TunaScape: Monitoring the Eastern Tropical Pacific Tuna Fishery from Space

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Our ultimate goal is to provide tuna fishery scientists and managers ecosystem-based decision support system for monitoring and analysis of their fisheries.

We have developed a three-dimensional simulation model that couples the circulation of the eastern tropical Pacific Ocean (ETPO) to the ecology and population dynamics of the three commercial tuna species (skipjack, yellowfin, and bigeye). *TunaScape*, will be run at both mesoscale and submesoscale and will help to answer two sets of questions.

- Why is the purse seine fishery, which catches younger fish of all three tuna species, clearly defined by the depth of the hypoxic layer and chlorophyll enriched surface waters? How does the circulation in the ETPO explain the formation of a shallow hypoxic layer?

- What features of circulation lead to tuna aggregation? Are these features apparent at mesoscale (10-100 km) resolution or is submesoscale (<10 km) resolution required?
ECCO-BLING Global Model and Plankton Dynamics
a 3-dimensional, mesoscale and submesoscale biogeochemical simulation running on Pleiades super computer: currents, T, S, PO4, Fe, O2, PhytoC & Chl,

TunaScape Agent-based Fish and Fishers Model
Population dynamics & movement of tuna schools, purse seine vessel search, movement, & catch as well as purse seine vessel movement and catch running within our EASy Geographical Information System.

Output
3-dimensional simulation of the Eastern Tropical Pacific tuna fishery driven by ocean dynamics: currents, temperature, O2, PO4, Fe, phytoplankton carbon & chlorophyll, tuna school distribution, species, age class, purse vessel distribution, catch

With support from NASA and NSF, we have been working on this model for several years and time today is insufficient to describe it fully. Instead and in deference to the theme of “Life in a Moving Ocean”, I will focus on our preliminary results of water motion over broad spatial and temporal scales shapes tuna habitat and distribution.
Yellowfin *Thunnus albacares*
Bigeye *Thunnus obesus*
Skipjack *Katsuwonus pelamis*
Inter-American Tropical Tuna Commission’s estimates of Natural (Unfished) Population Parameters have been incorporated in *TunaScape’s* Spatial, Population Dynamics Model

<table>
<thead>
<tr>
<th>Species</th>
<th>Maximum Length (cm)</th>
<th>Maximum Age (Yrs)</th>
<th>Maturation Age (yrs)</th>
<th>von Bertalanffy specific growth rate /yr</th>
<th>Natural Population</th>
<th>Natural Mortality /month</th>
<th>Natural Recruitment #/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bigeye</td>
<td>218</td>
<td>17</td>
<td>4</td>
<td>0.22</td>
<td>39,500,000</td>
<td>0.033</td>
<td>1,300,000</td>
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<tr>
<td>Skipjack</td>
<td>86</td>
<td>4</td>
<td>1</td>
<td>0.8</td>
<td>2,850,000,000</td>
<td>0.10</td>
<td>270,000,000</td>
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<tr>
<td>Yellowfin</td>
<td>222</td>
<td>9</td>
<td>1.5</td>
<td>0.36</td>
<td>110,000,000</td>
<td>0.06</td>
<td>6,500,000</td>
</tr>
</tbody>
</table>

All three species are serial spawners, schooling, and have navigational capabilities (a accurate sense of time and place) that are not understood but include sensing of the earth’s magnetic field, accurate clock to determine time and measure daylength, visual acuity, and sensitivity to sound. About to start work with an Artificial I team at USC to attempt to model their “migrational” brain.
Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the northeastern Pacific Ocean, ascertained through archival tag data

Kurt M. Schaefer · Daniel W. Fuller · Barbara A. Block

Fig. 6 *Thunnus albacares.* Depth and temperature records for a fish (tag no. 826) exhibiting type-2 diving behavior. a Seven days, February 13–19, 2003; b one day, February 13, 2003. Estimated location is 21.5°N 112.3°W
La Jolla, California
2006
The world’s site of largest source of release of CO2 from the ocean to the atmosphere and a key indicator of climate events and the impact of climate change.
Major currents and flow fields as revealed by ECCO Sea Surface Height & Flow Nov. 19, 2004
Scales of Motion and Subsequent Response of Fish and Fishers

The Pacific Ocean is so large that its dynamics are largely uninfluenced by land masses and thus its water “wanders” according to its own fluid dynamics. The scales of motion that determine tuna habitat and distribution range from regional to mesoscale to submesoscale. Here are examples of our initial analysis of model simulations.
PHAM screen shots.
The purse seine fishing ground (indicated by +) matches well surface waters where chlorophyll concentration exceeds 1 mg/m3 (upper panel) & overlies the hypoxic layer (lower panel).

Purse seine recording stations superimposed upon a MODIS satellite image of surface chlorophyll concentration.

Purse seine recording stations superimposed upon a climatological image of annual average oxygen concentration at 150 m depth.
The left panels show the distribution of the average monthly biomass catch from 1975 to 2008 of bigeye (top), yellowfin (middle) and skipjack (bottom) tuna caught by the purse seine fleet superimposed on an image of the average annual concentration of oxygen at 150 m, O2 [150]. The right panels show the distribution of the catch of bigeye (top) and yellowfin (bottom) caught by longline fleet, respectively for the same time period.
Air-sea O2 exchange

PO4 → PhytoP → ZooP → DetritalP

Upwelling & Vertical Diffusion

Diel Vertical Migration

Sinking

PO4 → ZooP → DetritalP

O2

NO3
Basin Scale

Time step of ECCO Bling simulation on January 1, 1996 of oxygen (upper) and temperature (lower)

plan view @ 105 m depth

cross section @ -130 ° from 25 ° to -10 °
QuickSCAT Zonal Wind Speed 2008-10-16 transect {20N-136}, {20S, -136}
El Nino  Number of Sets plotted on ECCO 2 zonal velocity 12/15/1997

La Nina Number of Sets plotted on ECCO 2 zonal velocity 12/15/1998
11/1/98-5/1/99 SKJ PS Catch, ECCO-2 Drifts, AVISO SSH
When a cyclonic eddy is spinning up, the velocity at the outer edge drops. This drop decreases the coriolis and centrifugal forces causing the inward gravitational pressure force to halt the outflow, producing convergent flow. This convergence drives downwelling at the periphery of the eddy and some level of recycling.

Bakun Scientia Marina (2006)
This coming year we will complete the coupling of the *ECCO-BLING Model* to the *Agent-based Fish and Fishers Model* and run sensitivity analyses to test responses to changes in the values of coefficients and variables. We will also examine the relationship submesoscale and mesoscale flows and fish distribution. Finally, we will present the model to the stock assessment scientists and others of Inter-American Tropical Commission and other international fisheries agencies such as Oman and Oman that are concerned about the impact of the spread of hypoxia.

Questions?