Workshop on Dynamics of Pelagic Fish in the North Pacific under Climate Change

Yeosu, Korea 16 Oct 2014

An ecosystem and optimization framework for fish population dynamics assessment under the influence of fishing and climate

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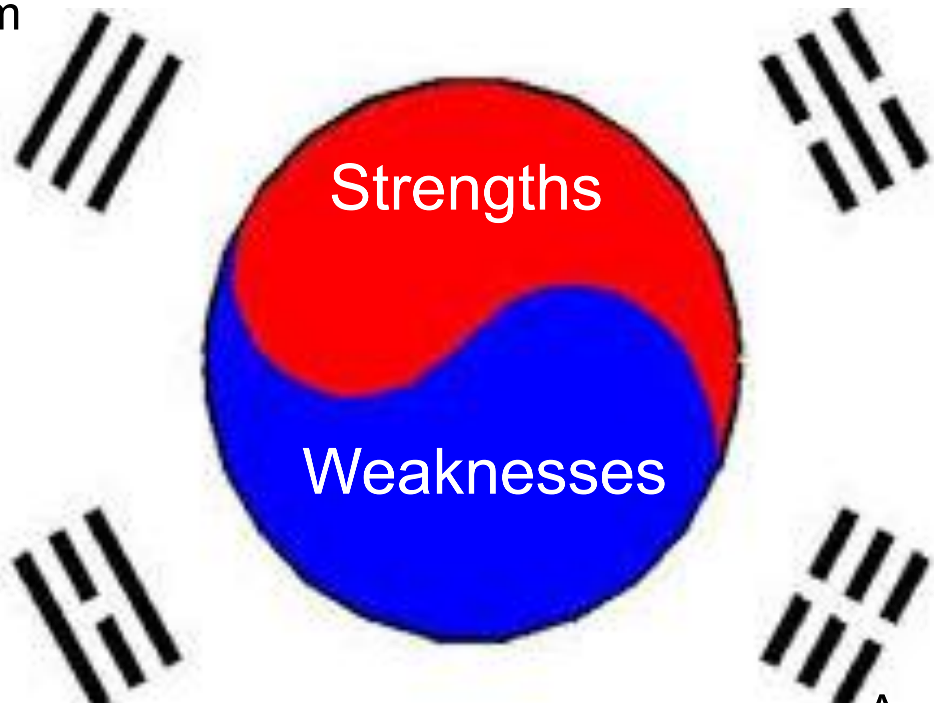
Content

Introduction to SEAPODYM (Spatial Ecosystem And Population Dynamics Model)

Micronekton and habitats
Environmental forcing variables



Optimization framework for parameter estimation (Maximum Likelihood Estimation)
Stock assessment

Applications to Climate Change impacts

SEAPODYM in brief

Predator (e.g., tuna) population

(Lehodey et al 2008 Prog Oceanog)

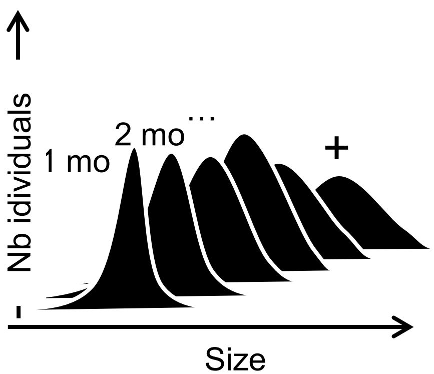
Spatial dynamics based on advection - diffusion equations with movement % to fish size and linked to habitats

+++ + -

Movement following habitat gradient

Feeding Habitat =
Prey abundance (micronekton)
x accessibility (T°,O2)

Mortality

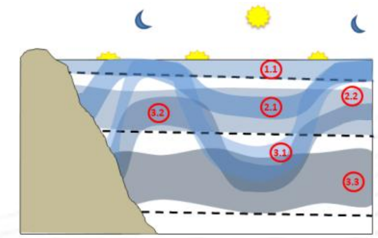


Growth

mortality

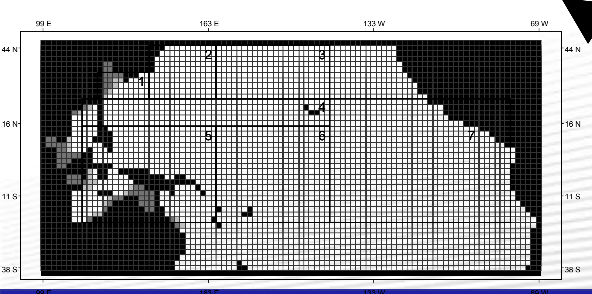
By cohort

IF MATURE seasonal switch



Simplified 3D vertical structure

Population: age structured over a regular grid



Local Larval Stock-Recruitment

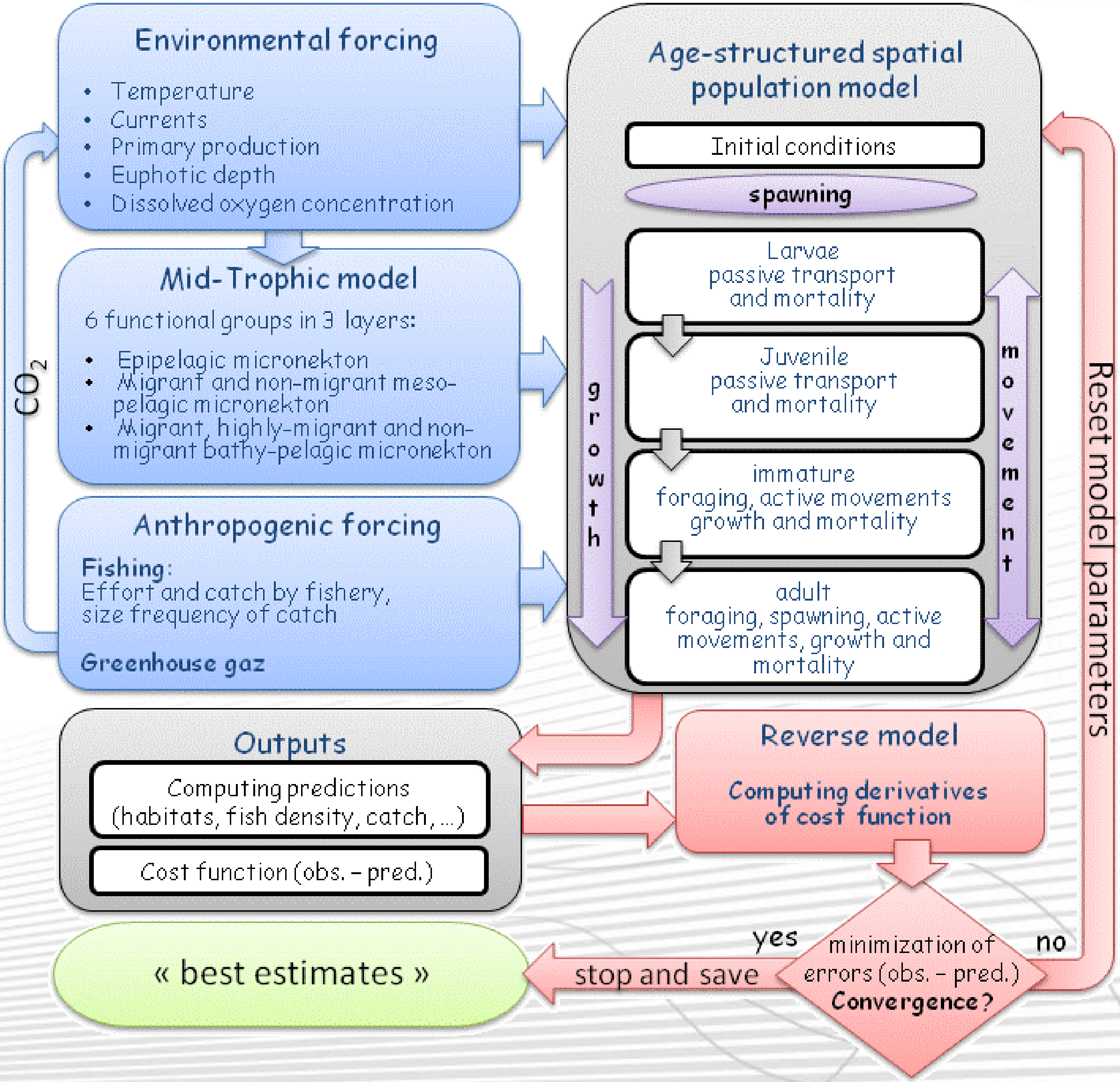
Drift in current

Spawning Habitat =
Temperature
Prey of larvae (zoopl.)
Impact of predation (micronekton)
Accessibility (T°, O2)

Spatial Ecosystem And Population Dynamics Model

SEAPODYM in brief

- SEAPODYM uses ocean bio-physical variables characterizing the environment of predator species to drive the population dynamics of this (these) predator(s).
- An original sub-model describes zooplankton and 6 functional groups of prey organisms (micronekton at the mid-trophic level: MTL)
- Observed effort by fisheries is used to predict catch and Maximum Likelihood Estimation approach fit the catch (and size frequency of catch) to observation to get the best set of parameters



Strengths and Weaknesses

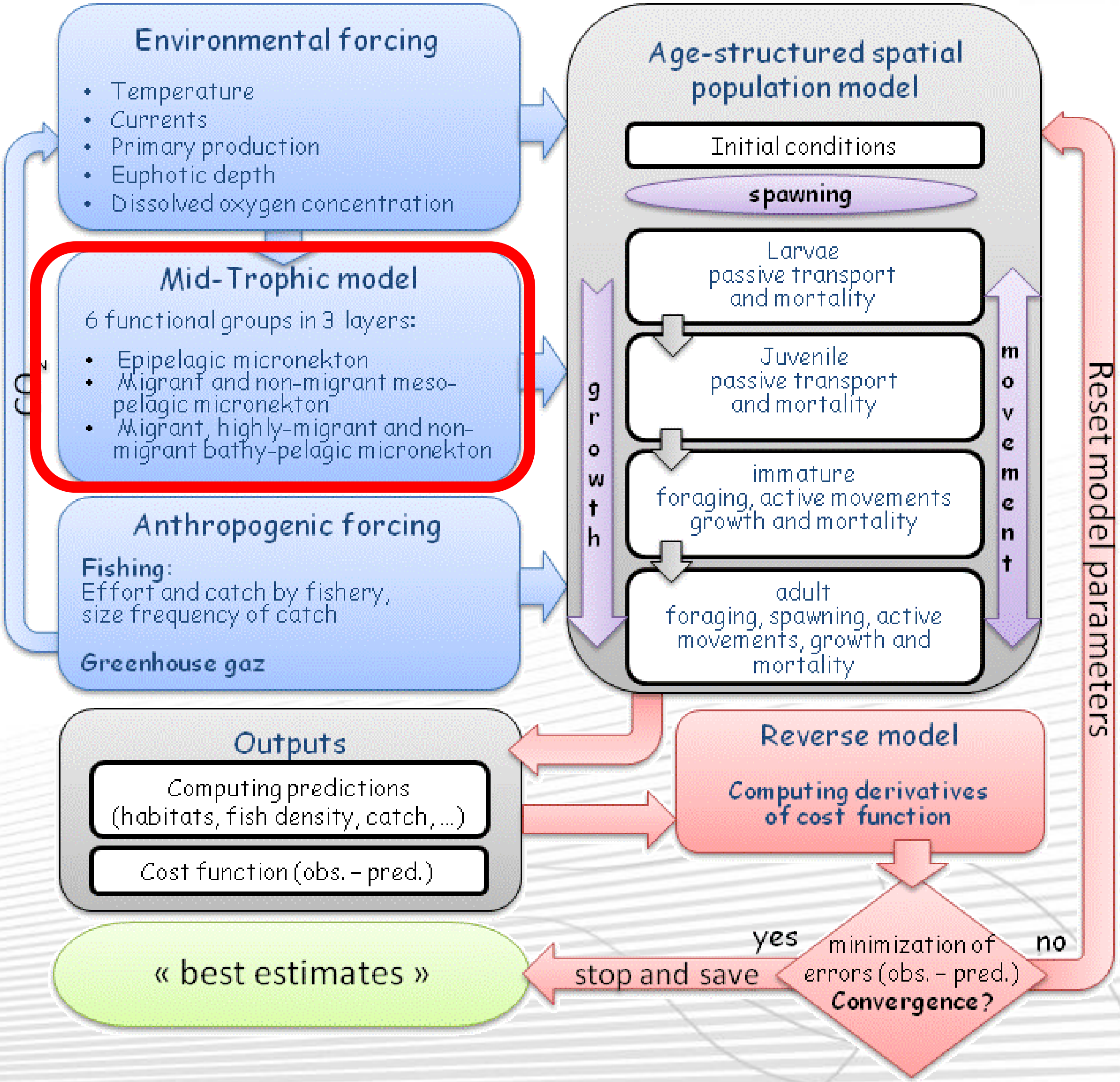
MICRONEKTON

STRENGH:

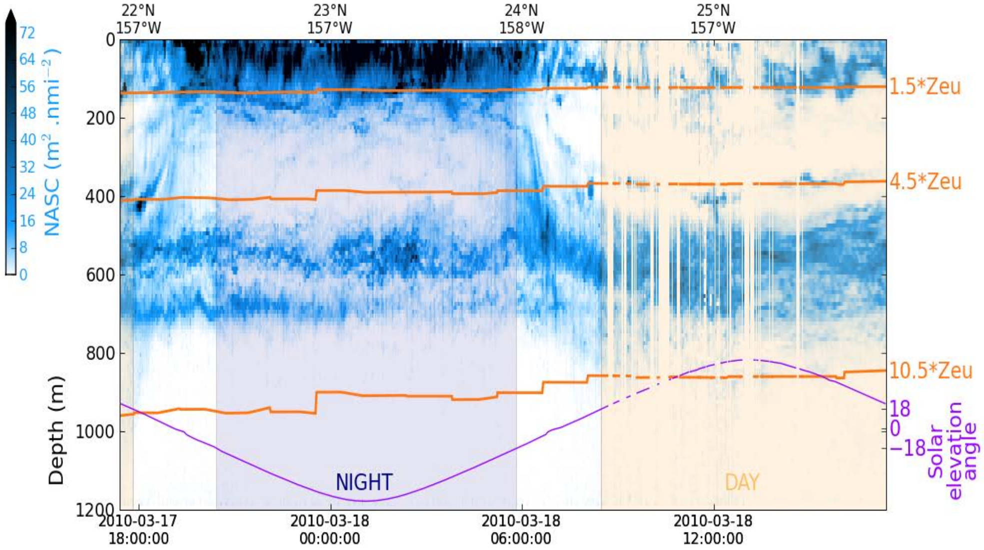
Micronekton (the prey of adults and predators of larvae) is THE KEY component of the system !

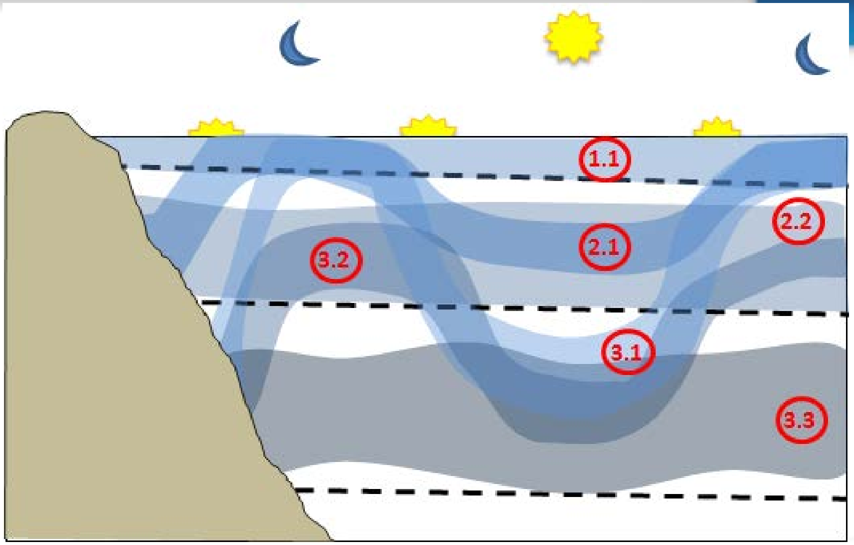
WEAKNESS:

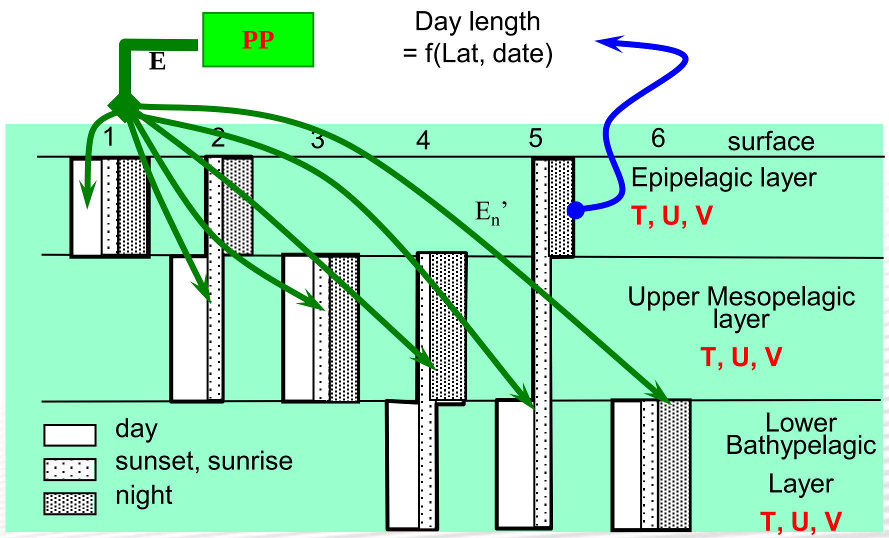
Wrong micronekton modeling = wrong predator simulation and fit to data based on spurious parameterisation



S&W: Micronekton







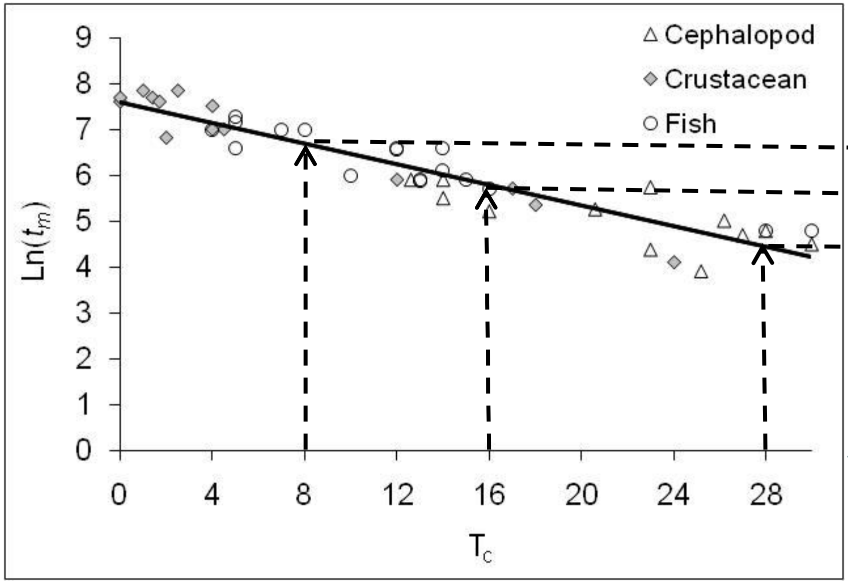
A model of micronekton

6 functional groups in 3 vertical layers. Three components exhibit diel vertical migrations, transferring energy from surface to deep layers.

The source of energy is the primary production PP.

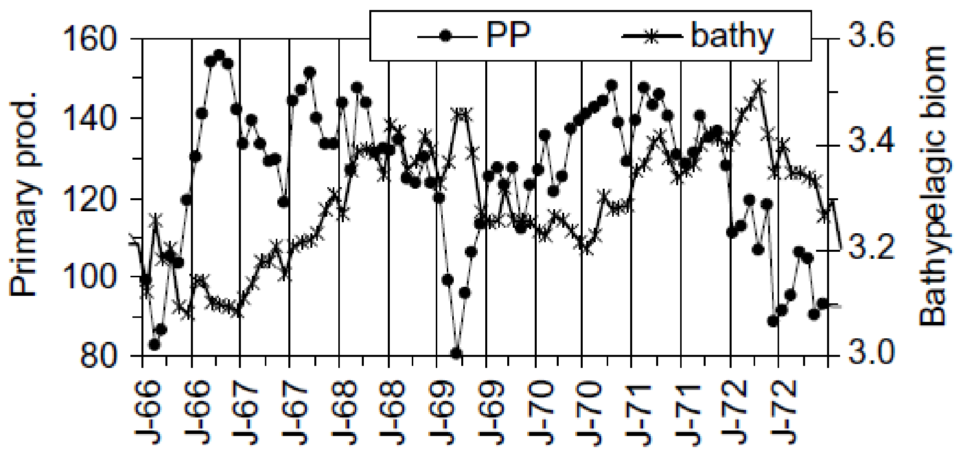
6 parameters (*E; E'$_n$*) to calibrate

S&W: Micronekton



Age at recruitment:	Age at maturity:
199 d	797 d
64 d	255 d
22 d	88 d

Time of development in days (Log scale) of mid-trophic organisms until age at maturity (t_m) in relation to their ambiant habitat temperature Tc



As a consequence the dynamic of biomass of MTL in deep (cold) layers can be decoupled of surface primary production

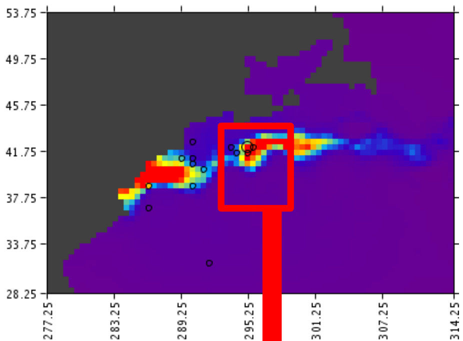
Box: 5°N-5°S; 120°W-100°W

Lehodey P., Murtugudde R., Senina I. (2010). Bridging the gap from ocean models to population dynamics of large marine predators: a model of mid-trophic functional groups. *Progress in Oceanography*, **84**: 69–84

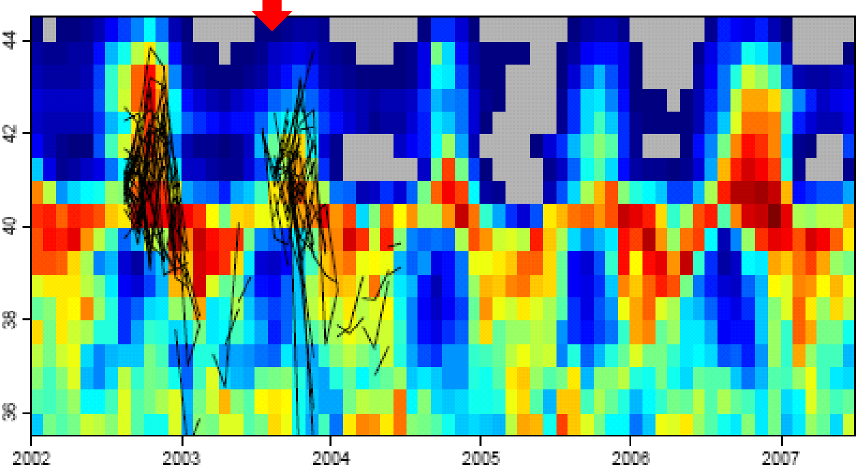
S&W: Micronekton - Habitats

Ex.: Feeding habitat of Atlantic bluefin tuna

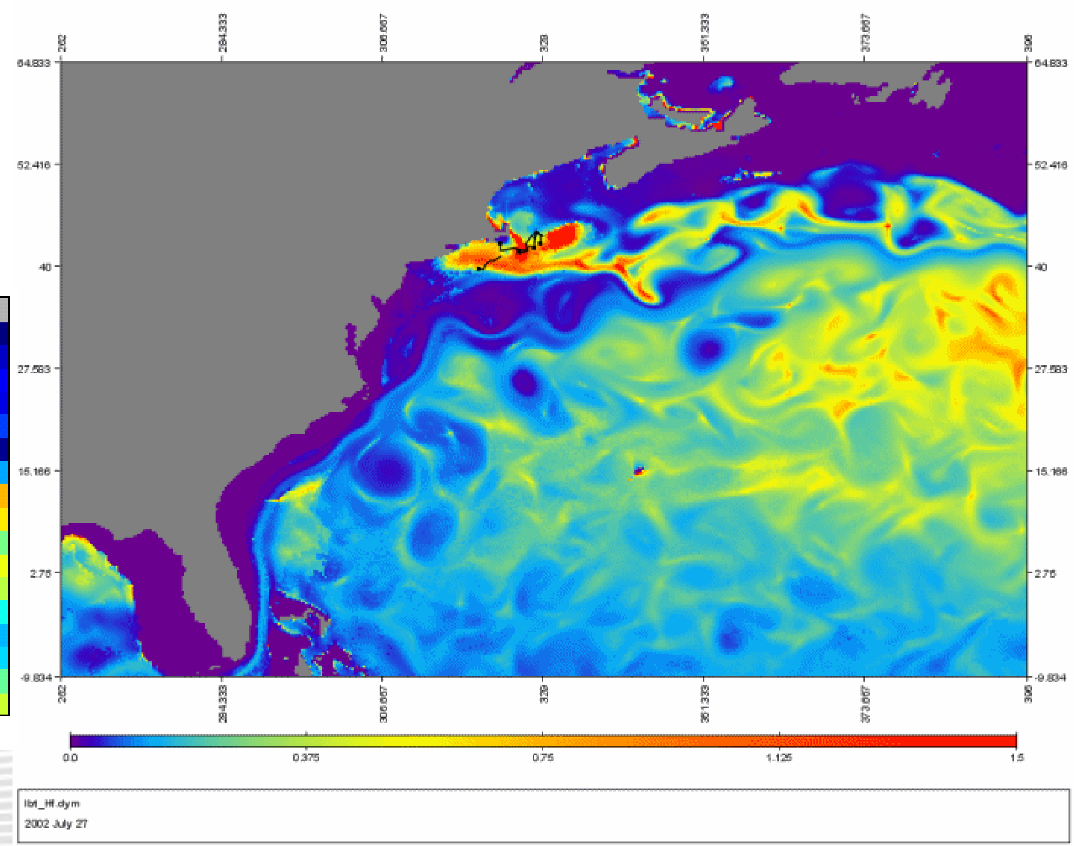
The model predicts the seasonal and interannual variability of feeding habitat in the North-East Atlantic where fish were released with PSATs



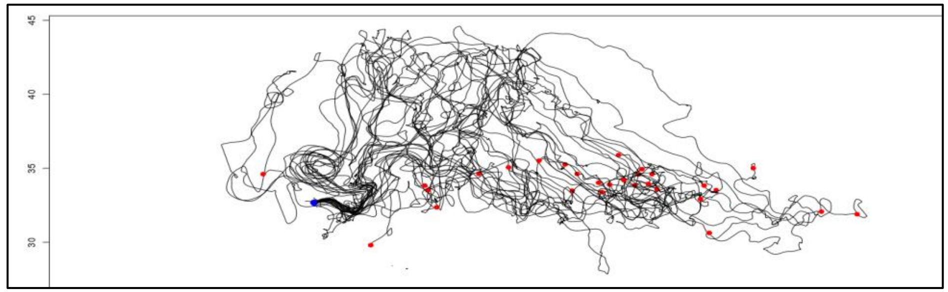
latitude-time plot of habitat index in the box (67W-71W; 35N-44N) estimated from tagging data. Black lines show Atlantic bluefin tag position trajectories.



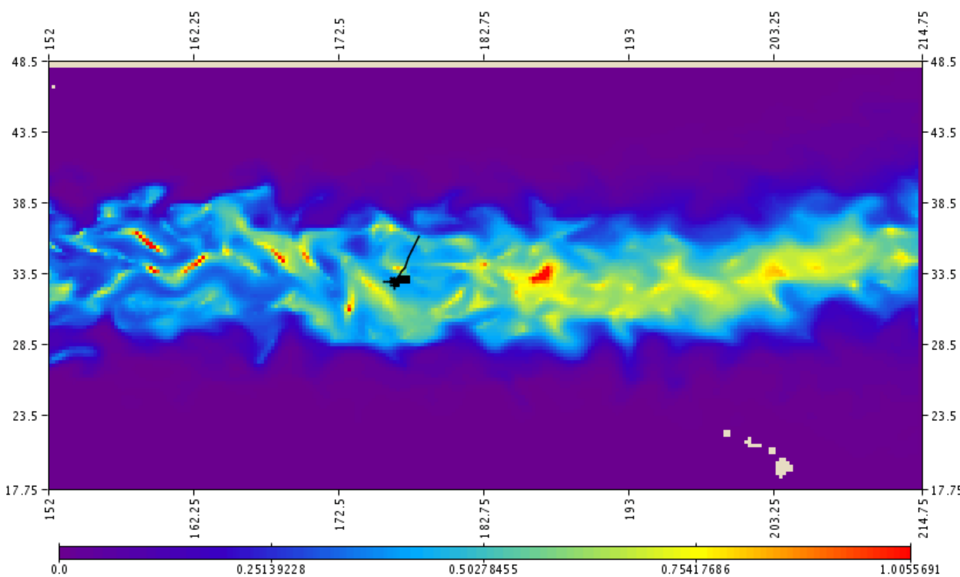
Electronic tagging data kindly from M. Lutcavage



Ex.: Feeding habitat of Loggerhead turtles in the north Pacific



Observed displacements between May 2005 and May 2006



lbt_Ha.dym
2005 May 02

Predicted habitat and observed tracks

Using temperature and micronekton it was possible to model the feeding habitat and movements of turtles opening the way to possible forecast of maps indicating the risk of turtle bycatch to assist fishermen in their activity.

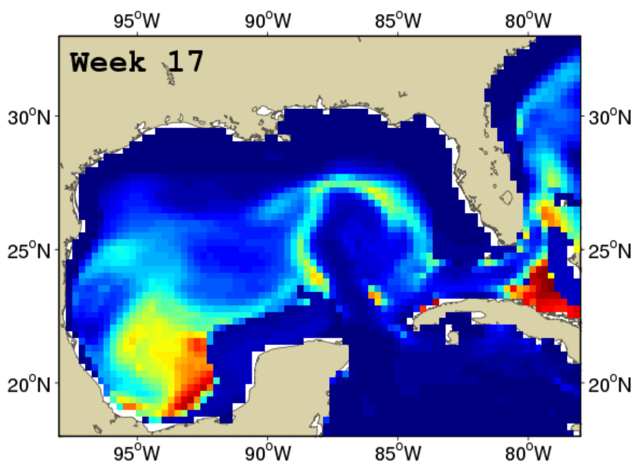
Abecassis M, Senina I, Lehodey P, Gaspar P, Parker D, et al. (2013) A Model of Loggerhead Sea Turtle (*Caretta caretta*) Habitat and Movement in the Oceanic North Pacific. PLoS ONE 8(9): e73274.

S&W: Micronekton - Habitats

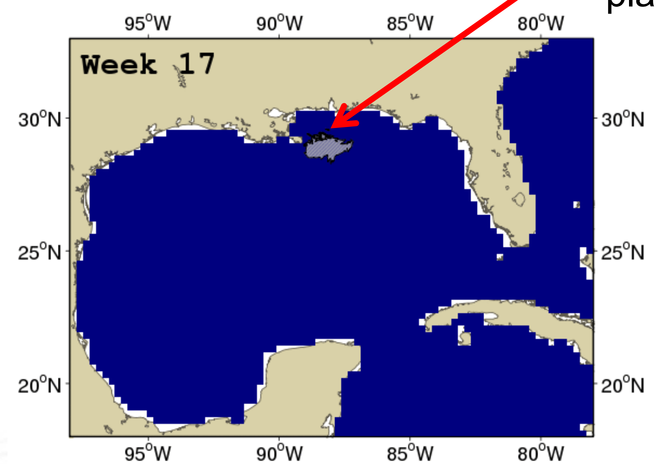
Ex.: Spawing habitat and larvae dynamics: Atlantic Bluefin tuna

- ❑ Favorable **temperature** for optimal growth
- ❑ Coincidence of spawning with presence of food **(zooplankton)** for larvae (match/mismatch of Cushing, 1975)
- ❑ Coincidence of spawning with absence of predators **(micronekton)** of larvae
- ❑ Retention by **currents** of larvae in favorable areas (i.e., with conditions above)
- ❑ Accessibility to spawners (oxygen, clear waters, deep cold waters)
- ❑ Food for spawners (micronekton)

Predicted Bluefin spawning habitat

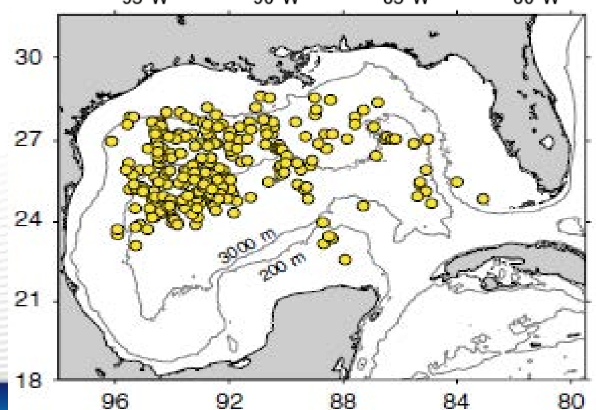


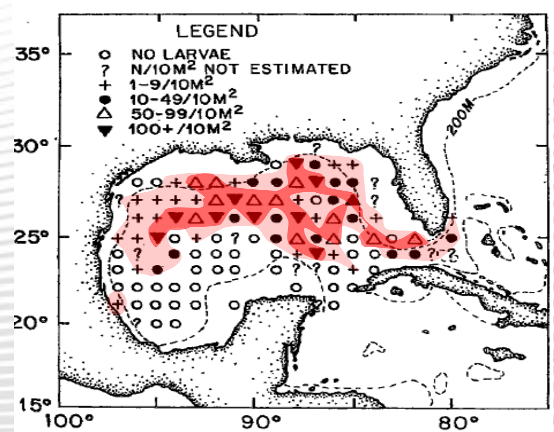
Oil spill from Deep Horizon platform accident



Predicted larvae density (âge 1-30 d)

Geolocation of 28 bluefin tuna identified from their vertical behaviour as in breeding phase (Teo et al. 2007).





Density of bluefin tuna larvae sampled in the Gulf of Mexico in 1973-74, from Mather et al. (1995)

S&W: Oceanic variables

STRENGH:

Parcimonious population model (<20 parameters) to describe complete and spatial dynamics independently of fishing data

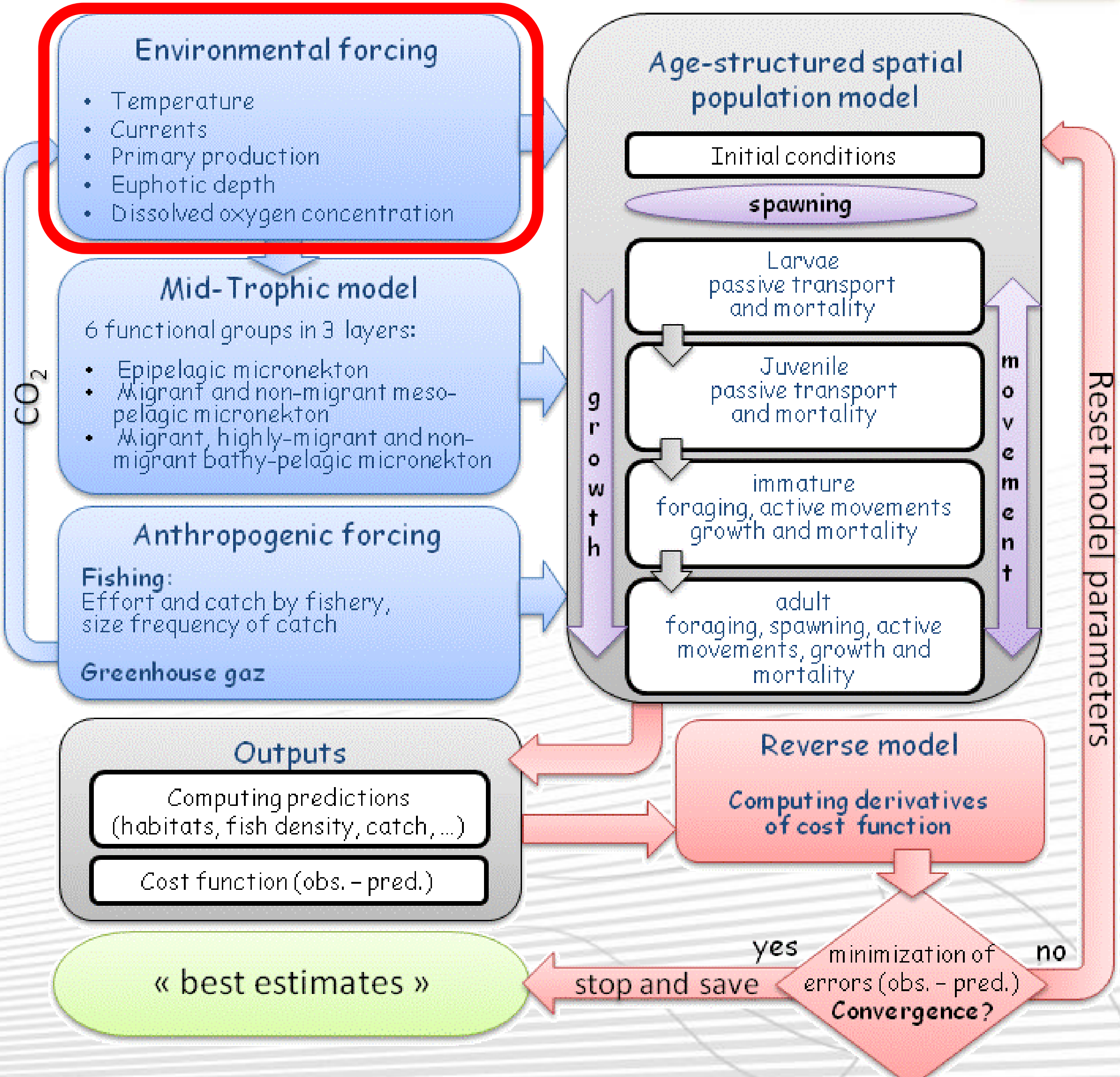
Combining (analyzing) fishing impact and environmental / climate effects.

Climate forecasts

WEAKNESS:

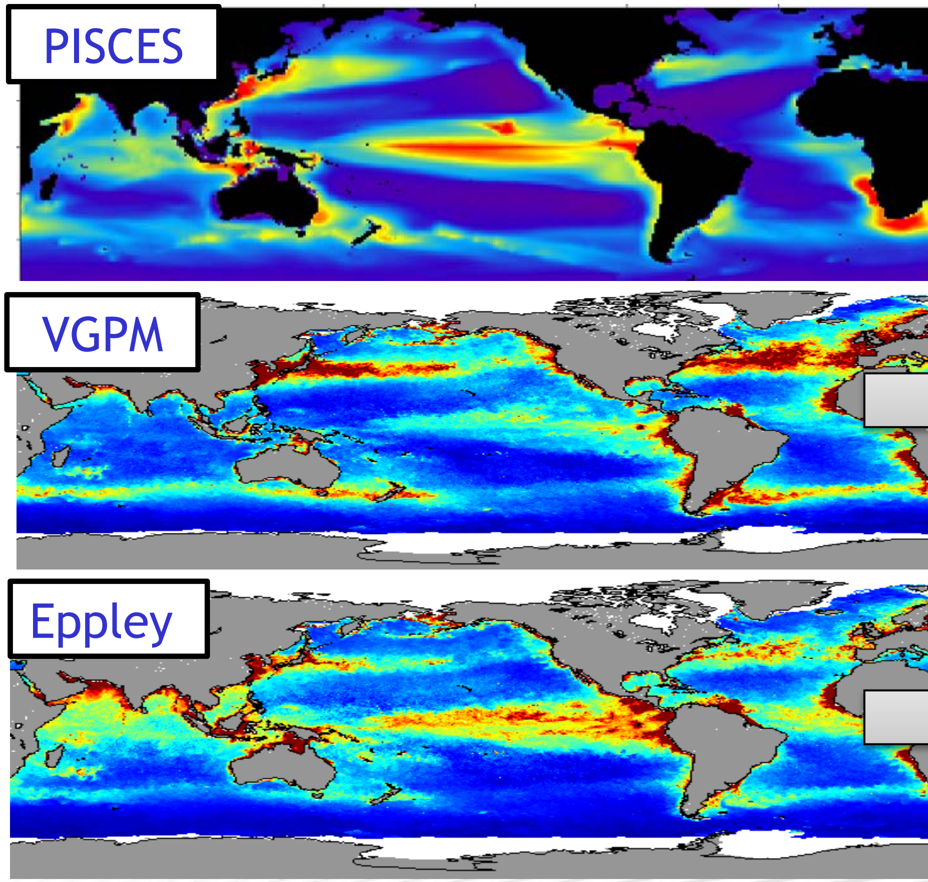
Despite obvious progress, there are still uncertainties, errors, biaises in 3D simulations of ocean physics and biogeochemistry...

Problem to access long historical reliable time series

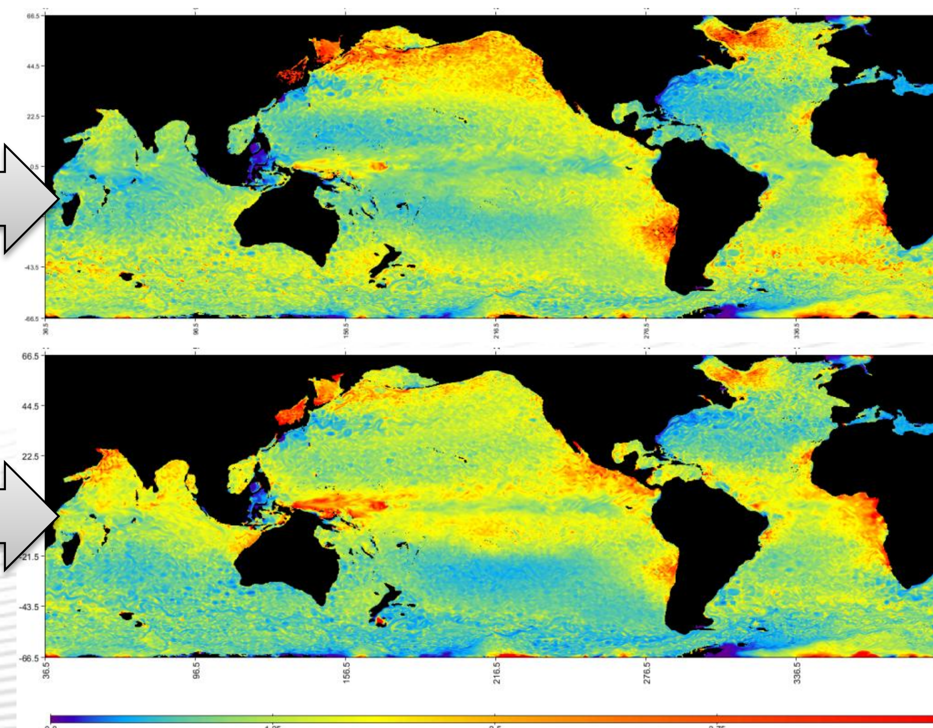


S&W: Oceanic variables

➢ Which Primary production ?



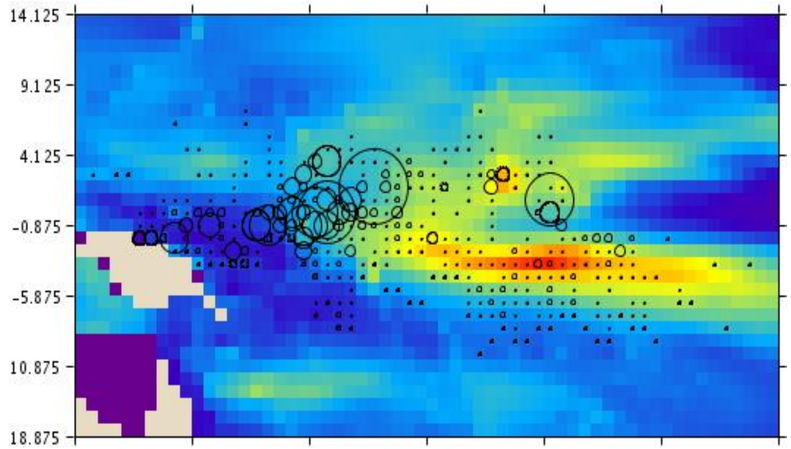
Deep non migrant micronekton



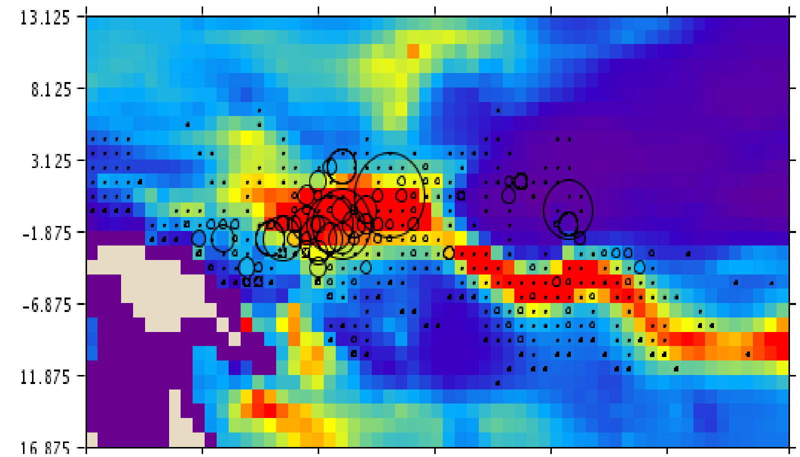
S&W: Oceanic variables

- Which currents?

Sep 2008

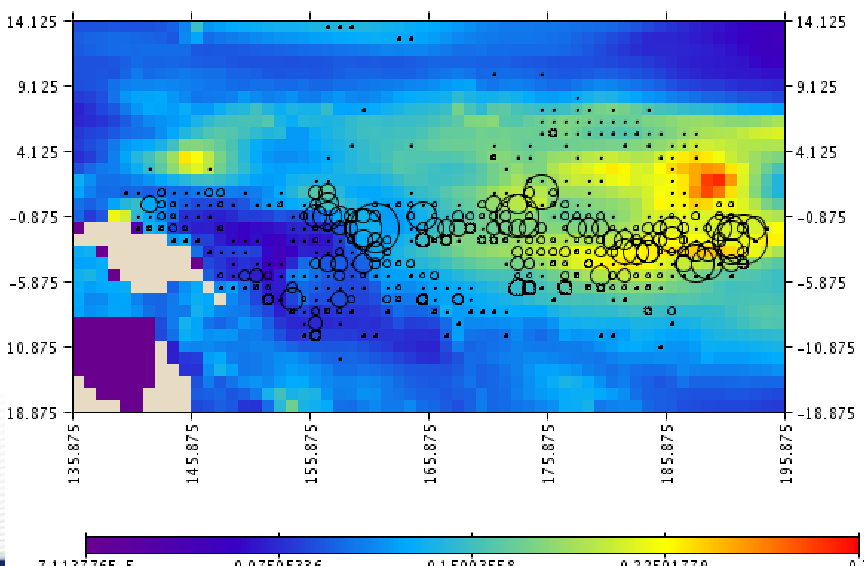


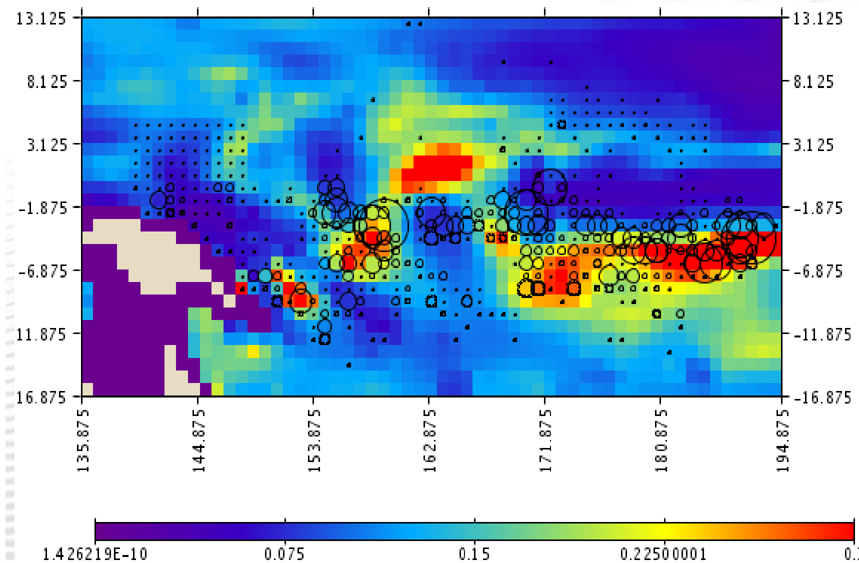
Skipjack with GLORYS



Skipjack with OMEGA

Jan 2010





S&W: Fisheries data

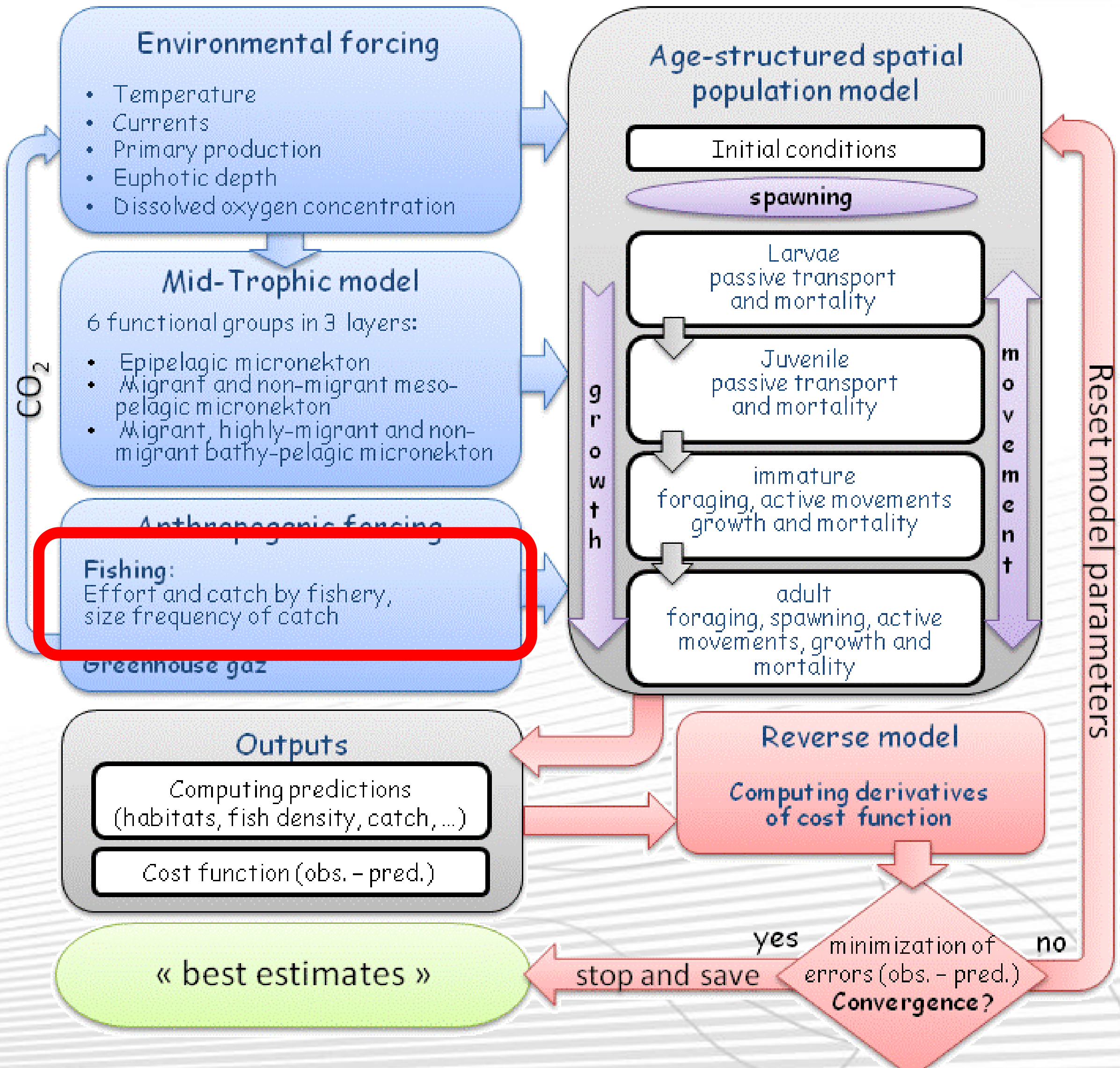
Geo-referenced fishing data

STRENGH:

Take advantage of all information at its highest possible resolution in time and space.
Link CPUE variability directly to change in abundance and linear trends in catchability

WEAKNESS:

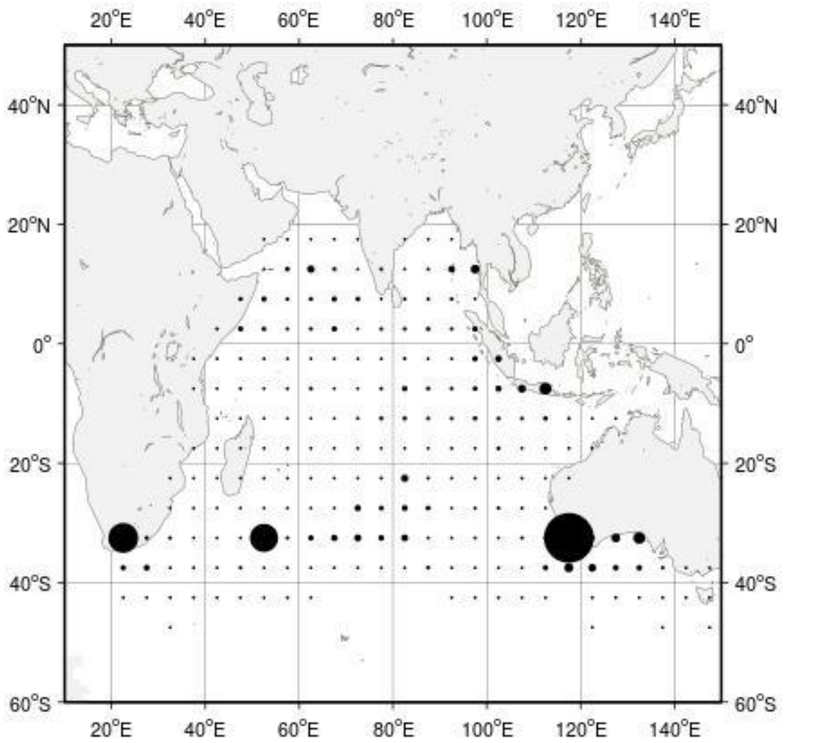
Historical spatially disaggregated fishing data frequently partial or not available.
Require careful homogeneous definition of fisheries and data screening.



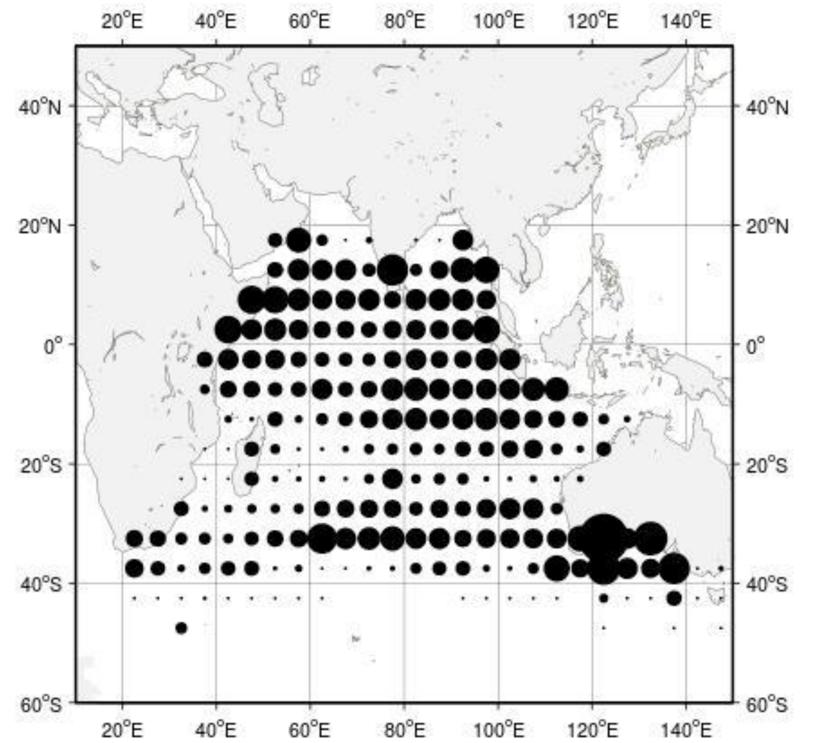
S&W: Fisheries data

Ex: Detection of outliers following Hampel outlier Identifier method

Raw data



After outlier screening



CPUE variance (bigeye) of Japanese longline dataset

S&W: Optimization

STRENGH:

MLE is a powerful robust approach to estimate model parameters

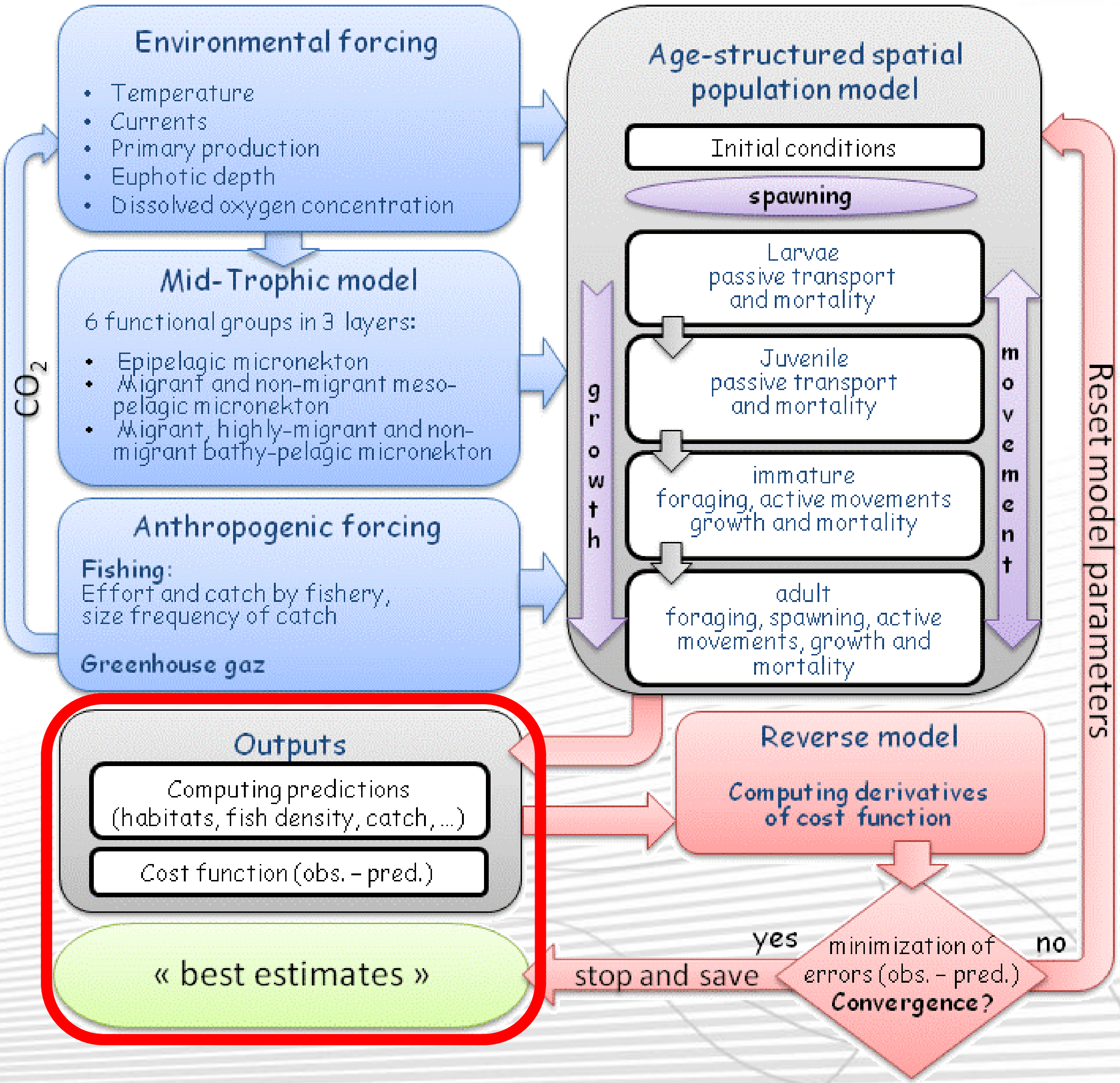
Various kind of data and « a priori » knowledge can be used to construct the cost function (CPUE LF, acoustic data, eggs and larvae densities, tagging data)

WEAKNESS:

The global minimum of the LL is 'hidden' by a large number of local minima

Sensitivity to error probability distribution selected

Some parameters cannot be estimated due to lack of informative data

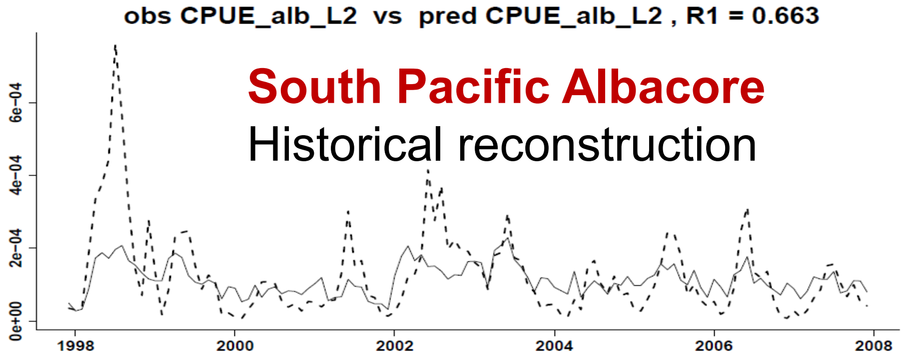


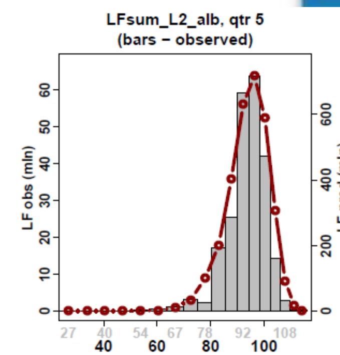
Optimization and stock assessment

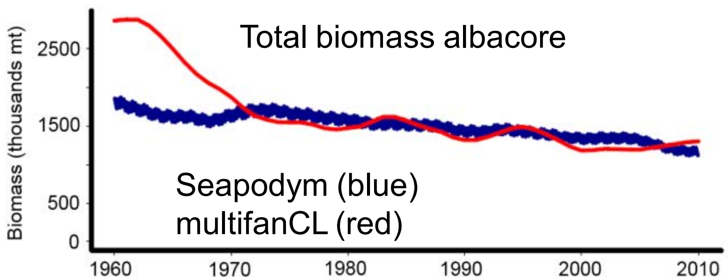
Applications of the model at basin scale at coarse resolution 2°x month, using hindcast simulation from coupled physical-biogeochemical models (OPA-PISCES)

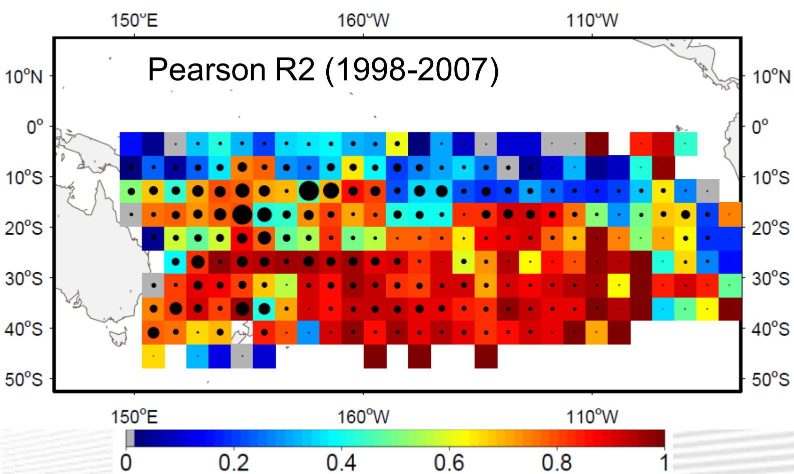
South Pacific Albacore

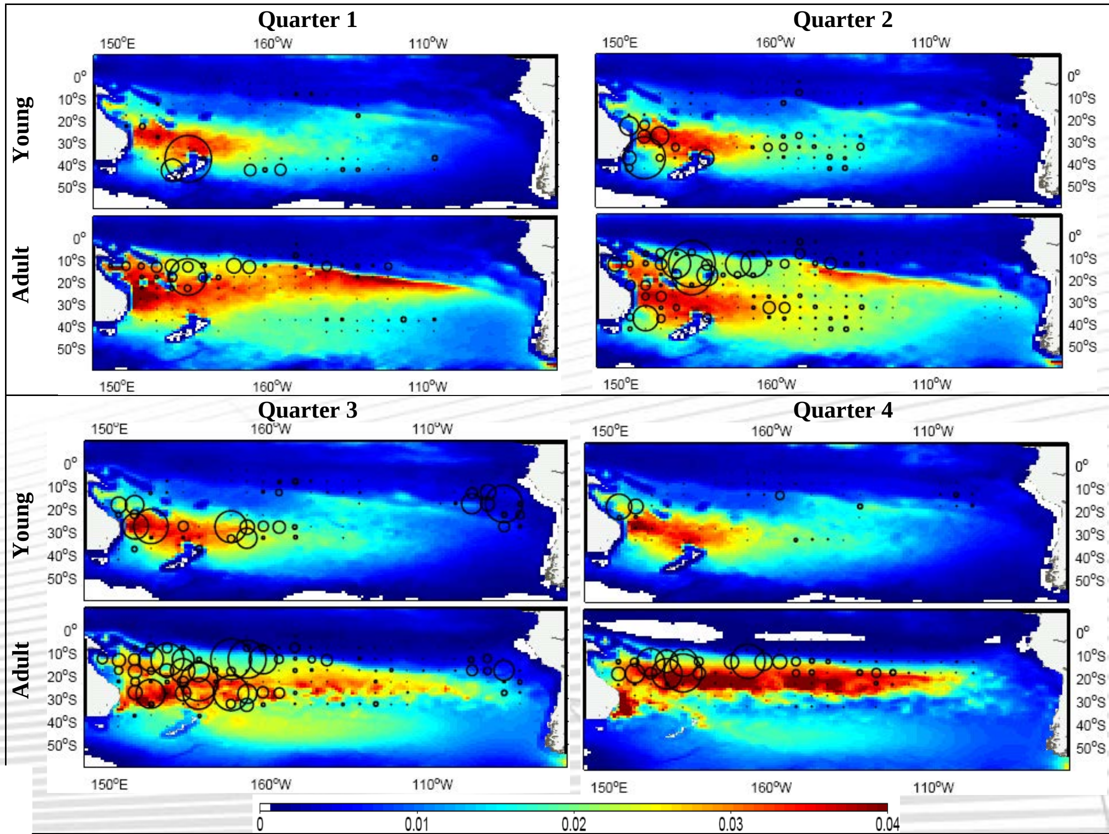
Historical reconstruction











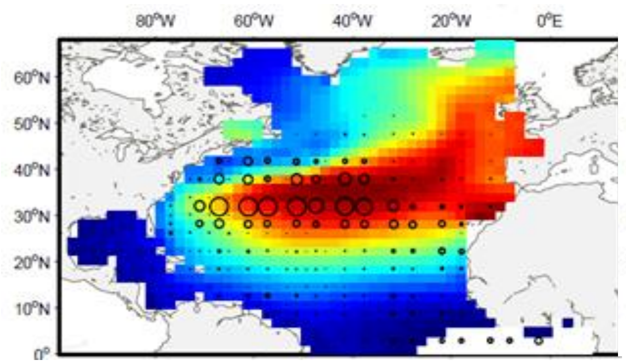
Lehodey et al (*in press*) Deep Sea Res.

Optimization and stock assessment

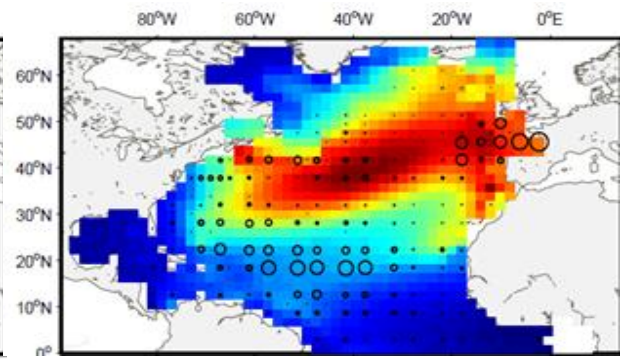
Historical hindcast forced by NCEP reanalysis

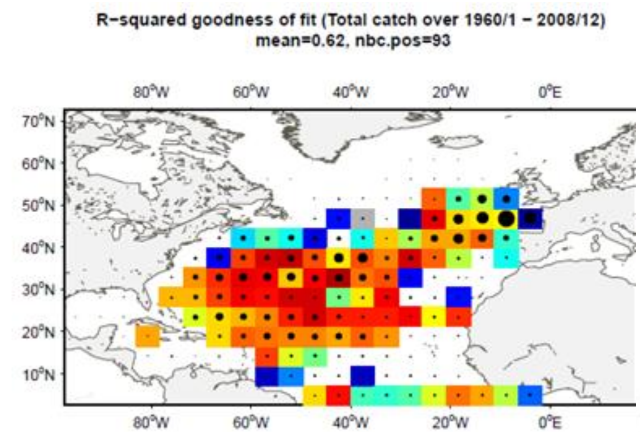
North Atlantic Albacore

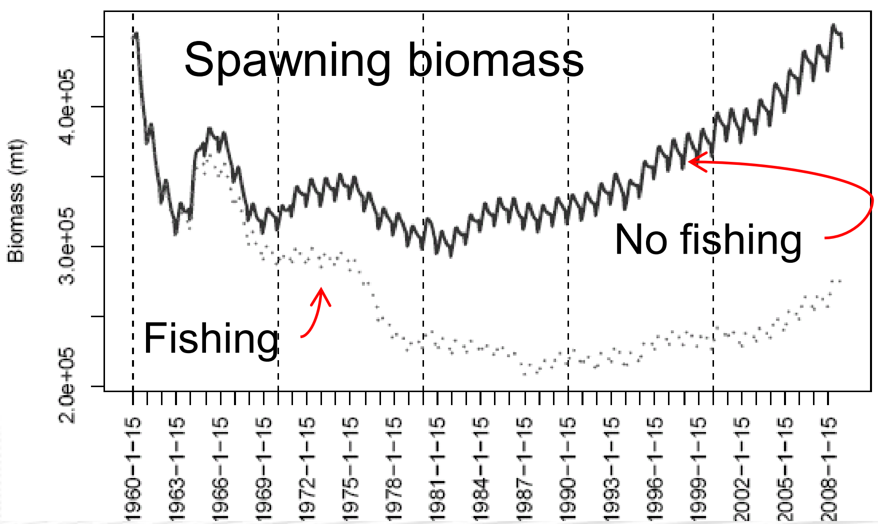
Average 1st Quarter

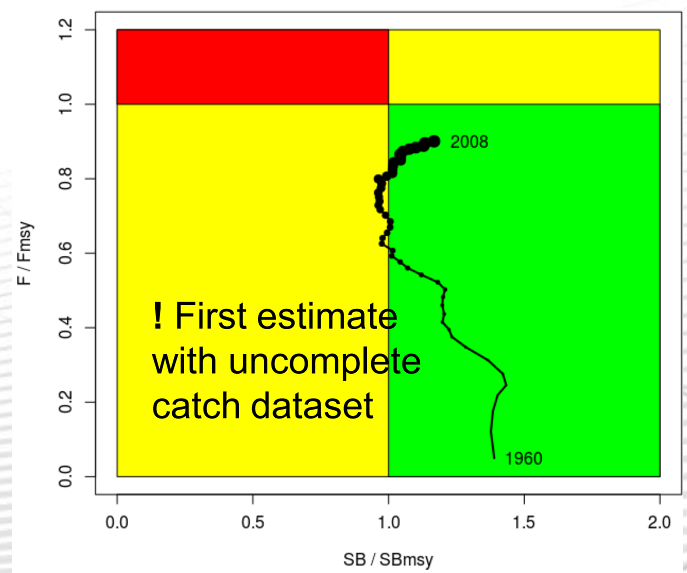


Average 3rd Quarter









Lehodey et al 2014, ESSC; Dragon et al. submitted Can. J Fis Aqu Sci)

Optimization and stock assessment

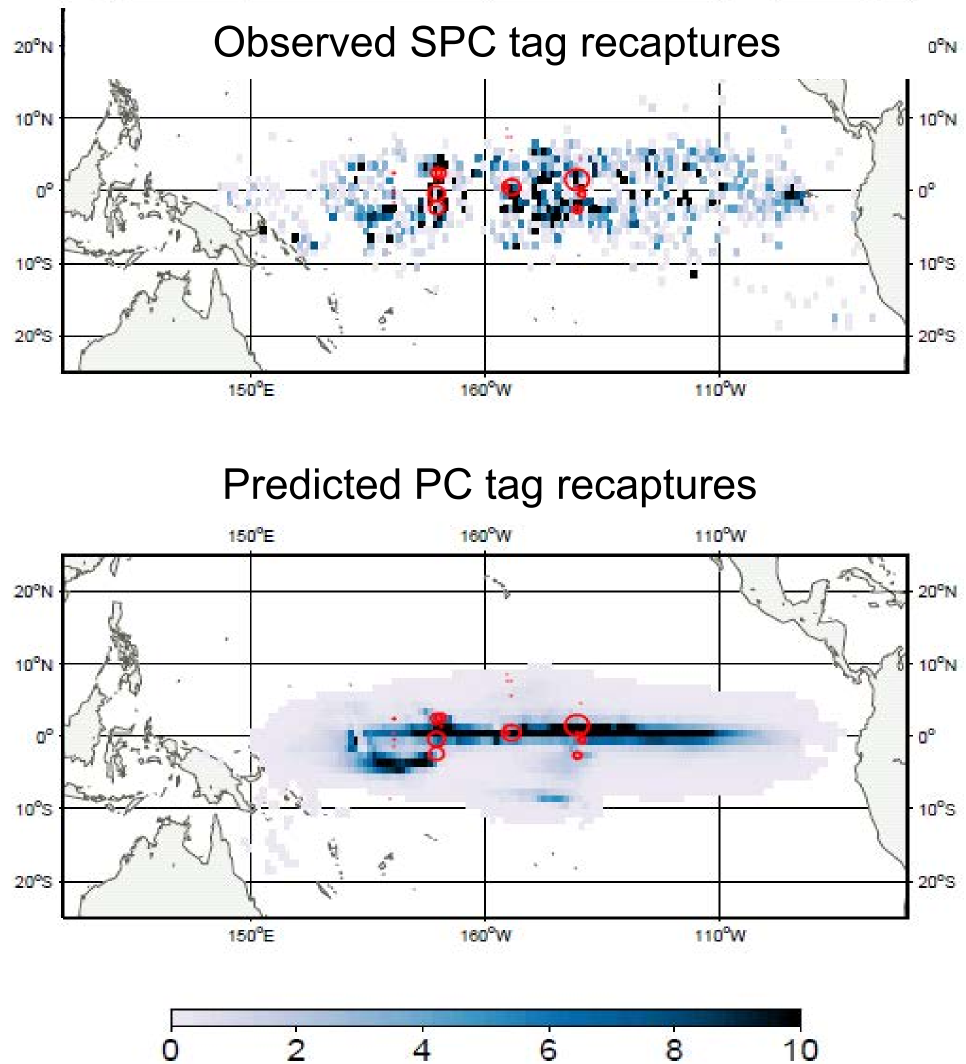
A typical ‘behaviour’ of the model optimization experiments based on catch data only is to increase biomass and diffusion to improve the fit to catch data (largely proportional to observed fishing effort)

1/ we can include an a priori total biomass estimate in the cost function

2/ Starting to use conventional and archival tagging data to constraint the movements parameters (using only recaptures to be independent of fisheries)

3/ if available acoustic biomass estimates can be also added

Pacific Bigeye



° Red circles proportional to releases

Optimization and stock assessment

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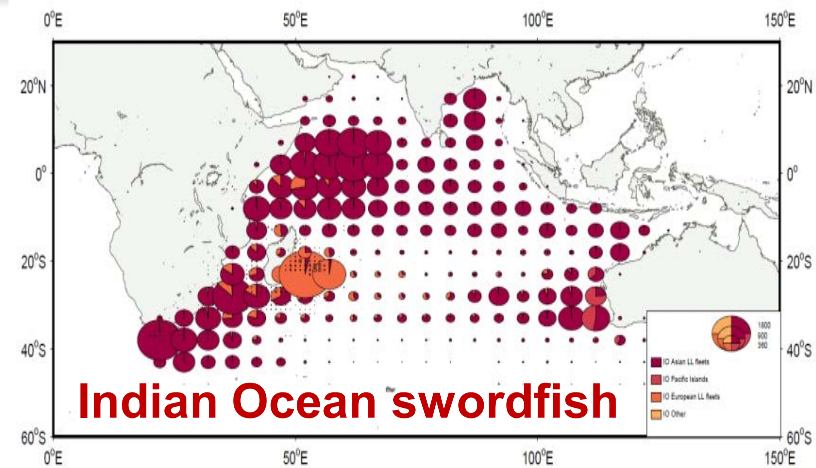
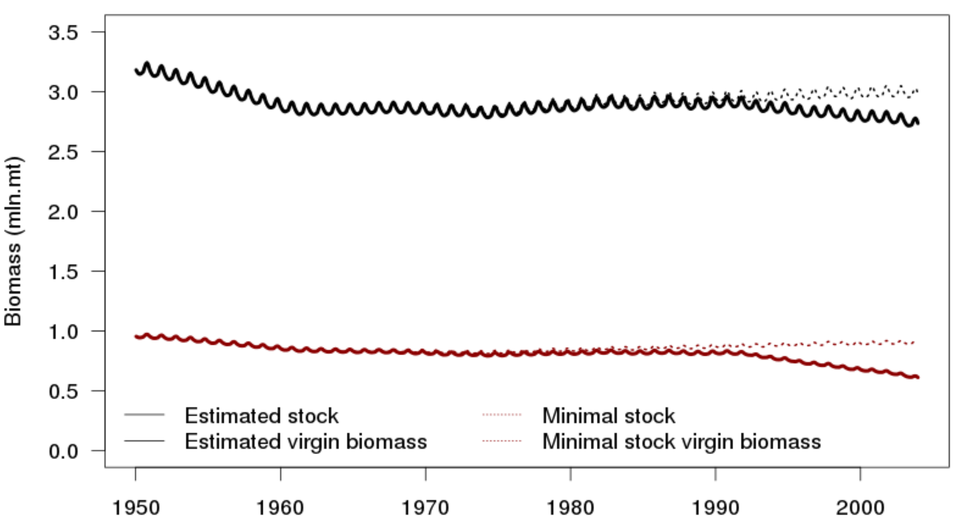
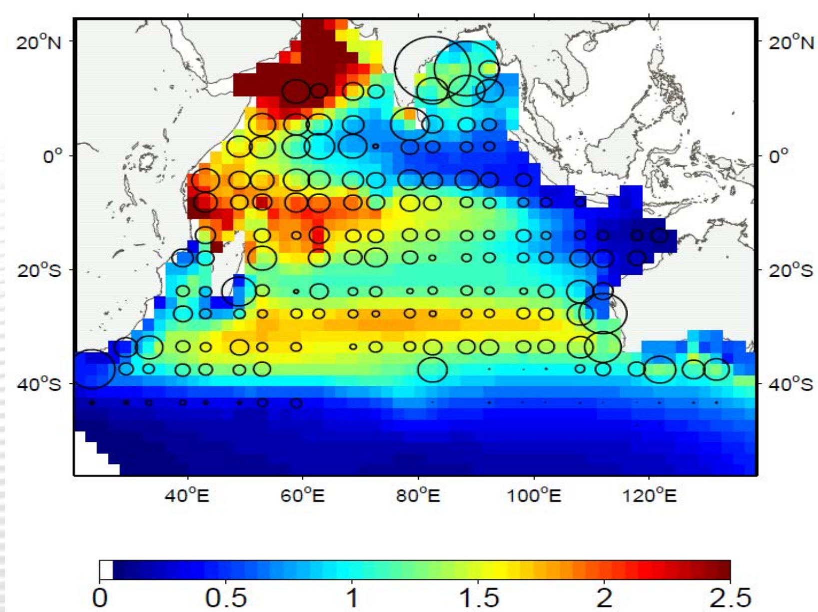
4/ Computing minimum biomass estimate given the spatial and temporal distribution of catch



Swordfish density (adult & immature)) in Nb. ind. km^{-2} with circles proportional to average CPUE of Japanese fleet (Nb.ind/100.hooks)

Indian ocean swordfish stock estimates





Optimization and stock assessment

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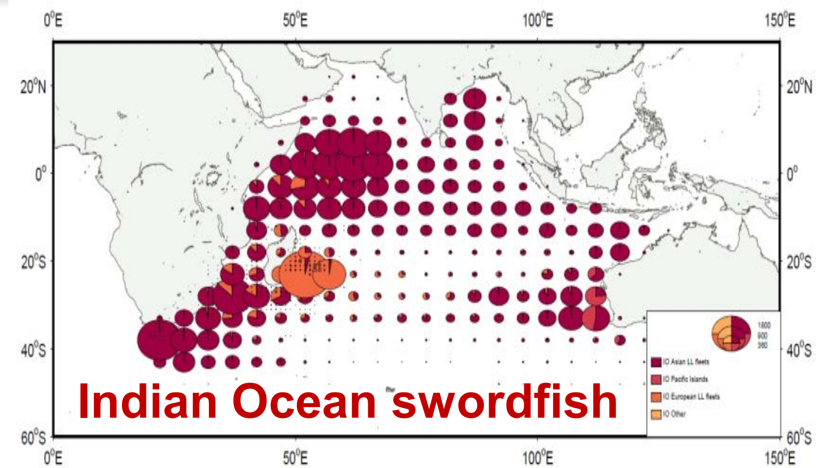

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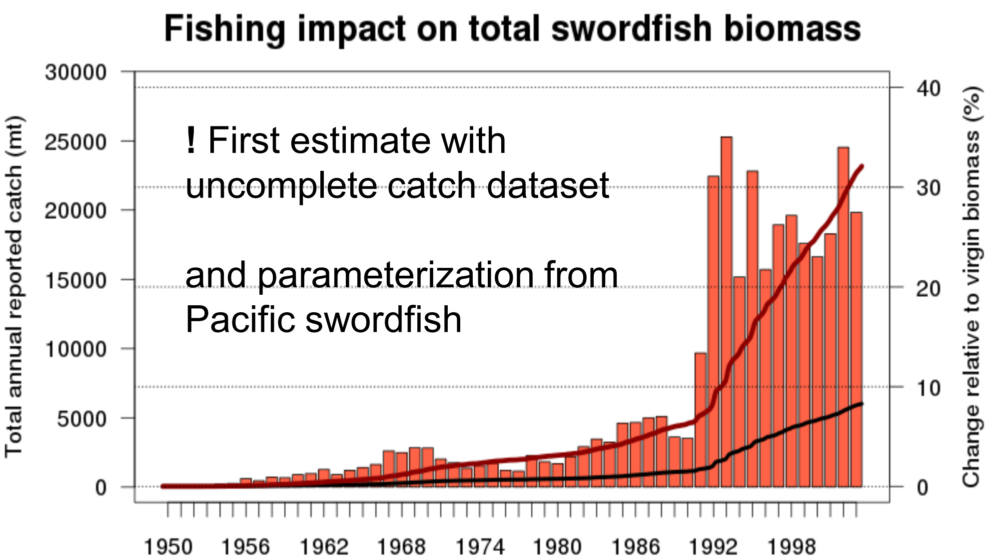
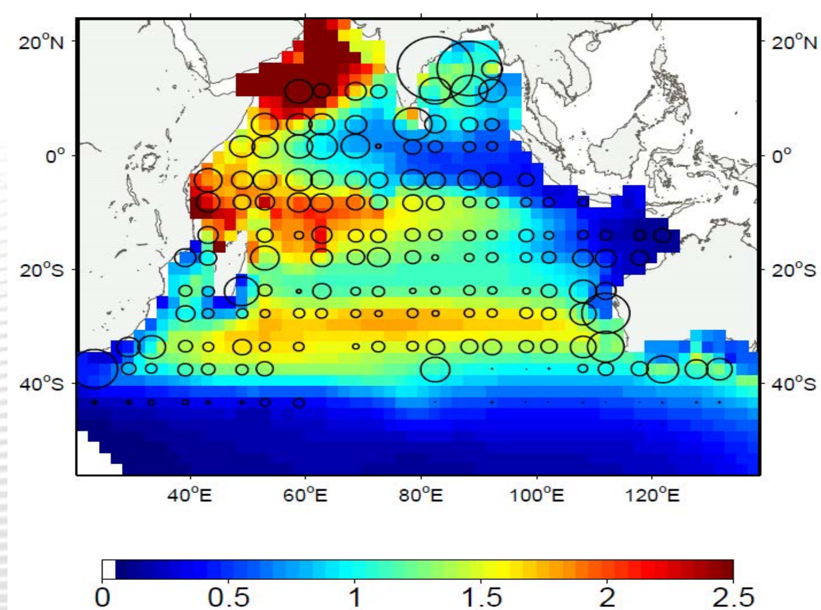




Application to Climate change impacts

Running SEAPODYM with Climate Earth Model forcing: Pacific skipjack (IPCC A2)

The model has a bias in temperature

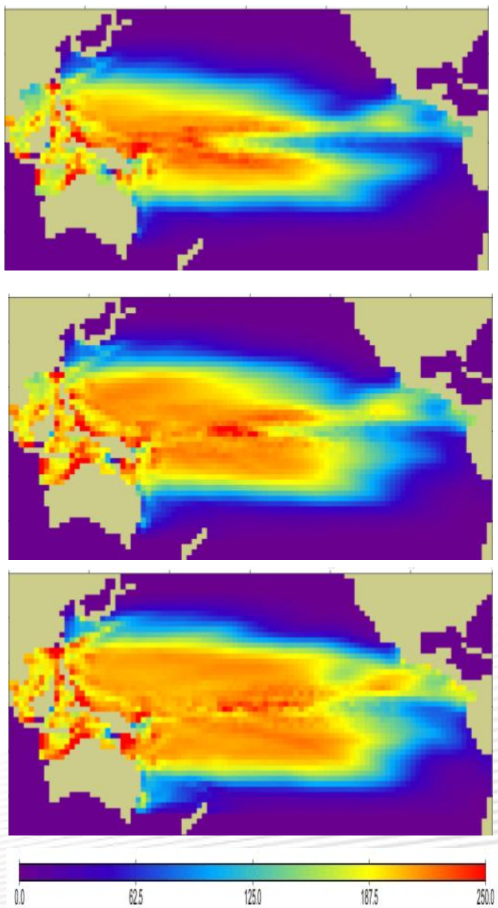
Larvae

1st Exp with IPSL-CM4

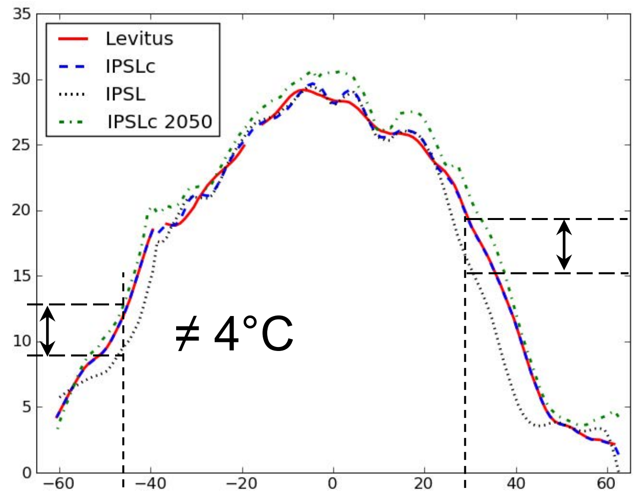
2000

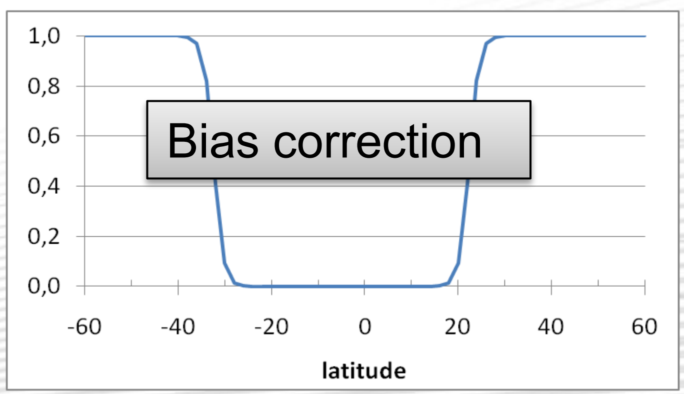
2050

2099



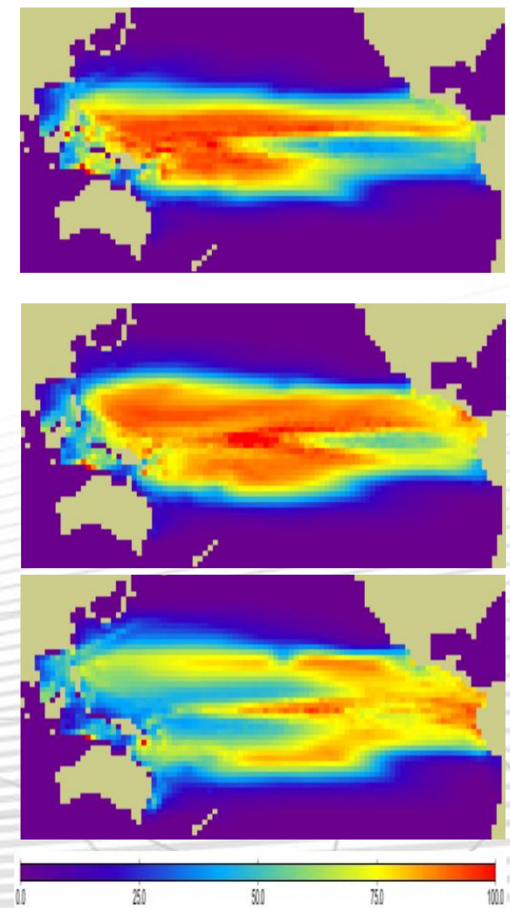
Temperature transect at longitude 180°





Larvae

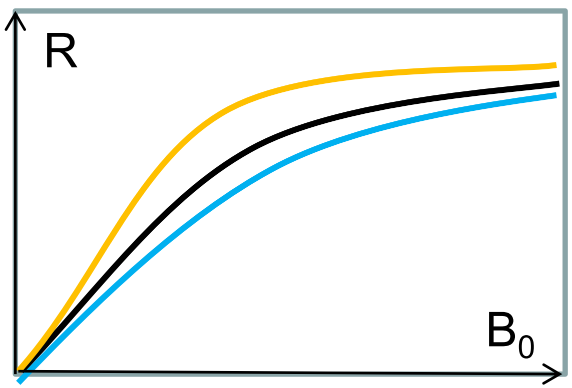
2nd Exp after T° correction



Lehodey et al., (2013) Climatic change 119:95–109

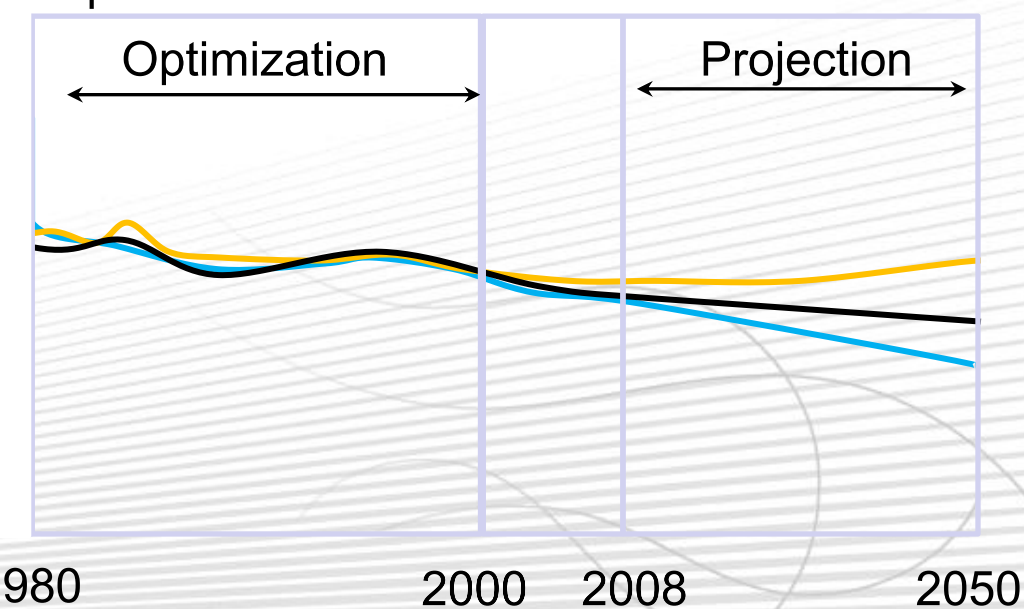
Application to Climate change impacts

Sensitivity to Stock-Recruitment parameters: ex. Albacore



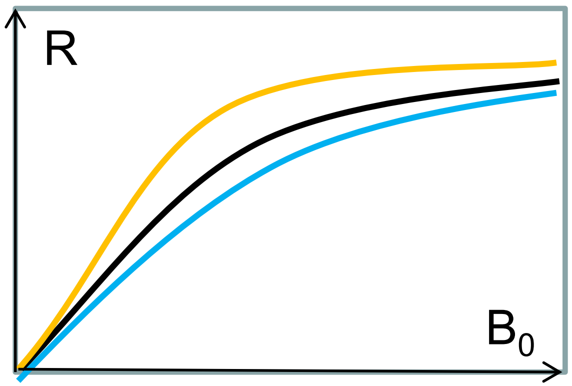
- Fish lifespan = 15 yrs
- Lack of model sensitivity to stock-recruitment relationship.
- Can lead to large error in CC projection

Check the fit of
pred vs obs catch

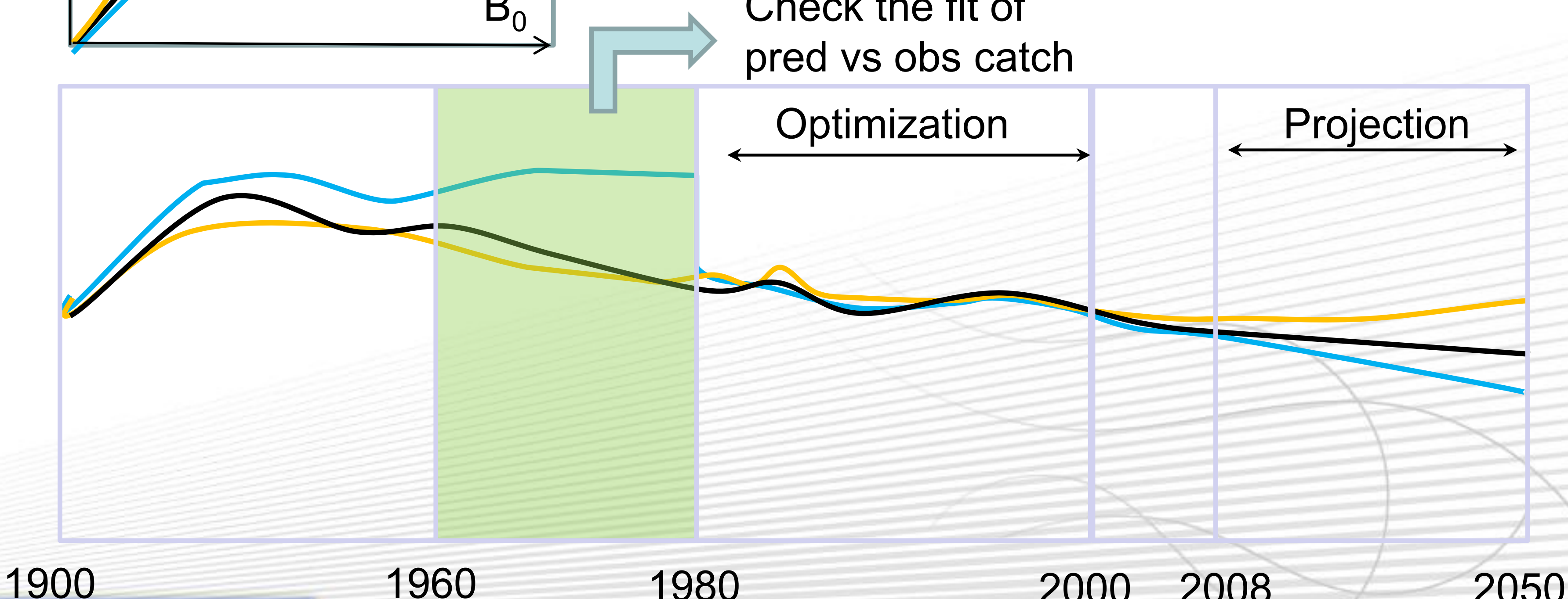


Application to Climate change impacts

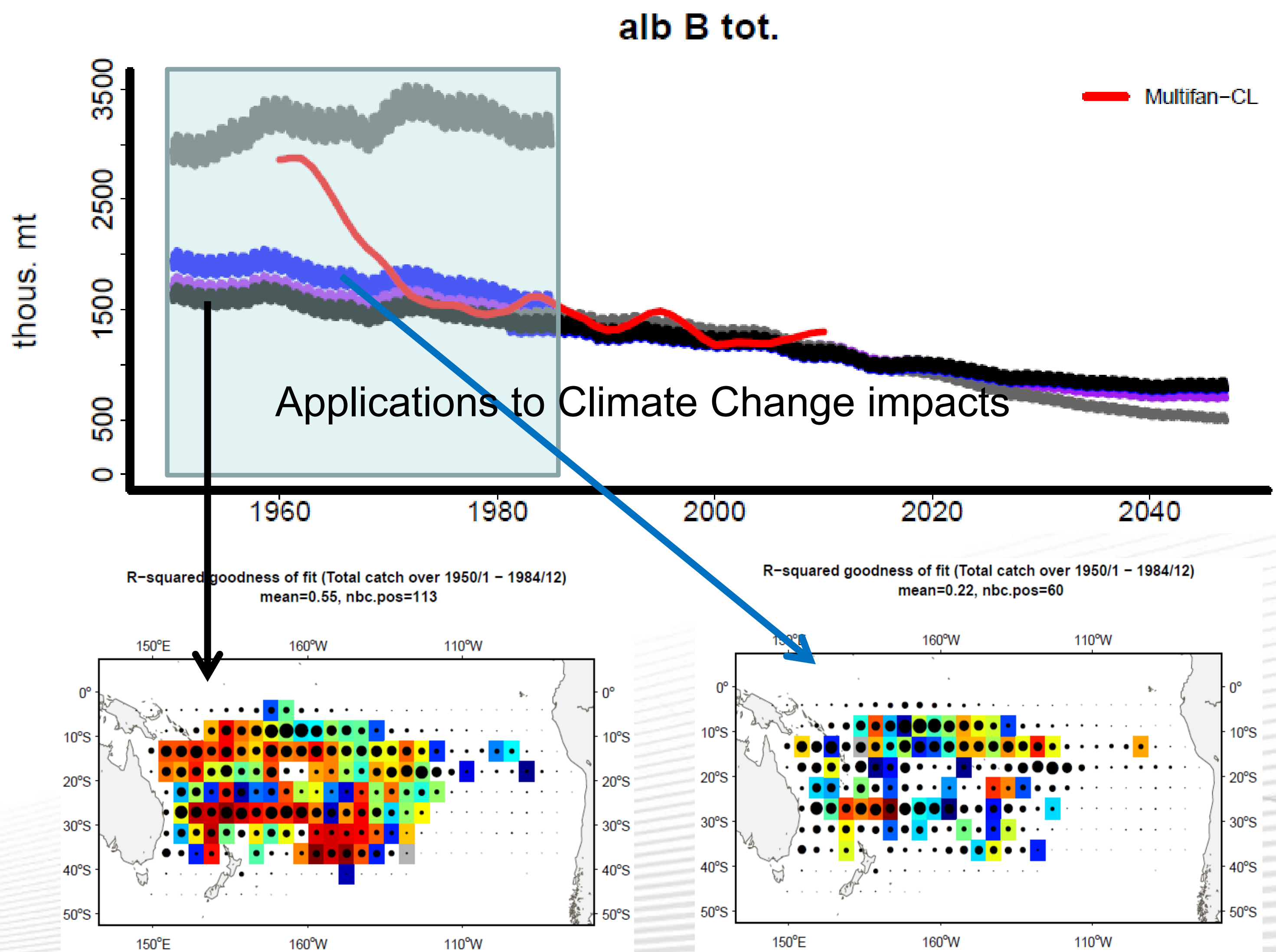
Sensitivity to Stock-Recruitment parameters: ex. Albacore



- Fish lifespan = 15 yrs
- Lack of model sensitivity to stock-recruitment relationship.
- Can lead to large error in CC projection

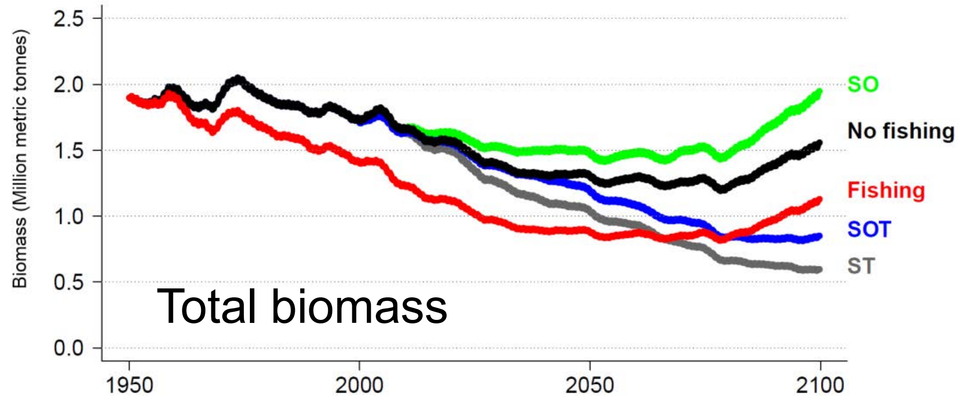


Application to Climate change impacts

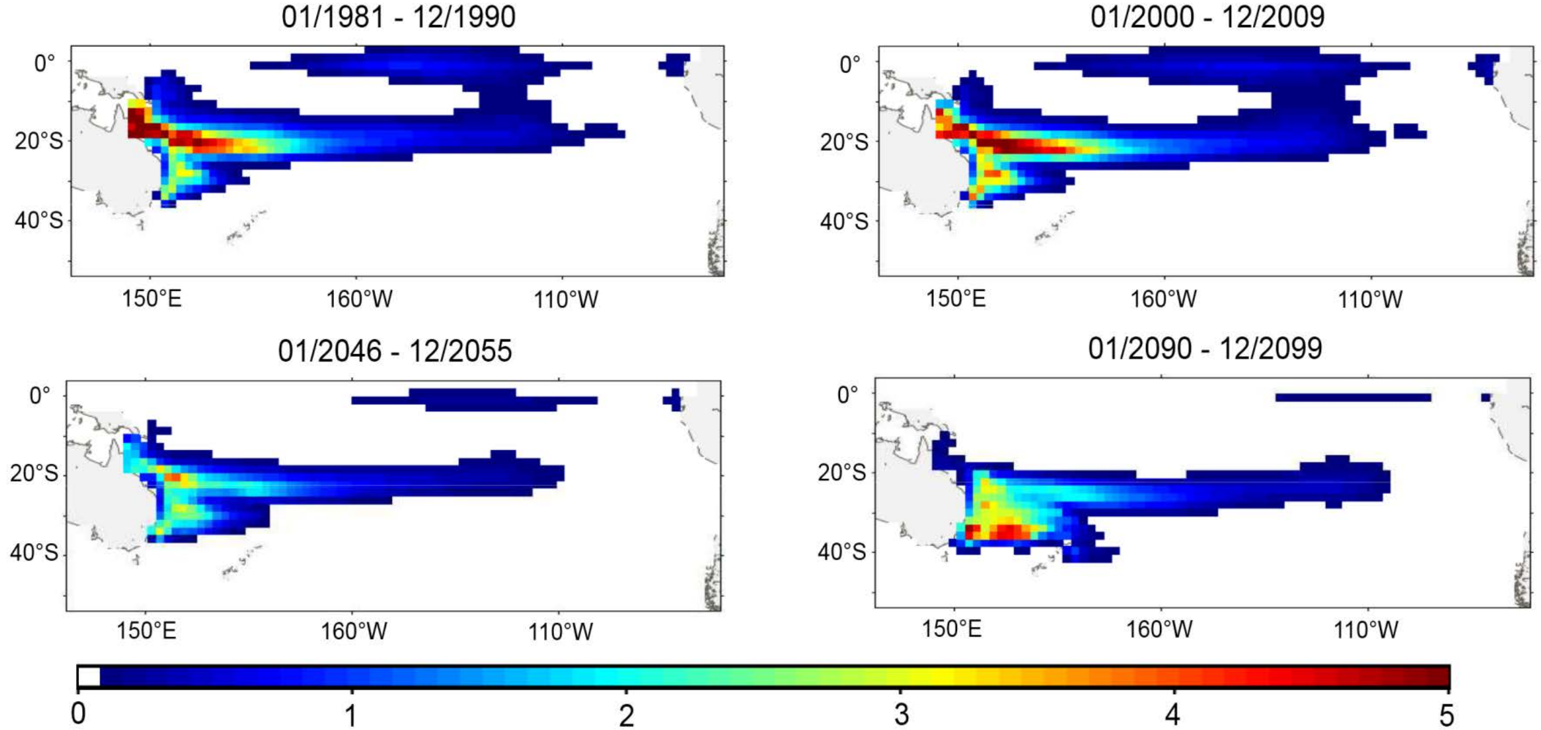


Application to Climate change impacts

Projected change in **South Pacific albacore** under IPCC A2 scenario with IPSL-CM4-PISCES forcing (temperature corrected)



Larvae density



Lehodey et al (*in press*) Deep Sea Res.

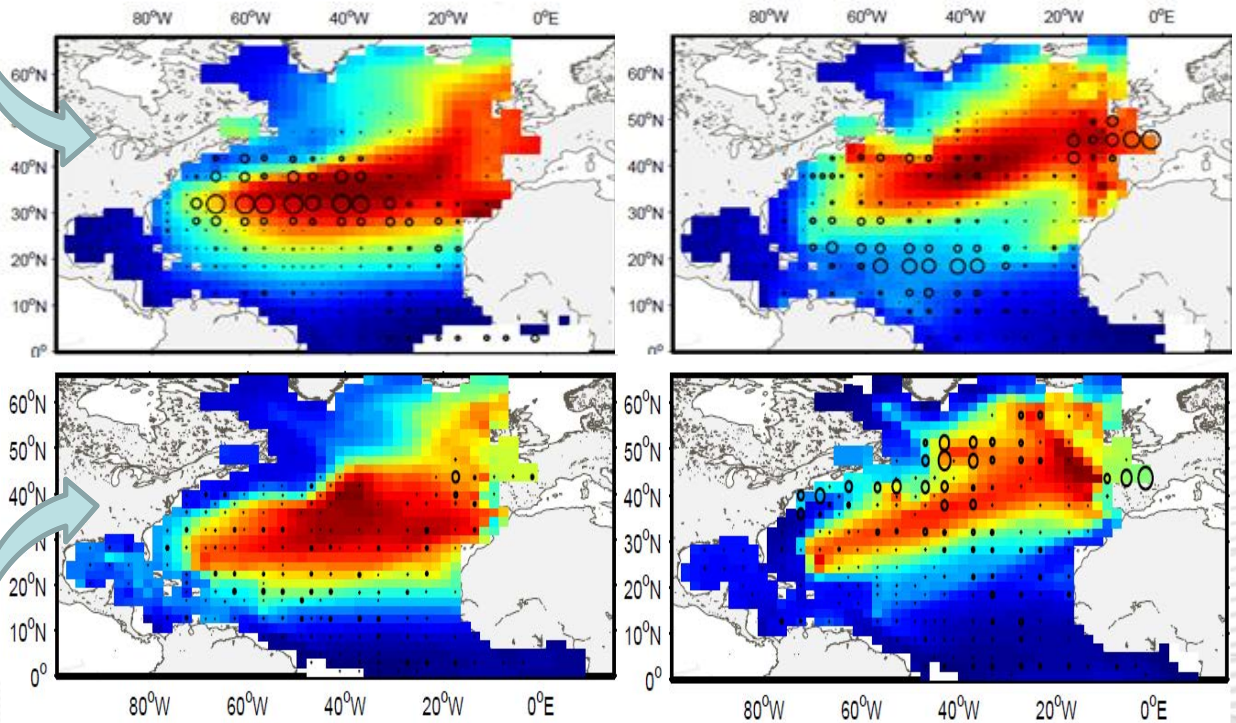
Application to Climate change impacts

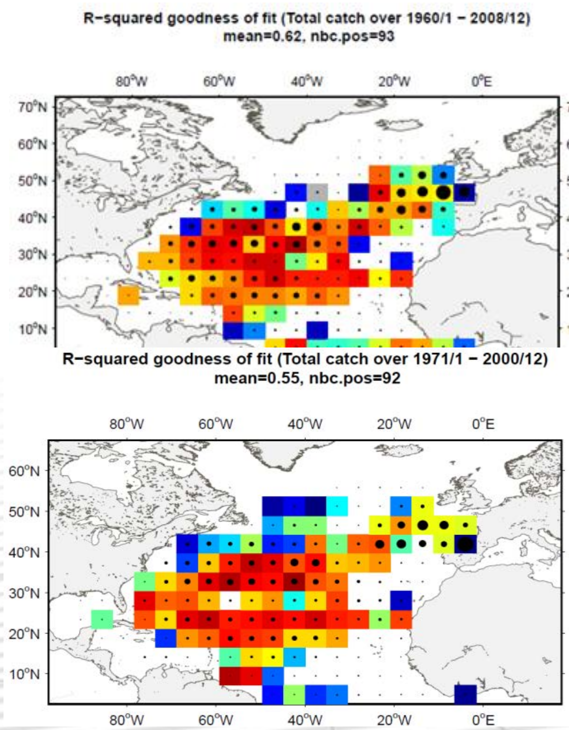
Projected change in **North Atlantic albacore** under IPCC A2 scenario with IPSL-CM4-PISCES forcing (temperature corrected)

Historical hindcast forced by NCEP-OPA-PISCES reanalysis

Average 1st Quarter

Average 3rd Quarter



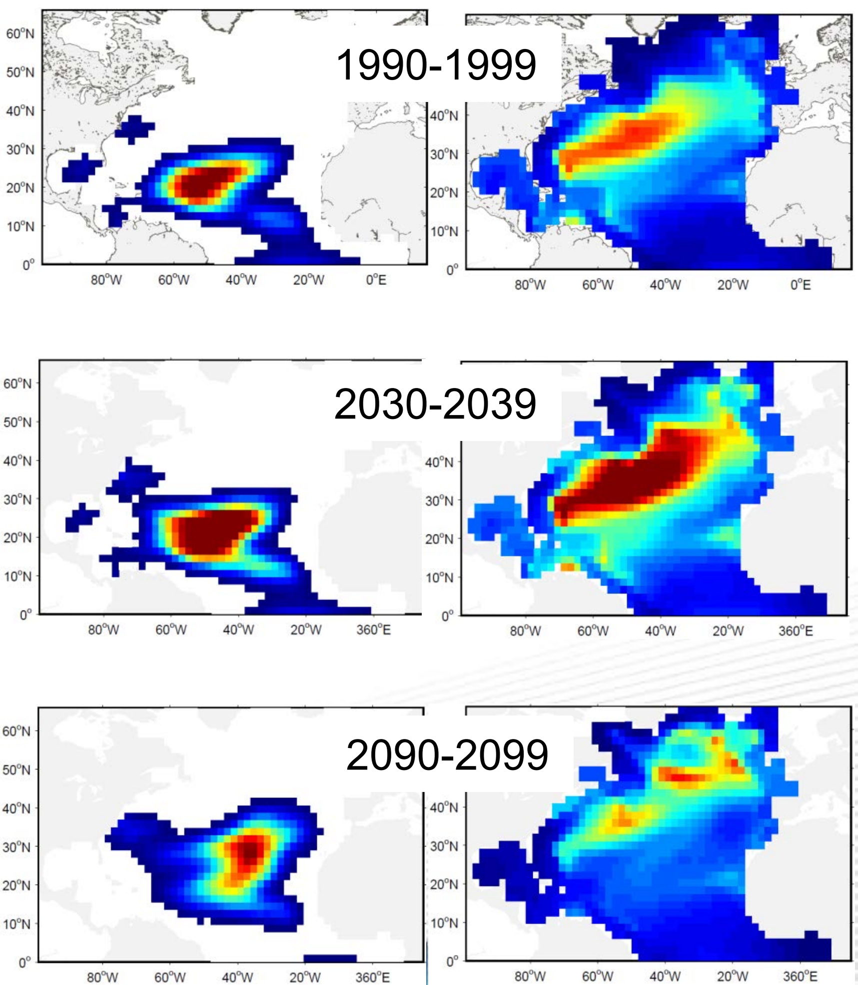


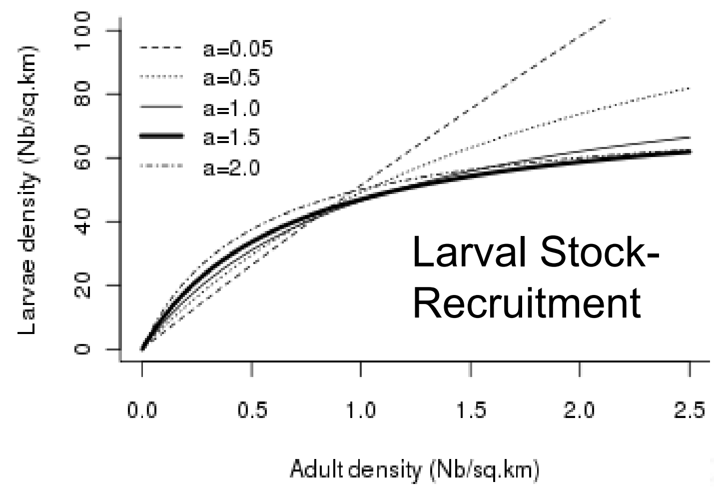
IPSL-CM4- PISCES – A2 IPCC

Applications to Albacore tuna

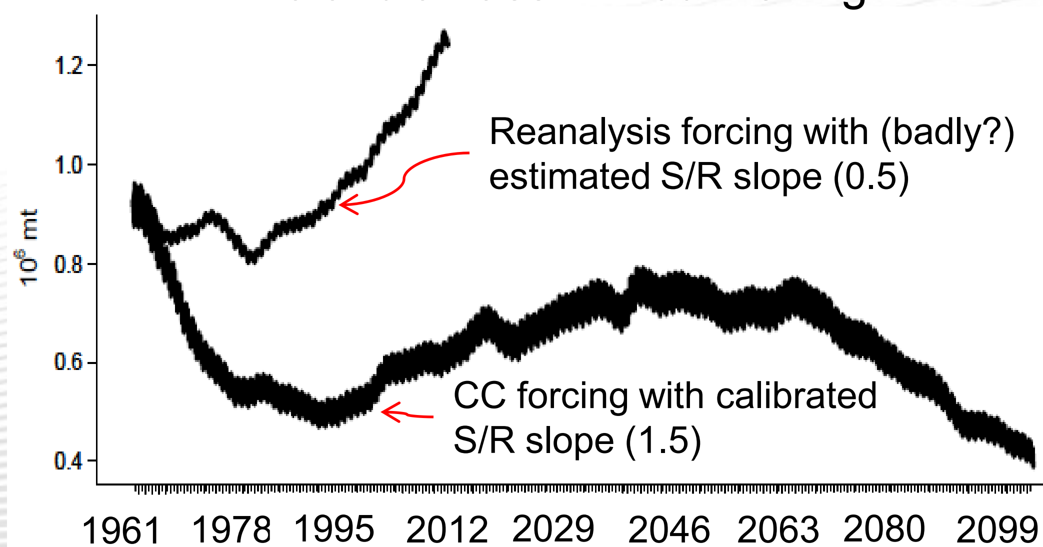
Projected change in **North Atlantic albacore** under IPCC A2 scenario with IPSL-CM4-PISCES forcing (temperature corrected)

Larvae | Immature





Total biomass without fishing



Conclusion and perspectives

Climate change simulations

- Long term simulations are interesting to estimate and test the impact of (larval) S/R relationship. (Will we be able to replace this relationship by a mechanistic detailed modeling approach one day?)

- There is no perfect simulated environmental forcing (especially from Earth Climate Models). This makes the parameter optimization approach necessary for each forcing… This is time consuming!

- To develop ensemble simulation forecast of CC, the idea is to use a single reference model for parameterization over the historical period,then to project the change with forcings from different Earth Climate models but using only their signal anomalies that would be extracted and added to the mean state of the reference model

-Other impacts to be investigated … pH, competition?

-Fishing is still the main driver!

Conclusions and perspectives

Further model developments:

Given the (very) large uncertainty on micronekton biomass, the links to micronekton are developed using relative mechanims, e.g.:

- gradient for movements
- penality over mean values of mortality relatively to food availability and intra and multi species competition

But the model does not include absolute parameterization of mechanisms accounting for carrying capacity (⇨weakness). In some way it makes the assumption of a large decoupling between prey production and predator consumption at basin scale.

-To answer this question (critical for climate change projection) we need absolute estimates of epi and mesopelagic micronekton biomass (ongoing work to optimize the micronekton model using acoustic data)

- We need to run multi-species optimisation experiments (implying code parallelization) to estimate the level of food competition.

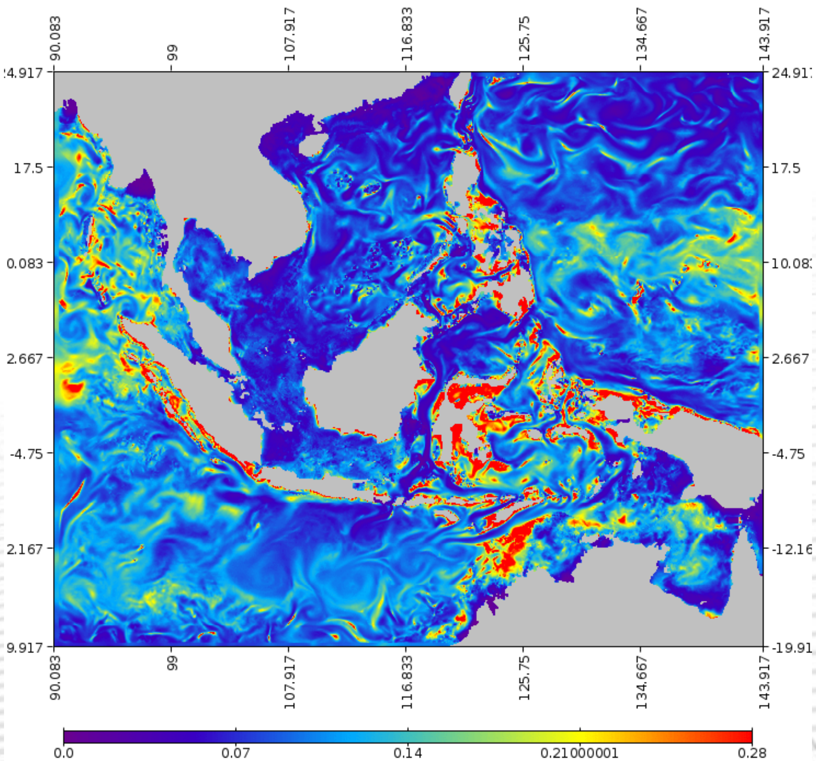
Conclusions and perspectives

Further model developments:

Ongoing regional, high resolution, and operational (real-time) applications could bring quick answers to various mechanisms and parameterisation of the model

Thank you very much for the invitation to this workshop!

Questions?



skj_totbm.dym
2010 October 01

Skipjack density at 1/12° x day