Predicting skipjack tuna dynamics and effects of climate change using SEAPODYM with fishing and tagging data

Working Doc.: WCPFC-SC12-2016/EB WP01

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Outlines

- SEAPODYM 3.0
- Pacific Skipjack optimization experiments
- Stock estimates
- Climate change projections
- Perspectives

SEAPODYM 3.0

✓ Fully explicit spatial representation of fish population dynamics

✓ Include Fish movements (currents + swimming)

✓ Population, not only « stock », meaning it includes spawning and larval stages

✓ Based on mechanisms that control life stage dynamics and relying on physical and biological characteristics of the ecosystem

✓ Using all detailed spatially disaggregated data in parameter optimization (i.e., Max. Likelihood Estimation as in Multifan-CL)

✓ Search for overall species parameterization, ie valid everywhere at basin-scale or even globally

✓Allowing to predict fish distribution even where there is no catch information

⇨ Less dependent from fishing data (especially effort) than standard S/R models

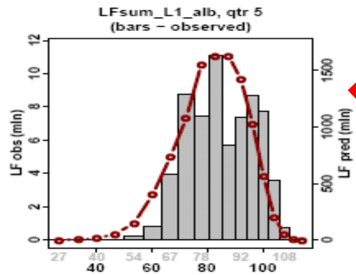
⇨ Becomes dependent of environmental data accuracy

SEAPODYM 3.0

In each cell of the grid domain, at **each time step**, the model computes:

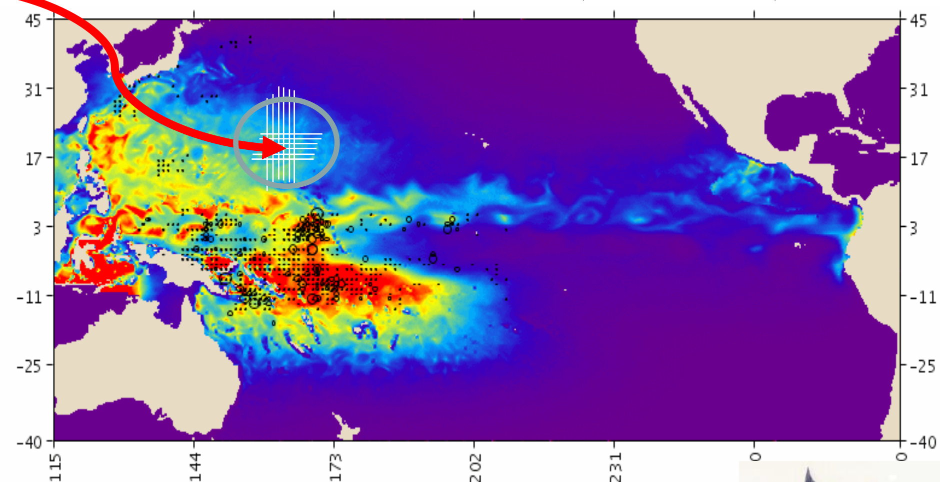
➢ the production and biomass of ecosystem functional groups (zooplankon and micronekton) that are prey of large fish

➢ the density of fish for each age-cohort from larvae recruits to oldest adult



Size (cm) of fish

Predicted skipjack density (all cohorts aggregated) and observed catch rates (% to circles)



Resolution: 1/4° x week

➢ the predicted catch by age (size) if a (observed or simulated) fishing effort for a defined fishery is available (or simulated).

SEAPODYM 3.0

Major changes in new version (3.0):

1. Revision of the spawning habitat with prey and predator functions defined separately (instead of using the prey-predator ratio as in previous version).

2. one additional parameter associated to each functional group of prey can be estimated providing more flexibility in the representation of vertical behavior and access to tuna forage.

3. Implementation of alternative approach to account for fishing mortality and to predict catch without fishing effort, i.e. based on observed catch and model biomass only, which can be particularly useful when reliable fishing effort is not available.

4. Use of Tagging data in the Maximum Likelihood Approach for parameter estimation (pre-processing with geo-statistical methods before integrating observed tag recapture data).

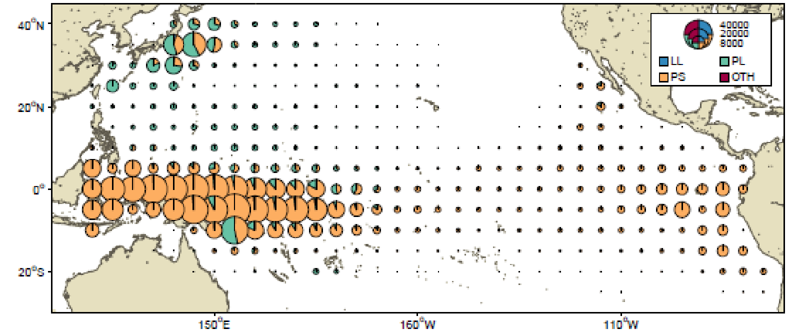
Pacific Skipjack optimization

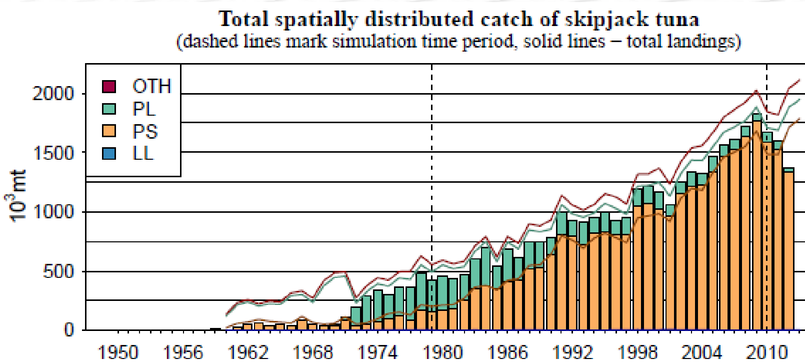
Table 3: Configuration of optimization experiments.

ID	Catch prediction method	Data in the likelihood
E1	Effort-based for PL, catch removal for PS	Catch, LF
E2	Catch removal for all fisheries	Catch, LF, tags
E3	Effort-based for PL, Catch removal for PS	Catch, LF, tags

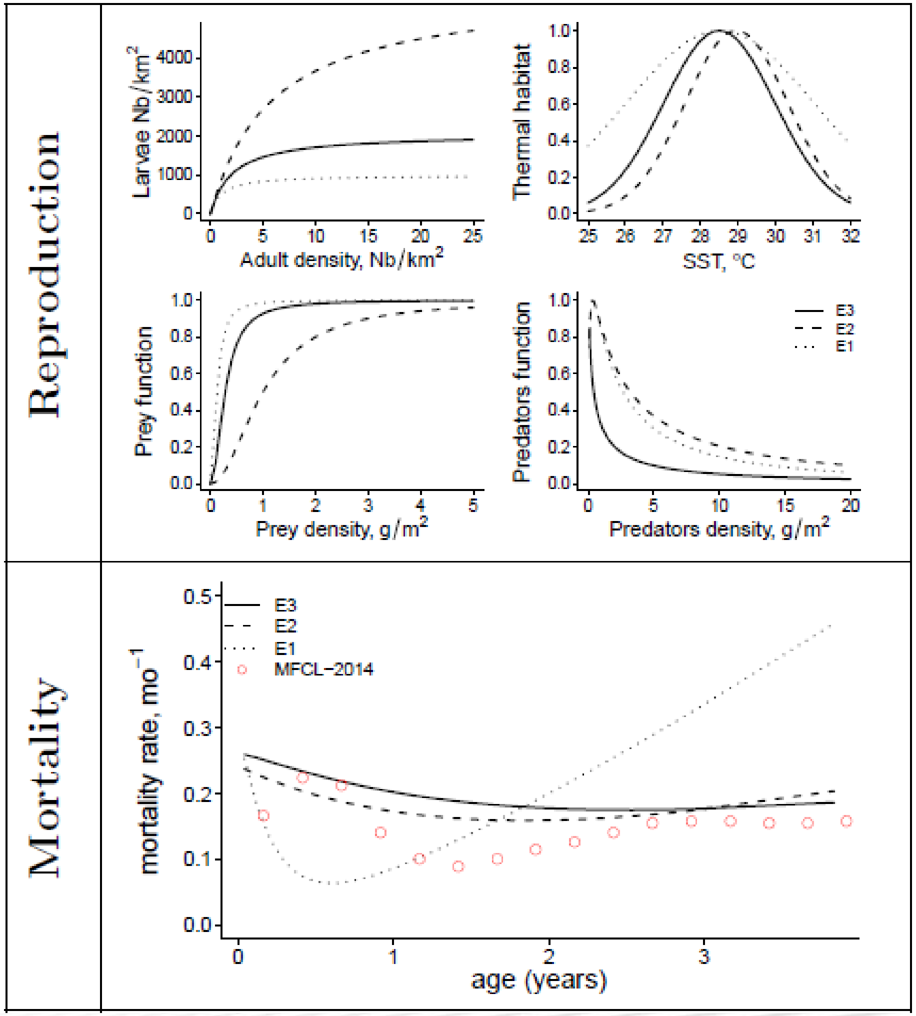
Table 1: Skipjack Fishing Dataset 2014. Definition of SEAPODYM fisheries in Pacific Ocean.

ID	Description	Nation	Resolution	Time period
P1	Sub-tropical pole-and-line	Japan	1°, month	1972 - 2012
P21	Pole-and-line	Japan	1°, month	1972 - 1982
P22	Pole-and-line	Japan	1°, month	1982 - 1990
P23	Pole-and-line	Japan	1°, month	1990 - 2012
P3	Tropical pole-and-line	Pacific Islands	1°, month	1970 - 2012
S4	Sub-tropical purse-seine	Japan	1°, month	1970 - 2012
S5	PS anchored FADs, WCPO	ALL	1°, month	1967 - 2012
S6	Purse-seine	Philippines, Indonesia	1°, month	1986 - 2010
S7	PS free schools, WCPO	ALL	1°, month	1967 - 2012
L8	Longline, WCPO	ALL	5°, month	1950 - 2012
L9	Longline, Domestic fisheries	Philippines, Indonesia	5°, month	1970 - 2011
S10	PS FADs, EPO	ALL	1°, month	1996 - 2013
S11	PS LOGs, EPO	ALL	1°, month	1996 - 2013
S12	PS Animal associations, EPO	ALL	1°, month	1996 - 2013
S13	PS Free schools, EPO	ALL	1°, month	1996 - 2013
S14	PS Unknown log, EPO	ALL	1°, month	1996 - 2013
P15	Pole-end-line, EPO	ALL	5°, month	1972 - 2008



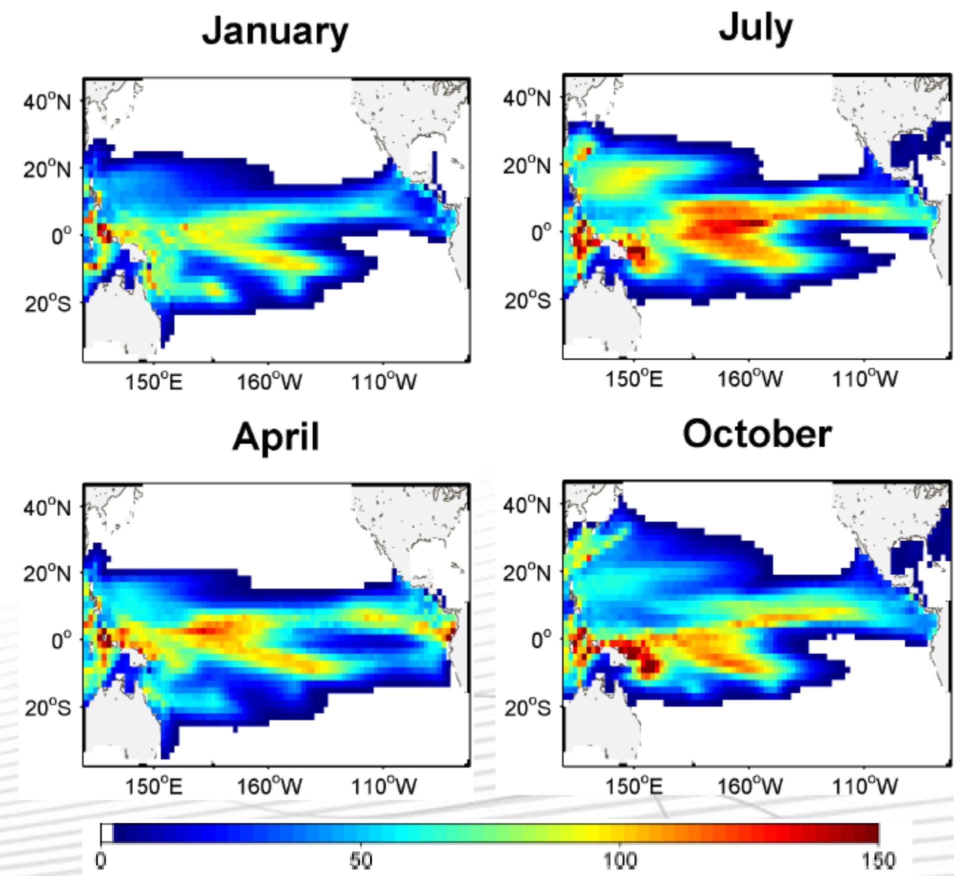


Pacific Skipjack optimization

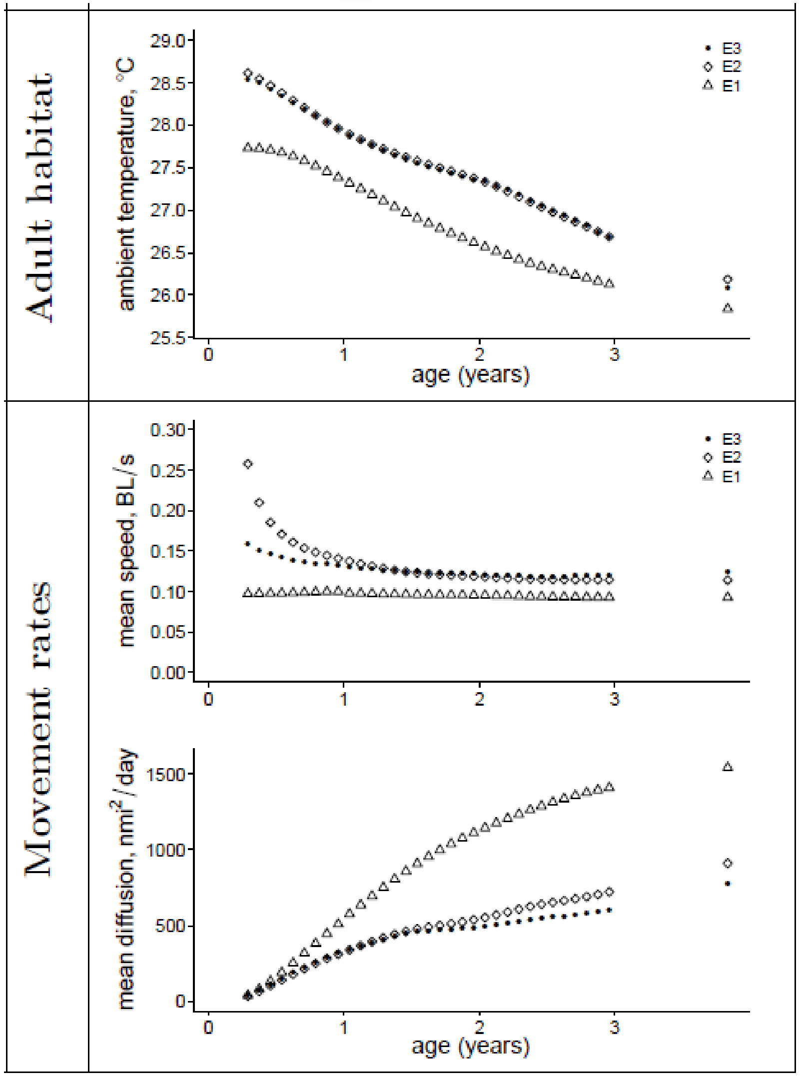


Estimated parameters in the optimization experiments

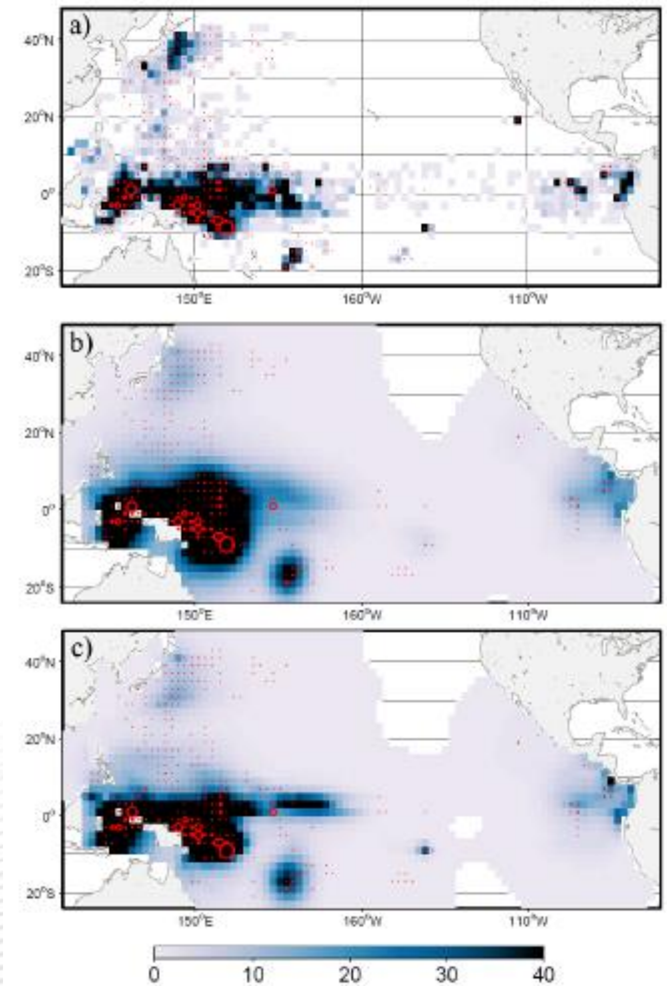
Mean monthly distributions of skj larvae (2001-2010) with E3



Pacific Skipjack optimization



Estimated parameters in the optimization parameters



Observed tag recaptures (a) and predicted using parameter estimates of E1 (b) .and E2 (c). Red circles are releases.

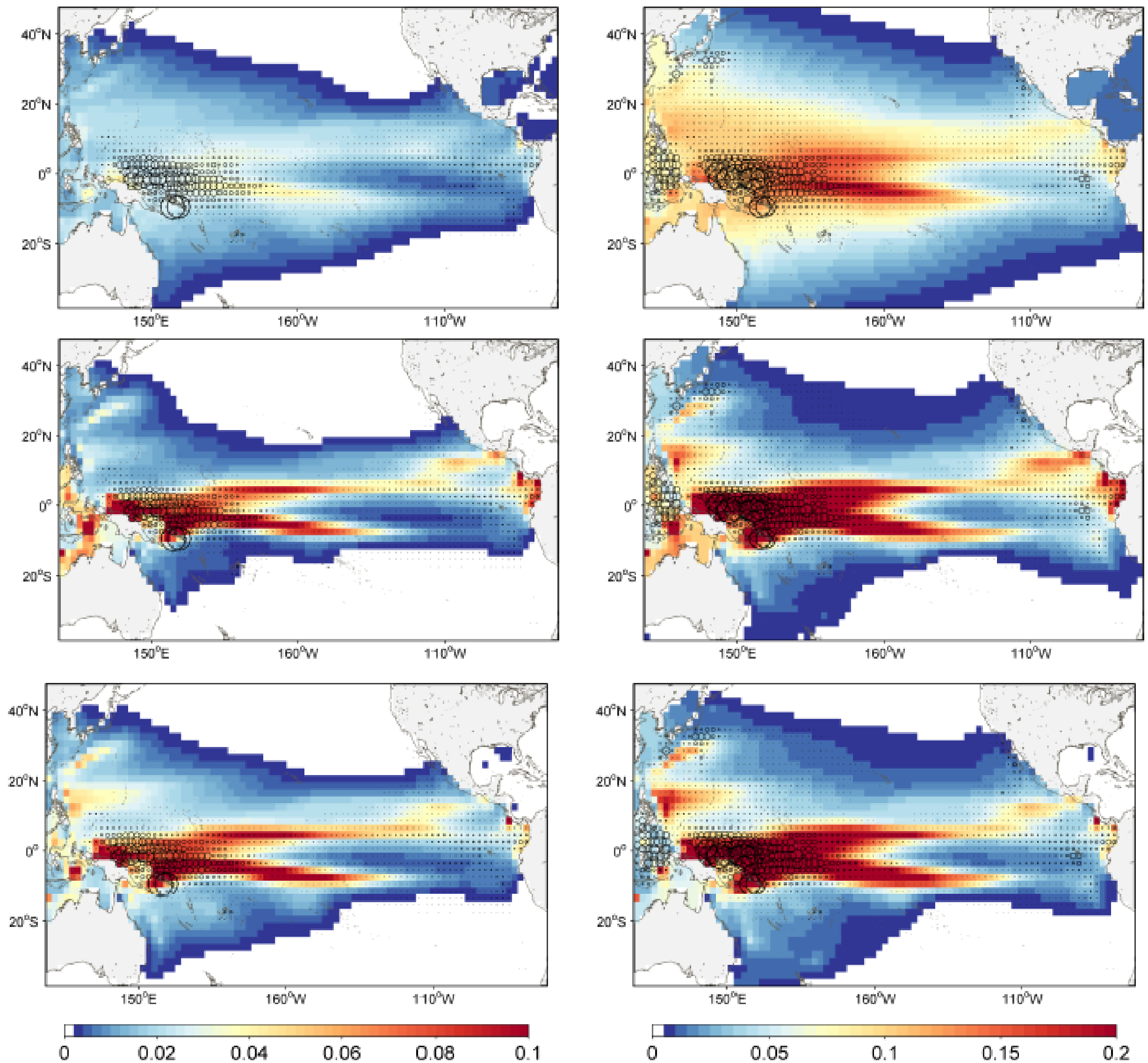
Skipjack stock estimates

Mean distribution 1980-2010

	Catch prediction method	LL
E1	PL –effort PS- catch removal	Catch, LF
E2	Catch removal	Catch, LF, tags
E3	PL –effort PS- catch removal	Catch, LF, tags

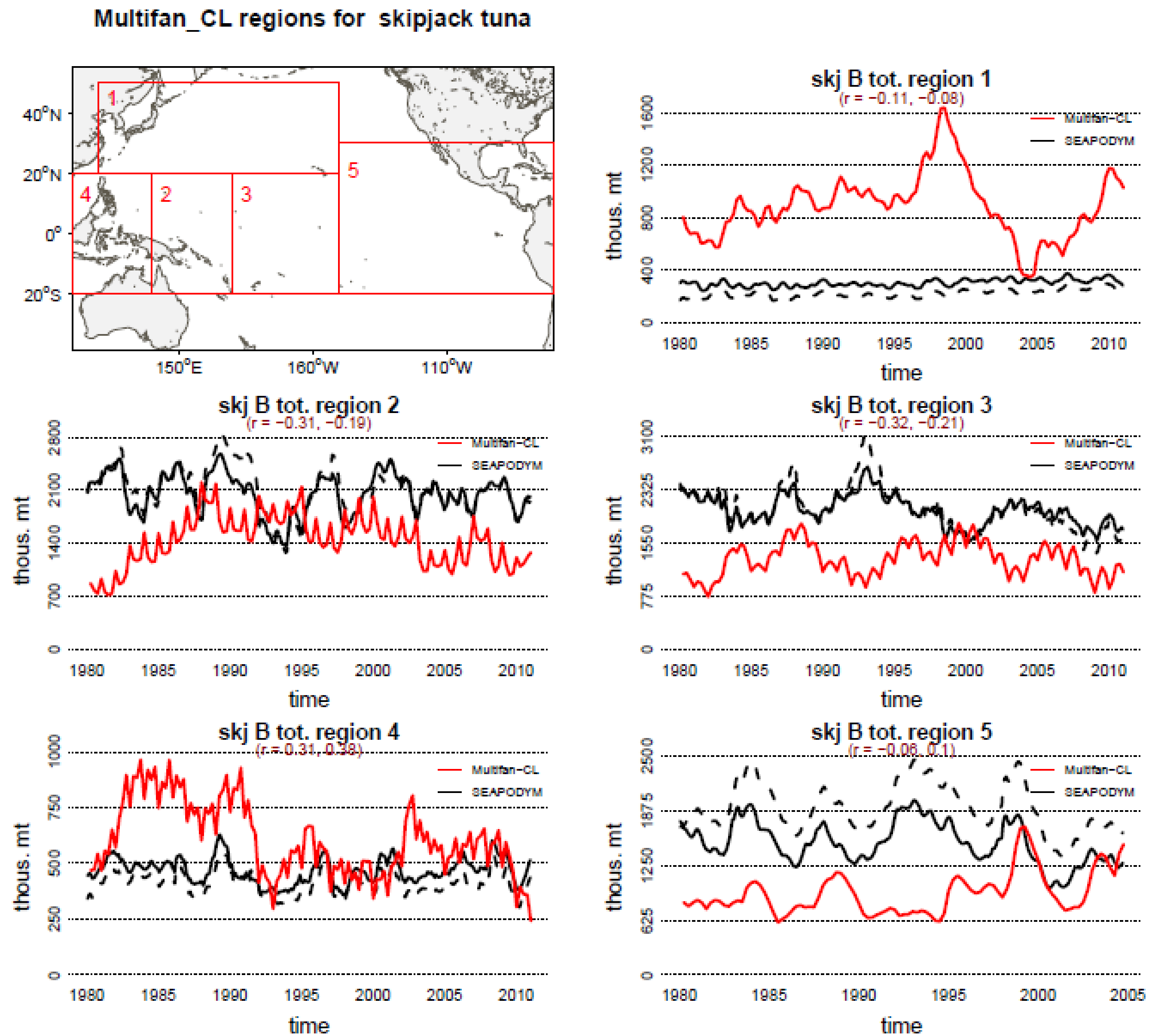
Immature skj: age 3 to 9 months

Adult skj: > 9 months

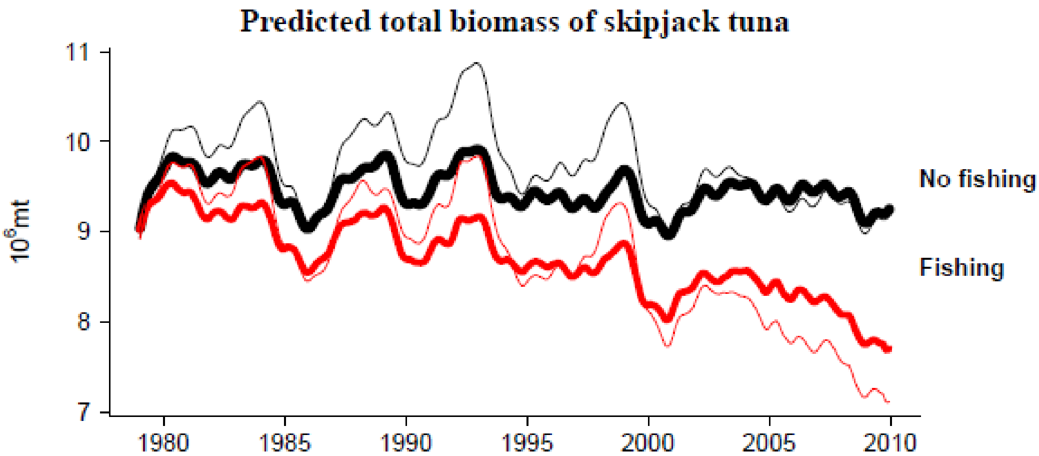


Skipjack stock estimates

Regional comparison between SEAPODYM (black line: dashed E2; solid E3) and MULTIFAN-CL estimates for total skipjack biomass



Skipjack stock estimates

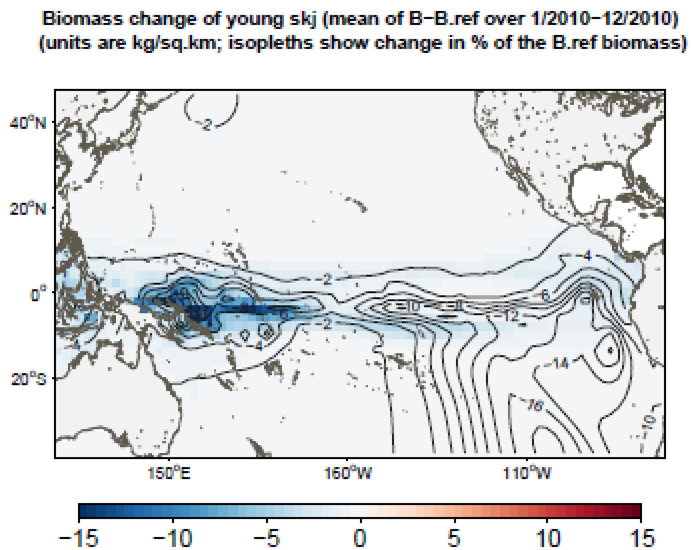


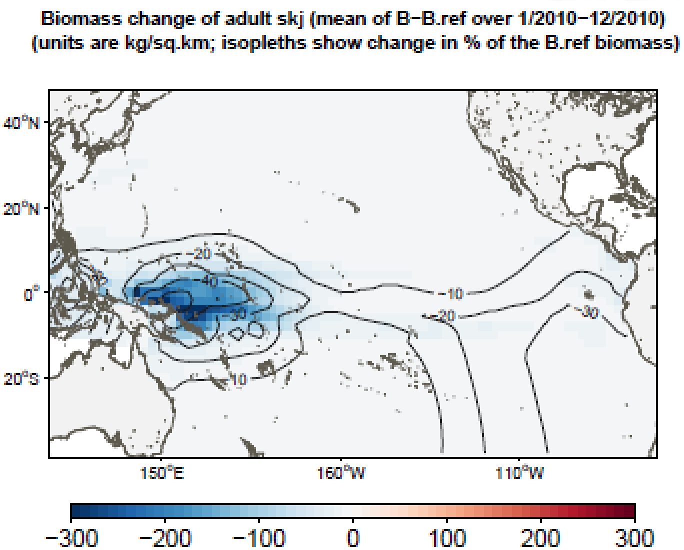
Fishing impact

Figure 3: Pacific-wide total skipjack stock estimate with and without fishing (E2 = thin line; E3 = thick lines)

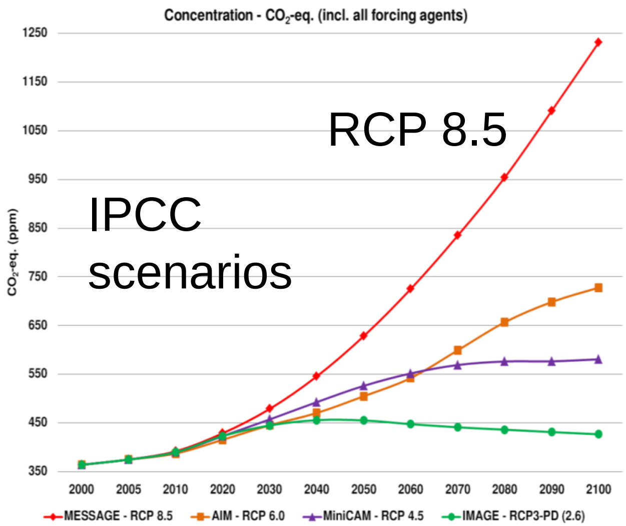
End 2010: 20% (total)
25% (Spawning B)

Spatial fishing impact on young immature and adult skipjack for E3 experiment. Contour lines show the index [B_{F0} - B_{ref}] / B_{F0} and colour shows the average biomass reduction due to fishing

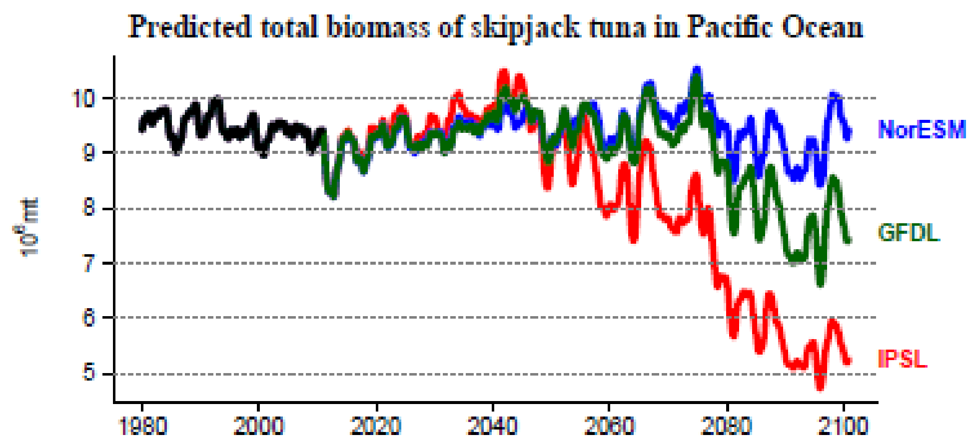




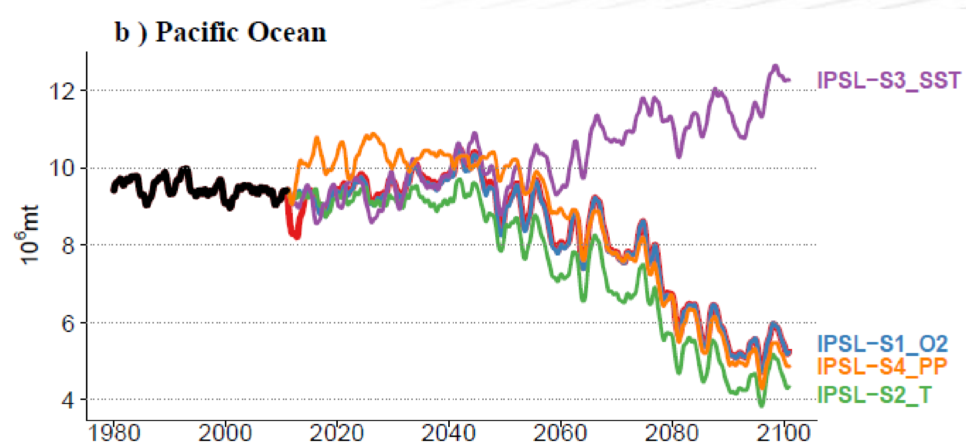
Climate change projections



Projection without fishing

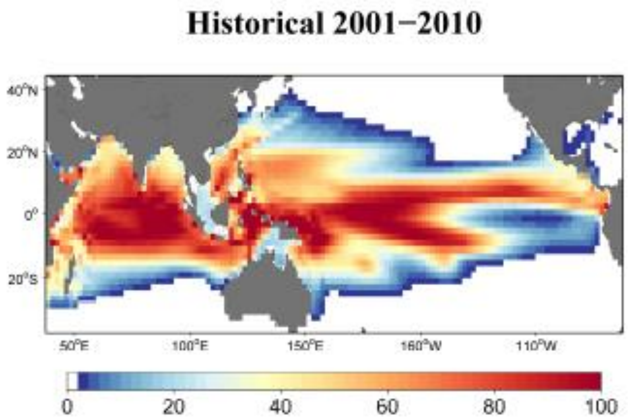


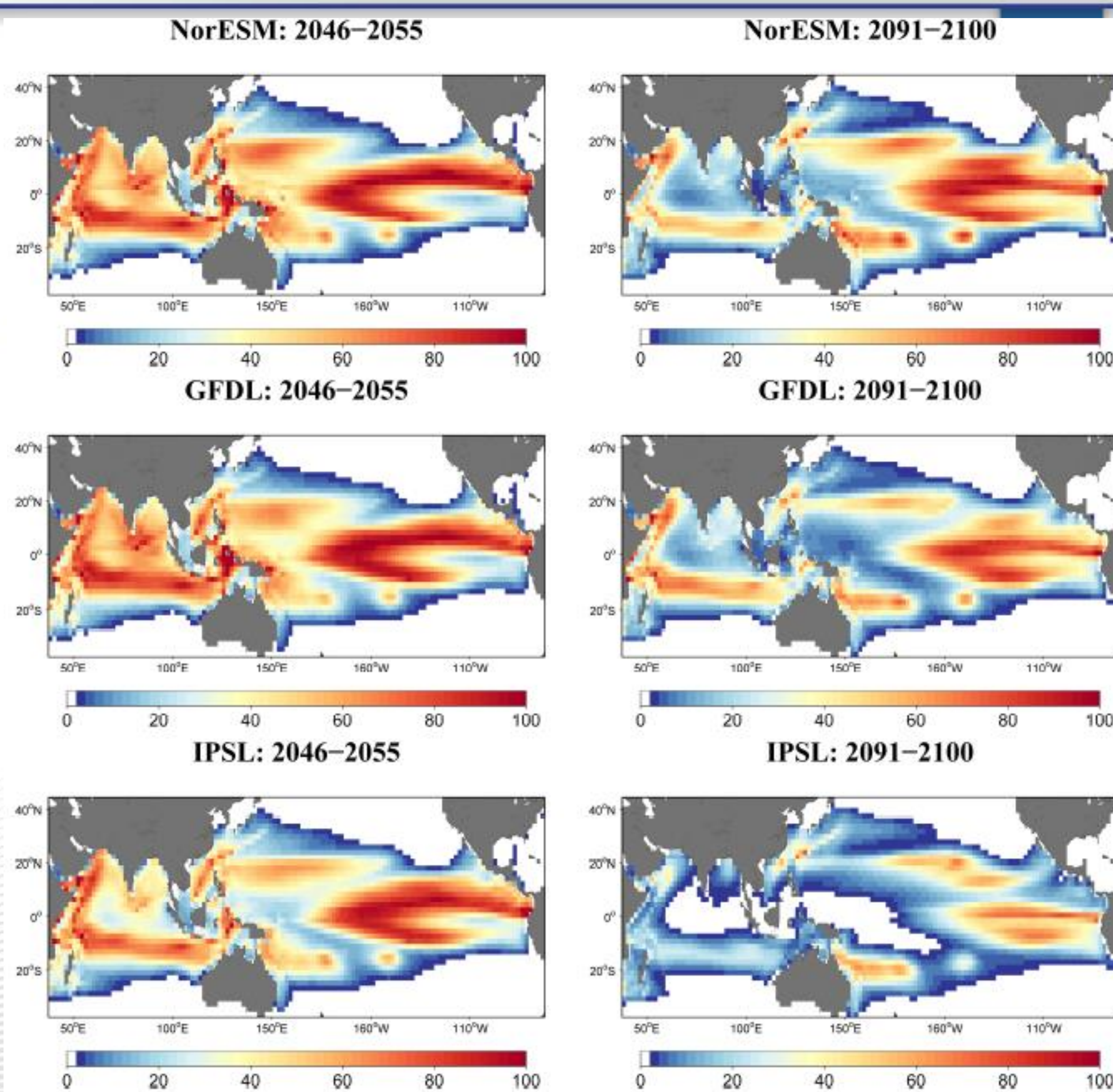
Testing each forcing variable by replacing projection with climatology (historical average)



Climate change projections

Mean distribution of skipjack larvae





Perspectives: Climate Change

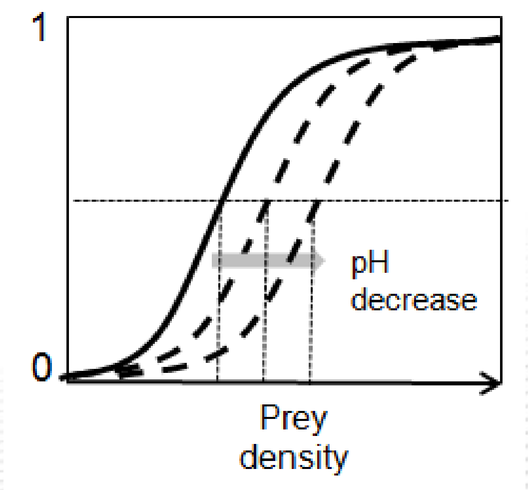
- Ensemble simulations with more simulations
- Simulations at higher resolution

(Matear et al 2015: Deep-Sea Research II 113: 22–46)

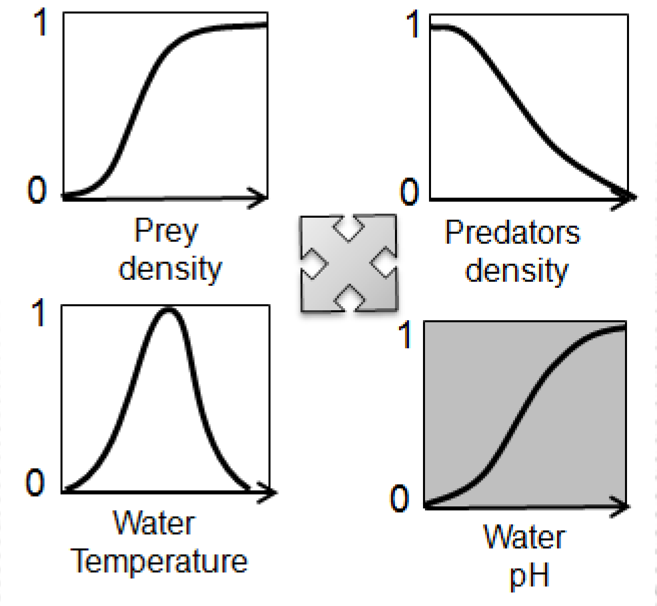
- Test ocean acidification impact

Two examples of introducing pH effect through functional relationships in the modeling of early life history of tuna

With the financial support from the New Zealand Ministry for Foreign Affairs and Trade, the Principality of Monaco (The Pacific Islands Partnership on Ocean Acidification Project) and the Global Environment Facility (Oceanic Fisheries Management Project II).



a) Assuming lower pH has an energetic cost (requiring higher prey density).

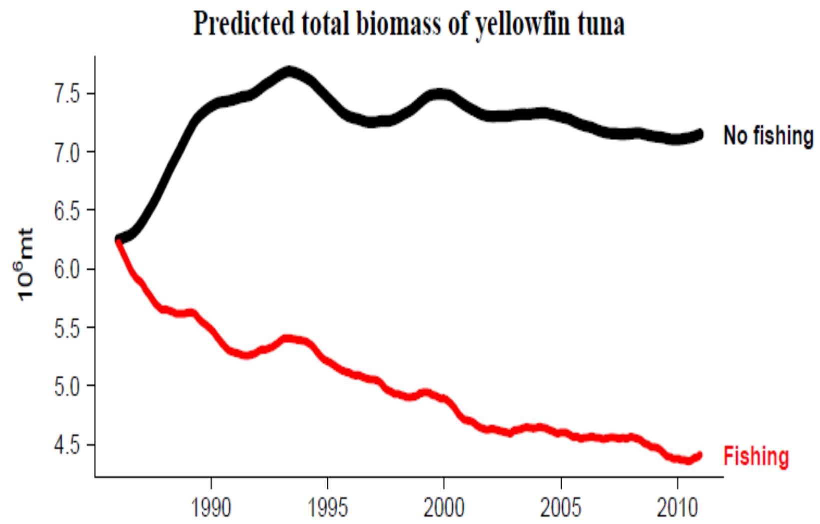


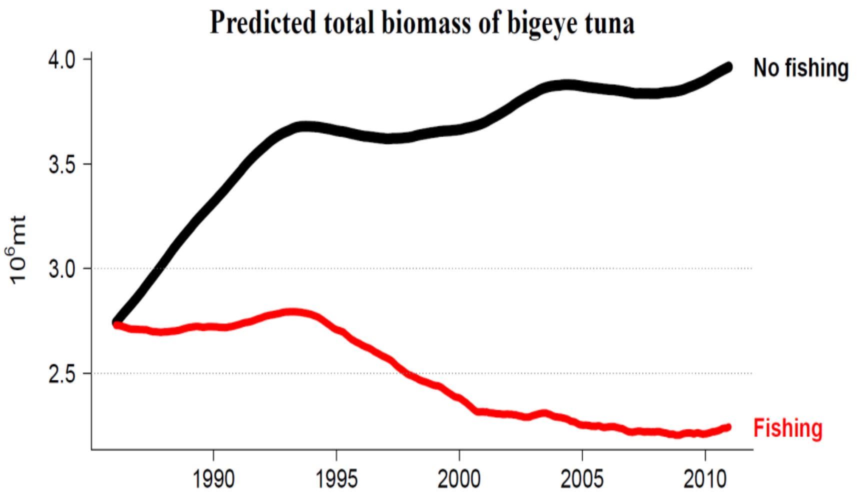
b) Introducing a more general functional relationship between pH and favorability in the definition of the spawning habitat index.

Perspectives: Other Species

- Other species: YFT BET ALB SWO

Ongoing update for yellowfin and bigeye tuna using

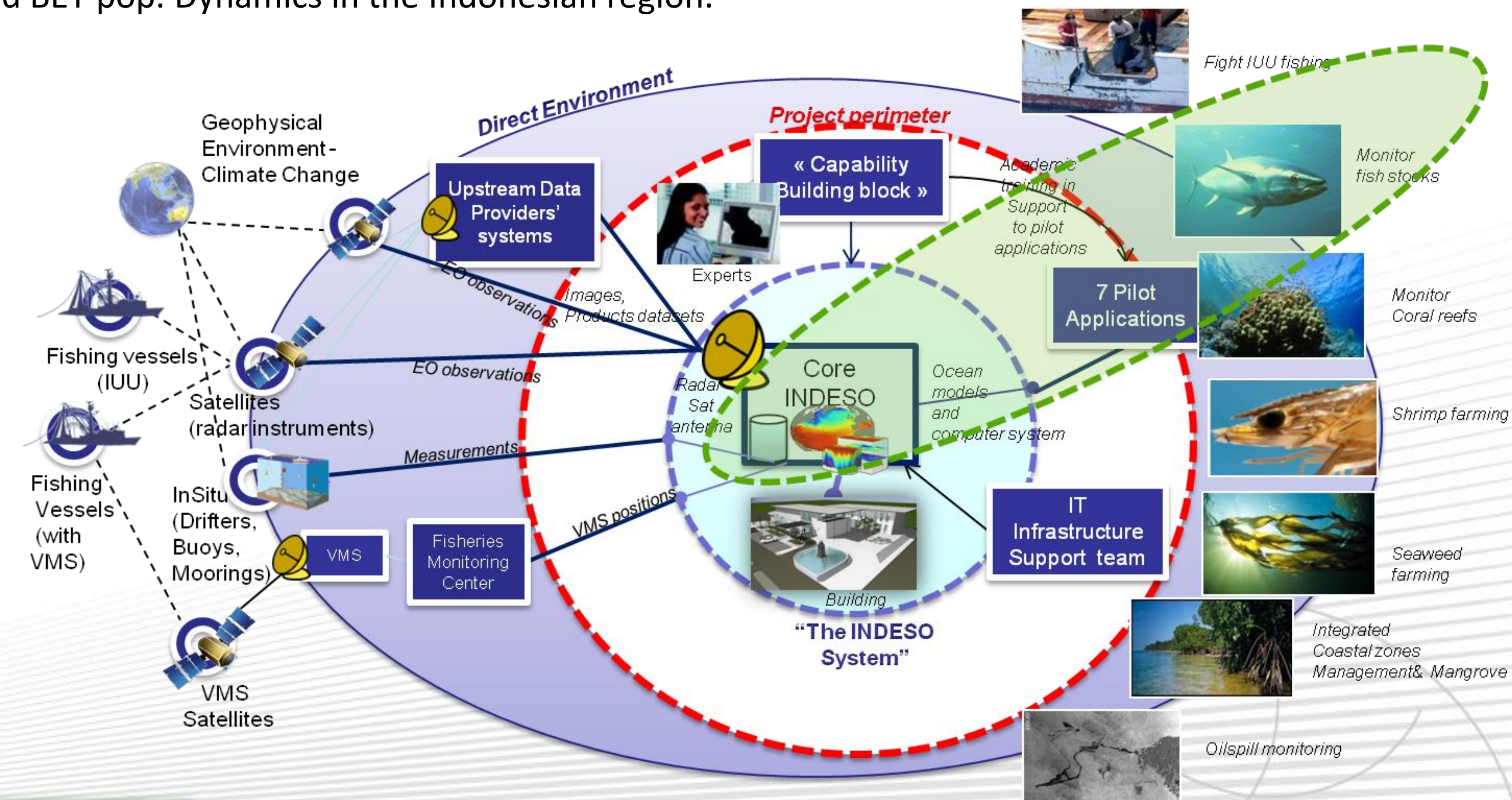




Perspectives: Operational

INDESO: INfrastructure DEvelopment for Space Oceanography (2013-17)

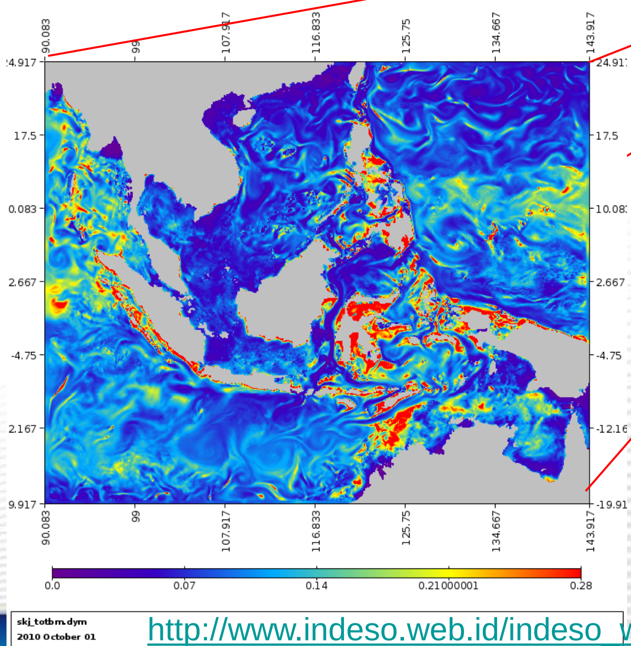
INDESO project for the Gov. of Indonesia (Balitbang KP: Research & Development Agency of the Indonesian Ministry of Fisheries and Marine Affairs), with support of French Agency for Development, includes the development of an operational configuration of SEAPODYM to provide real-time and forecast of SKJ, YFT and BET pop. Dynamics in the Indonesian region.

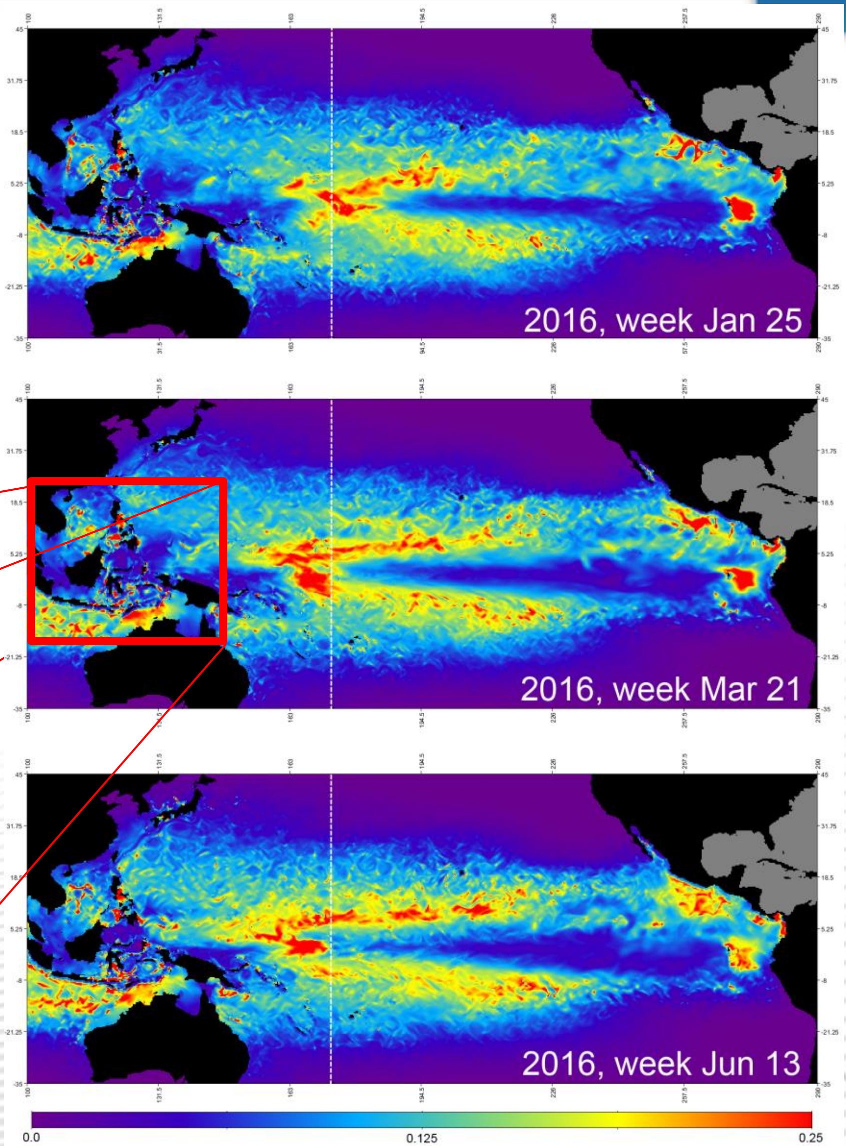


http://www.indeso.web.id/indeso_wp/index.php

Perspectives: Operational

To provide initial and boundary conditions to the high resolution **regional model at 1/12° x day, a global model at resolution of ¼° x week** has been developed **.**
Realtime and 2-week forecast are generated each week.
Basin scale optimization conducted with SPC are used to update the system.





Total skipjack tuna density

http://www.indeso.web.id/indeso_wp/index.php

Perspectives: Operational

The final objective is to use real time catch and effort information in the system rather than the average fishing effort based on the last few years, using Electronic Reporting System (ERS) or /and Vessel Monitoring Systems (VMS).

Longliner VMS data

Setting Soak time Hauling

Data mining techniques to detect regular patterns without any prior information
are used to get accurate estimates of fishing effort