimization of negative log-likelihood function. For electronic archival tagging data, the same method is used but assuming that recaptures occur at every time step of the model at the tag recorded positions.

3 Pacific skipjack

- The configuration using the SODA ocean reanalysis at 1°x month with satellite-derived primary production has been updated and will be used by SPC for regional EEZ analyses.

- The pre-operational model using near real time oceanic environment will be used to provide boundaries for regional high resolution modelling.

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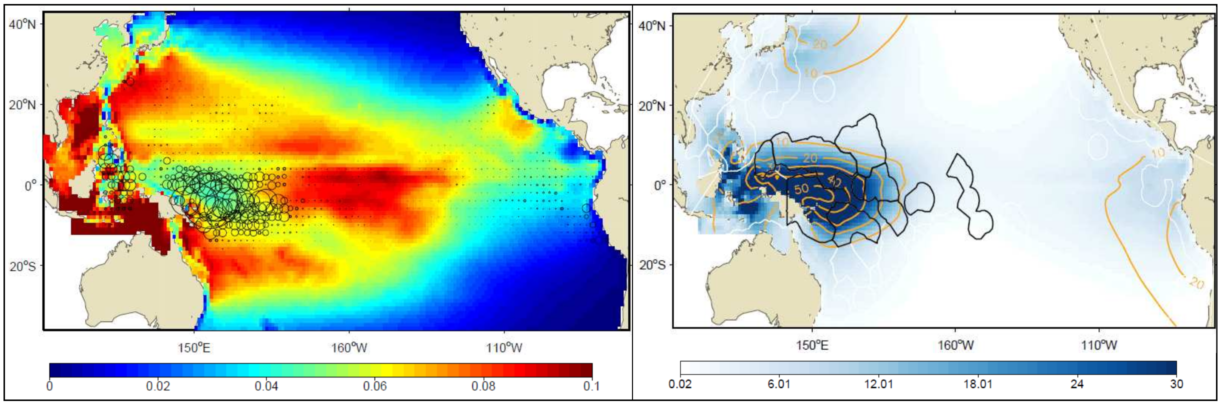
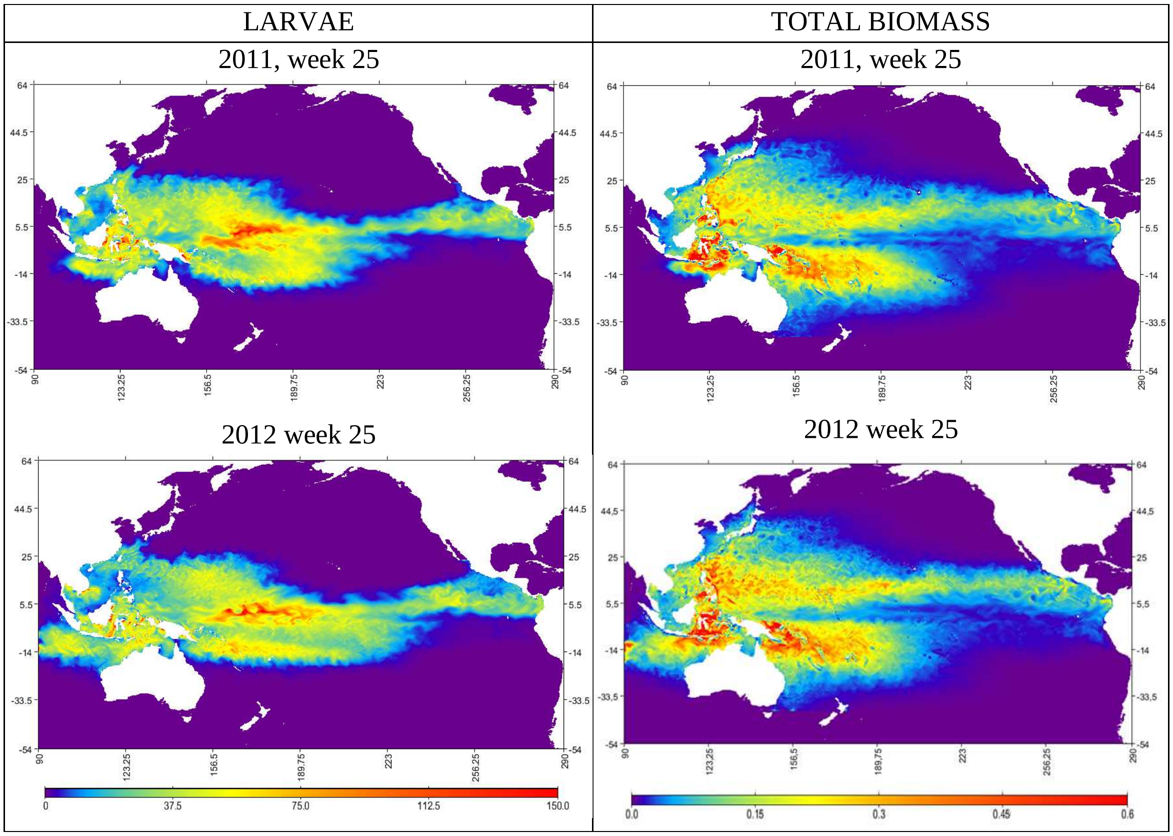


New configuration for skipjack based on SODA 1°x month. Total average biomass of skipjack (2004-08) with total catch (circles) and change in spawning (adult) biomass (isopleths give % relative change with respect to unfished biomass).



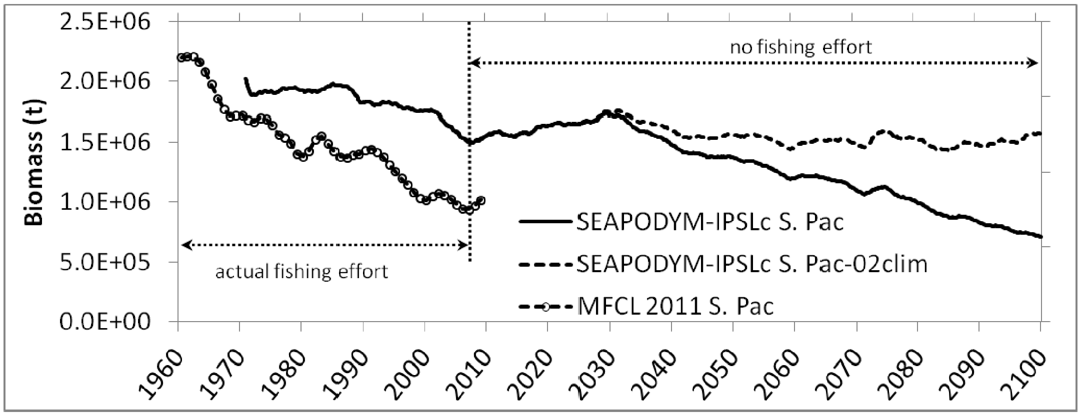
Pre-operational model at 0.25°x week. Distribution of larvae density and total skipjack biomass predicted without fishing effort, for the calendar week 25 in 2011 compared to 2012 (18-24 June).

4 Pacific albacore

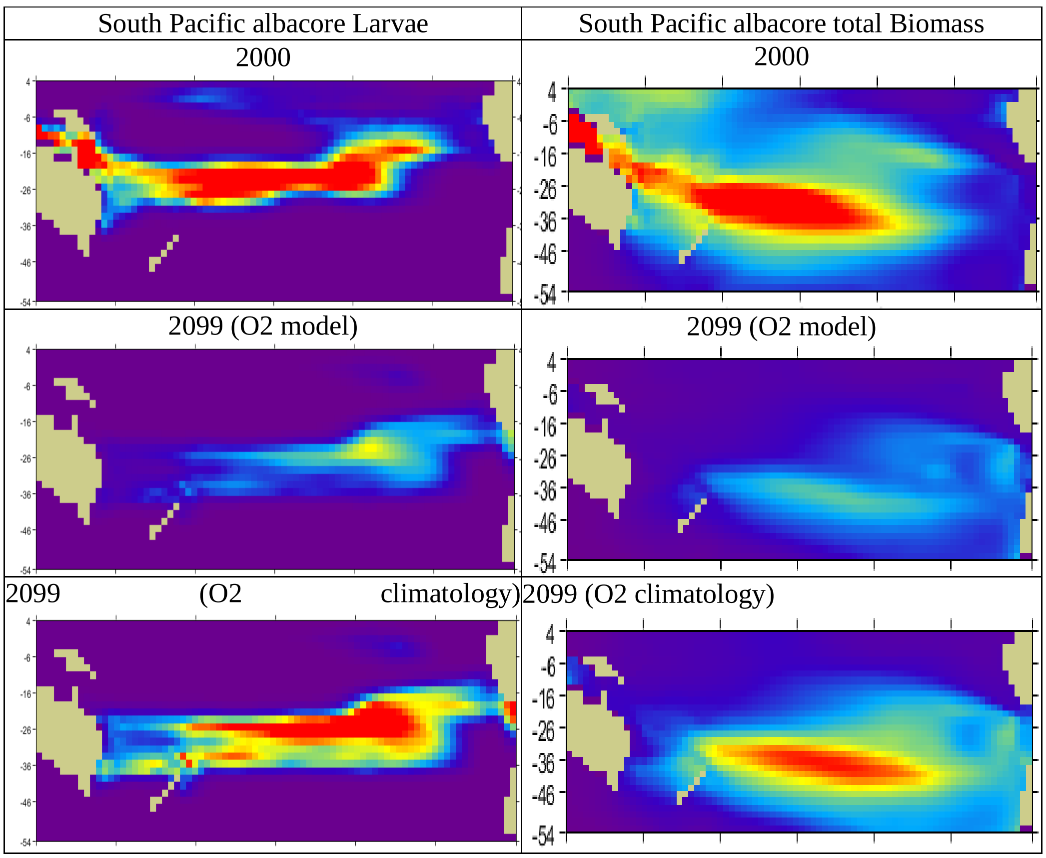
The projected effects of climate change on the distribution and abundance of south Pacific albacore has been investigated after a correction of temperature anomaly detected in the forcing provided by the Climate model IPSL-CM4. The Environmental forcing inputs for SEAPODYM are predicted from a biogeochemical model (PISCES) coupled to the climate model IPSL-CM4. The scenario used was the SRES A2 IPCC scenario for the 21th century, i.e., atmospheric CO_2 concentrations reaching 850 ppm in the year 2100, and historical data between 1860 and 2000.

The correction of the IPSL CM4 anomaly resulted in establishing, for the first time, an optimised model for South Pacific albacore based on the A2 climate change scenario. The forecasts of albacore population dynamics under this scenario were strongly influenced by the assumptions of dissolved oxygen (O_2) applied in the IPSL CM4 model and the results need to be interpreted with some caution as the accuracy of dissolved O_2 concentration in the IPSL CM4 remains unclear. Nevertheless, the results from the simulation show:

- In the absence of future fishing mortality, the total biomass is predicted to stabilize until 2030, and then either remain stable if there is no change in dissolved oxygen concentration in the ocean or decrease if the change predicted by the IPSL-CM4 model is correct.
- Spatially, the spawning habitat is predicted to shift progressively eastward during the 21st Century (Figure 2). More favourable conditions for young and adult fish become evident in the south-east of the species range and become less favourable in the western tropical and sub-tropical region.



Total albacore biomass estimates for the South Pacific Ocean with comparison to the last WCPFC stock assessment estimate (MFCL 2011) in the WCPO (Hoyle et al. 2011).



Mean annual density of south Pacific albacore larvae (ind. km^{-2}) and total biomass (t km^{-2}) predicted from the A2 climate scenario in 2000 and 2099 using dissolved oxygen concentration from the model or climatology from historical observation (WOA).

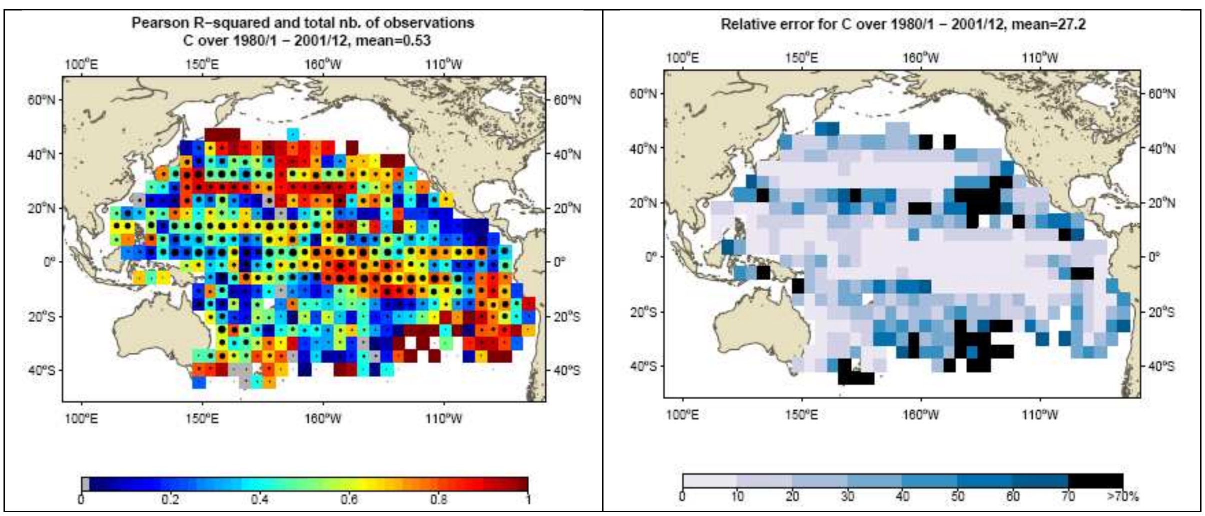
5 Pacific swordfish

A SEAPODYM application to Pacific swordfish has been developed. After definition of the population structure and initial parameterization, optimization experiments were conducted based on accessible fishing data (catch, effort and size frequency). Fishing data for the eastern Pacific fisheries were not available. The model was able to converge with a reasonable parameterization and fit to catch data. Three sub-stocks emerged from the simulation that represented the overall distribution of catch spatially, in the North Pacific, South-west Pacific and eastern Pacific. The young immature fish are mainly caught in the tropical region (20°N-20°S) and their distribution strongly influenced by the El Nino Southern Oscillation (ENSO).

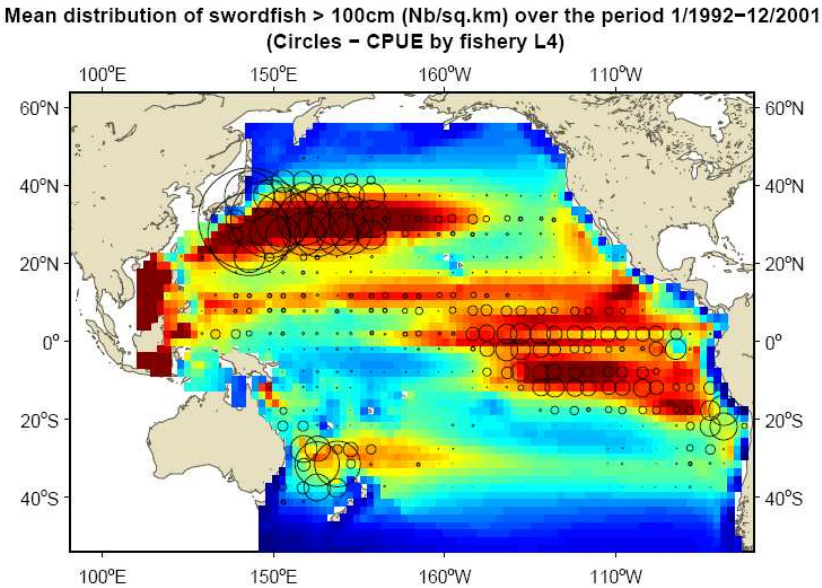
The overall Pacific adult stock biomass was estimated between 3.4 -3.7 million tonnes. This is certainly overestimated since i) the fishing mortality due to large fisheries in the EPO is not taken into account, and ii) previous analyses with the model have shown a tendency to increase biomass to achieve a better fit to fishing data, especially when using coarse resolution (e.g. 2°x month) and when fisheries are defined (ie aggregated) with too much heterogeneity. It would be particularly useful to revise this study using higher resolution (eg. 1deg x month) environmental forcing and a complete fishing data set.

L1	Hawaii – shallow sets
L2	Hawaii – mixed sets
L3	Hawaii – deep sets
L4	Japan
L5	Korea
L6	Taiwan
L7	Australia

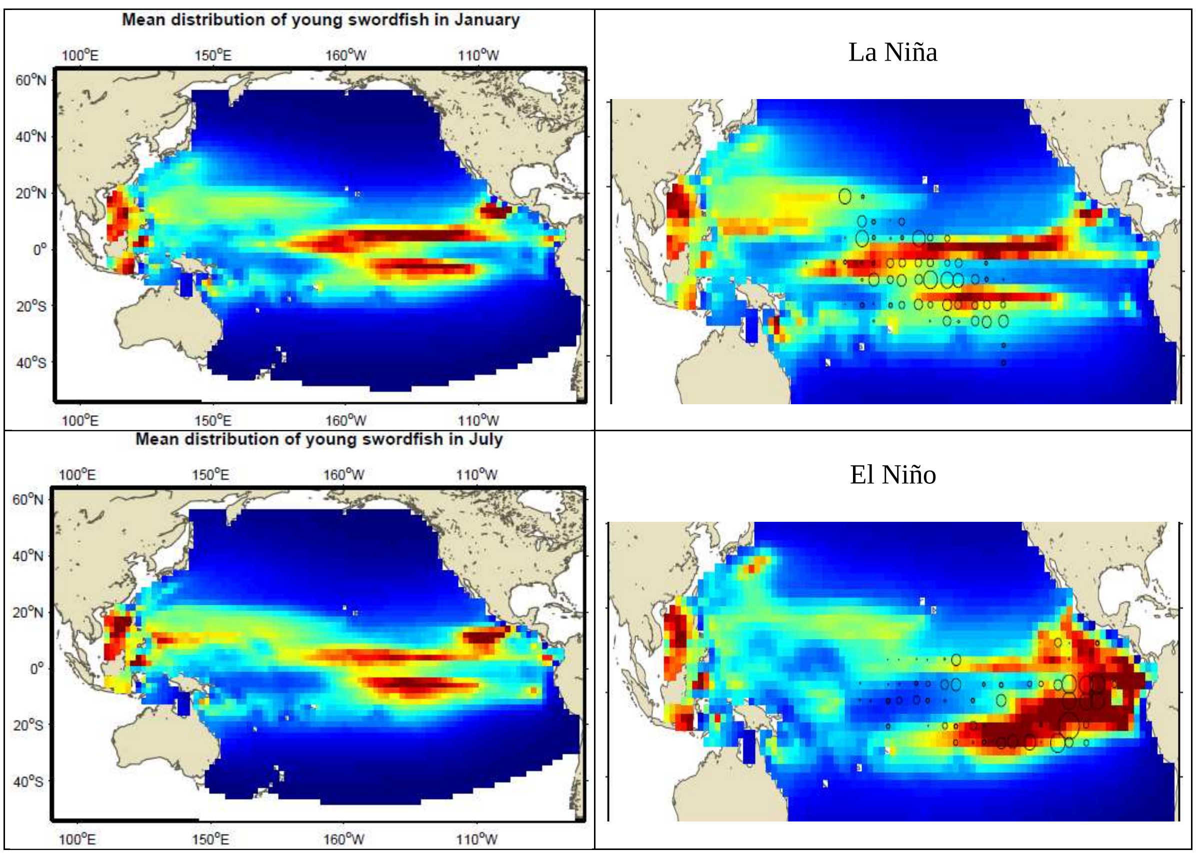
Table 1. Longline fisheries included.



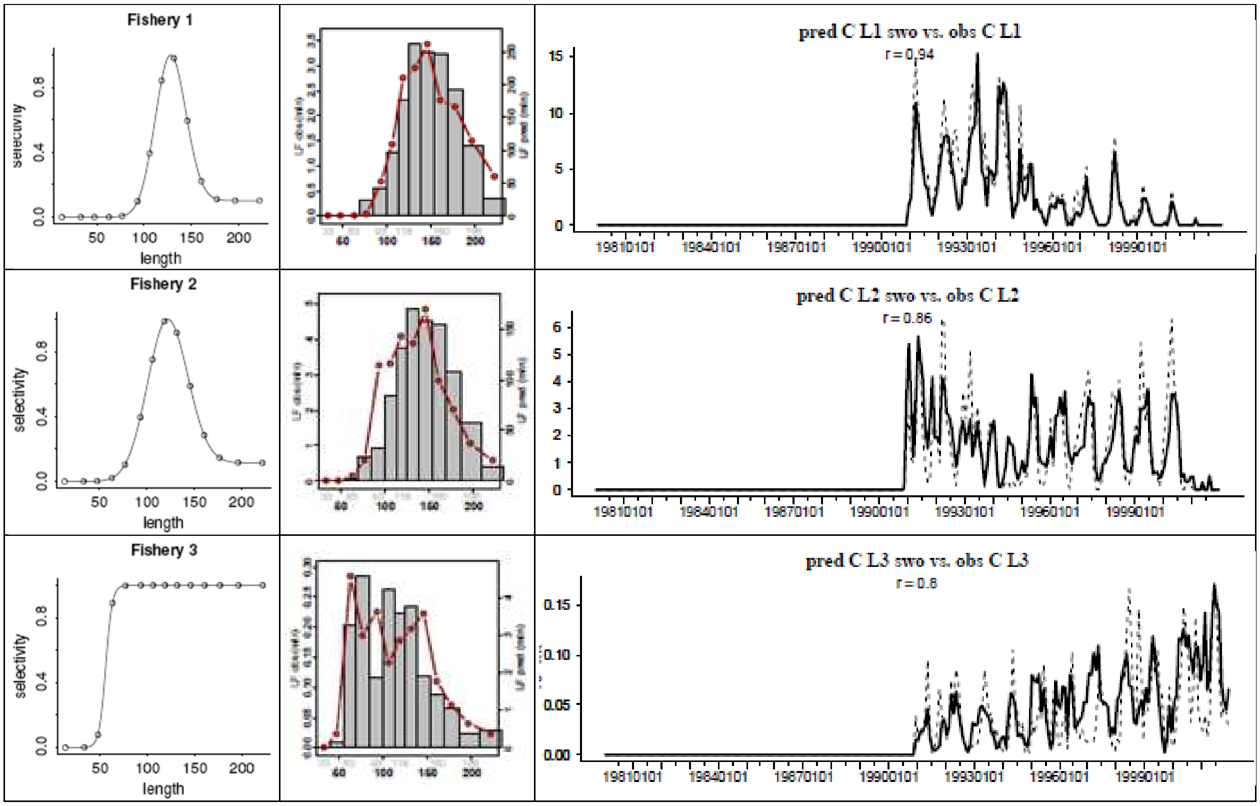
Overall spatial and temporal fit to swordfish catch. Likelihood comprised CPUE and LF data. Model predictions were aggregated on the resolution of the data (5degx30d) before contributing to the likelihood.



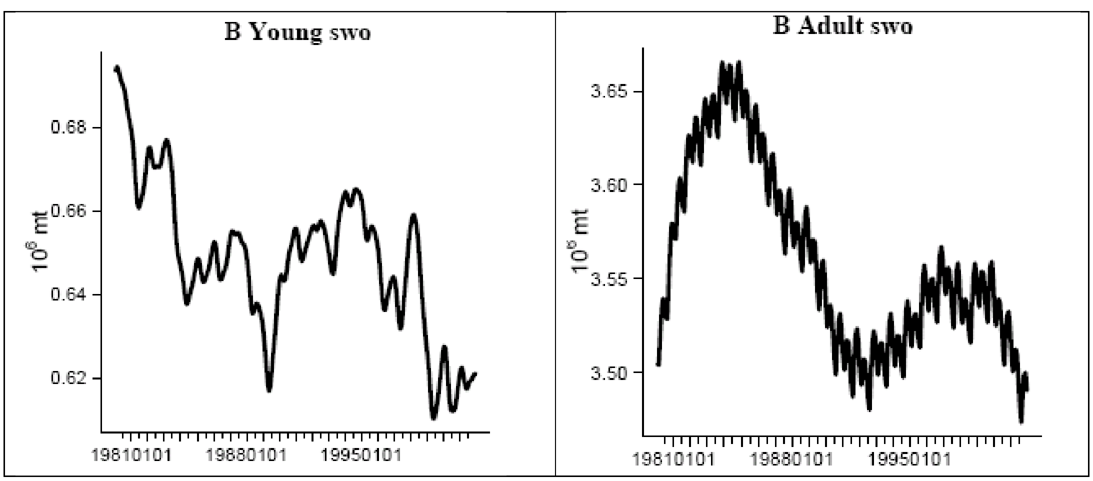
Mean distribution of swordfish larger than 100 cm (Nb / km^2) over the period 1992-2001 with CPUE superimposed and proportional to the size of circles.



Distribution of young immature swordfish. Left: mean distribution in January (top) and July (bottom). Right: distribution during El Niño (top) and La Niña (bottom) events.



Examples of fit to catch data for the three Hawaiian longline fisheries. Left: selectivity function; middle: fit between observed (bars) and predicted (line) size frequencies (all data aggregated); right: observed (dotted line) and predicted (continuous line) catch data.



Total Pacific swordfish biomass estimate of young immature and adult biomass

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