Tuna movements and large scale variation in prey abundance

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Observations
catch and SST

Distribution of skipjack
tuna catch (t) and
mean sea surface
temperature in the
Pacific Ocean. a, in the
first half of 1989 (La
Niña period); b, in the
first half of 1992 (El
Niño period).
**Hypothesis**

- **Eq**: Equator
- **PNG**: Papua New Guinea

Legend:
- High primary productivity
- High tuna forage productivity
- Tuna habitat highly favourable
- Limit of the warm pool
- Movements of skipjack tuna population
- Positive effect on the recruitment a few months later

Diagram showing the relationship between La Niña and El Niño events, Southern Oscillation Index, primary productivity, and tuna forage.
Modelling: forage \((F)\)

We consider the prey species as a single population and we use a fish population dynamics approach: constant mortality \((\lambda)\) and continuous recruitment \((S)\) at age \(T_r\).

\[
dF/dt = S - (\lambda F)
\]

\[
S = P \exp(-m_r T_r)
\]

Transfer with time of primary production towards forage according to the model \((S\) is assumed constant). The thin curve describes the evolution in time of a single source of primary production. The thick curve gives the total forage population.
Modelling: including spatial scale

• The model covers the Pacific basin with a grid of 1 degree square
• The forage is passively transported by currents
• This transport in the two horizontal dimensions, is based on an advection-diffusion equation
Parameterization:

Very simple!

Energy transfer from new primary production to forage:

\[ \text{4\% according to Iverson (1990)} \]

Using the biological characteristics of typical tropical tuna prey species (oceanic anchovy, squids, red crab, euphausides, juveniles of tuna,...) a reasonable parameterization is defined for:

- Tr : 60 d.
- \( 1/\lambda \) (mean age) : 120 d.

leading to a lifespan (defined as the age at which 99\% of the cohort has disappeared) of 336 d.
**Physical-Biogeochemical Model**

- **Micro-Zooplankton** [Z1] → **Nitrate** [NO$_3$] → **Ammonium** [NH$_4$] → **Diatoms** [P2] → **Silicate** [Si(OH)$_4$] → Physical Model
- **Small Phytoplankton** [P1] → **Micro-Zooplankton** [Z1] → **Detritus-N** [DN] → **Detritus-Si** [DSi] → Sinking
- **Micro-Zooplankton** [Z1] → **Predation** → **Meso-Zooplankton** [Z2] → **Fecal Pellet** → Sinking
- **Meso-Zooplankton** [Z2] → **Grazing** → **Small Phytoplankton** [P1] → **Excretion** → **Ammonium** [NH$_4$] → **Meso-Zooplankton** [Z2] → **Grazing** → **Diatoms** [P2] → Sinking
- **Small Phytoplankton** [P1] → **Grazing** → **Detritus-N** [DN] → **Fecal Pellet** → Sinking
- **Ammonium** [NH$_4$] → **Detritus-Si** [DSi] → **Sinking**
- **Diatoms** [P2] → **Silicate** [Si(OH)$_4$] → **Sinking**
- **Total CO$_2$** [TCO$_2$] → **Air-Sea Exchange**
Surface Phytoplankton Concentration (mmol/m$^3$) - 1990 Mean

Nino3 (5°S-5°N, 150°W-90°W)
Phytoplankton Concentration (mmol/m$^3$) in Nino3 Box (5$^\circ$S-5$^\circ$N, 90$^\circ$W - 150$^\circ$W), 1965-92
NO$_3$ (mmol/m$^3$) in Nino3 Box (5°S-5°N, 90°W-150°W) from 1965 to 1992, Decadal Cycle
Main south Pacific albacore spawning area

Main skipjack spawning area
South Pacific Albacore: Comparison with Multifan CL ...

... and prediction?
Conclusions

• There is a convincing relationship between the distribution of simulated tuna forage and tuna distributions inferred from fishery data.

• This relationship can be used as the basis of a forage-tuna coupled model in which tuna dynamics are a function of the forage distribution.

• Such a model may be useful for investigating many different questions on tuna biology or fisheries (recruitment, variability in growth or natural mortality, migration patterns, interaction between fleets, ecosystem approach, etc…).