REGIME SHIFTS AND RECRUITEMENT: OCEAN CLIMATE/ECOSYSTEM VARIABILITY AND LINKS TO TUNA RECRUITEMENT

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Aims and motivation for the project

Ecosystems exhibit natural variability at multiple scales – diel, seasonal, inter-annual, decadal

‘Regime shifts’ – broadly defined as transitions from one quasi-stable ecosystem state to another – have been observed in the North Pacific in the late 1970s and 1990s; have they occurred in the WCPO? Are they relevant to top predators such as tuna?

Can we derive objective measures of long-term variability in multiple ecological time series?

Can we use an improved understanding of ecosystem variability to improve recruitment estimation for tunas?
Project has 3 elements:

Comparative analysis of OLD tuna diet data from 1959-1974 (New Caledonia) and 1990s (French Polynesia) vs. NEW data from 2001-2005

Objective characterisation (univariate/multivariate analysis) of oceanographic time series

Use of oceanographic time series to develop statistical models for tuna recruitment; incorporate these into stock assessment model, leading to improved recruitment estimation
Comparing the diet of tunas between old and new datasets from New Caledonia and French Polynesia

**NEW CALEDONIA**

**GRANDPERRIN-IRD** 1959-1974

**GEF-PFRP** 2001-2005

<table>
<thead>
<tr>
<th>Fish</th>
<th>1959-1974</th>
<th>2001-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albacore</td>
<td>235</td>
<td>50</td>
</tr>
<tr>
<td>Yellowfin</td>
<td>435</td>
<td>96</td>
</tr>
<tr>
<td>Bigeye</td>
<td>28</td>
<td>59</td>
</tr>
</tbody>
</table>

**FRENCH POLYNESIA**

**ECOTAP-IRD** 1995-1997

**GEF-PFRP** 2001-2005

<table>
<thead>
<tr>
<th>Fish</th>
<th>1995-1997</th>
<th>2001-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albacore</td>
<td>82</td>
<td>97</td>
</tr>
<tr>
<td>Yellowfin</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>Bigeye</td>
<td>140</td>
<td>97</td>
</tr>
</tbody>
</table>
Diversity of Fish Prey families

- Large loss in diversity of fish prey
- Changes in fish prey composition
Prey vertical class proportions (% weight):

NEW CALEDONIA

albacore

+12% C

yellowfin

+18% F

-10% M

bigeye

Changes

FRENCH POLYNESIA

+46% C

-10% M

+22% C

-12% M

+14% F

-7% M
Conclusions from diet study

Changes have been observed in the diet of the 3 tunas species:
- decrease in biodiversity
- decrease in mesopelagic squid Ommastrephidae
- increase of epipelagic crustaceans
- changes in prey functional groups proportions

Changes in prey composition and biomass
Changes in predator behavior/distribution

Scale of changes? Decadal vs. Inter-annual?

[Graph showing SOI and FP indices with La Niña and El Niño periods highlighted]
**Conclusions from diet study**

**METHODS**

Comparing diet studies is a difficult task especially when working on ‘rescued’ data; this study highlighted the importance of metadata.

Taxonomic identification level appears to be a major problem in the comparison process as it highly depends on the identification skills; analysis of the data at the family level is probably a good compromise between accuracy and precision.

**RESULTS**

Environmental variability is likely to play an important role in the changes apparent in the diet data.

However, the lack of continuous monitoring and the lack of precision in the ‘rescued’ data make it difficult to conclude that these changes are the result of an ecosystem ‘regime shift’ between two stable states.
Oceanographic data analysis and recruitment estimation

Objectives...

• Characterise oceanographic variability

• Develop statistical models relating oceanographic variability and tuna (YFT) recruitment (during a period for which there is confidence in data used to estimate recruitment)

• Use the statistical model to hindcast recruitment throughout the history of the fishery
Shifts in the mean for SOI, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1

Shifts in the mean for PDO, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1

Shifts in the mean for PDOJanuary-centered, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1
Environmental data

Surface ocean *u and v current vectors* and *temperature* were generated from a ocean general circulation model (OGCM); a biogeochemical NPZD (nutrients-phyto-zooplankton-detritus) model computed *primary production* [Earth System Science Interdisciplinary Center, University of Maryland, USA ]

Temperature, primary production, east-west current component, north-south current component and forage biomass were available for 1948–2004. The resolution of these environmental data fields are 30 days and 0.5° square.

Historical monthly mean wind data for 1958–2001 were obtained from the ECMWF (European Centre for Medium Range Weather Forecasting) ERA-40 re-analysis. *U and V wind components at 10 meters height*, as well as east-west surface stress, were obtained on 2.5° square resolution.

Estimates of *absolute wind speed W* were calculated as : \( W = \sqrt{U^2 + V^2} \).

An index of *turbulence* was also calculated, using the fact that turbulent kinetic energy is proportional to the cube of absolute wind speed
Generalised Linear Model derived iteratively over 99 different areas – for which environmental data averaged by area and quarter – and 3 time periods, i.e. quarters prior, during and post spawning.
ZONE 1: Rodionov* analysis
Cutoff length=10; P=0.2

Principal Components Analysis for Zone1

Projection of the variables on the factor-plane ($1 \times 2$)

Factor 1: 41.70%

Factor 2: 32.44%
Principal Components Analysis for Zone1

**Shifts in the mean for PC1, 1948-2004**

- Probability = 0.2, cutoff length = 10, Huber parameter = 1

**Shifts in the mean for PC2, 1948-2004**

- Probability = 0.2, cutoff length = 10, Huber parameter = 1

41.70%

32.44%
ZONE 2: Rodionov analysis
Cutoff length=10; P=0.2
Principal Components Analysis for Zone2

Projection of the variables on the factor-plane (1 x 2)

Factor 1: 58.15%

Factor 2: 19.53%

Variables:
- T100Z2
- V100Z2
- UwindZ2
- VwindZ2
- turbulenceZ
Principal Components Analysis for Zone 2

Shifts in the mean for PC1, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1

58.15%

Shifts in the mean for PC2, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1

19.53%
ZONE 3: Rodionov analysis
Cutoff length=10; P=0.2
Principal Components Analysis for Zone 3

Projection of the variables on the factor-plane (1 x 2)

Factor 1: 32.94%

Factor 2: 28.39%

Variables:
- turbulenceZ3
- PPZ3
- VwindZ3
- T100Z3
- U100Z3
- UwindZ3
- V100Z3
Rodionov analysis for Zone3

32.94%
Shifts in the mean for PC1, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1

29.14%
Shifts in the mean for PC2, 1948-2004
Probability = 0.2, cutoff length = 10, Huber parameter = 1
### Generalised Linear Model for yellowfin recruitment, 1980-2004:

<table>
<thead>
<tr>
<th>Variable</th>
<th>R-squared</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST average Zone 3</td>
<td>0.1651</td>
<td>90.23</td>
</tr>
<tr>
<td>+ SST average Zone 1</td>
<td>0.2722</td>
<td>83.04</td>
</tr>
<tr>
<td>+ SST range Zone 3</td>
<td>0.3588</td>
<td>76.88</td>
</tr>
<tr>
<td>+ current v range Zone 3</td>
<td>0.4160</td>
<td>73.90</td>
</tr>
<tr>
<td>+ wind stress Zone 3</td>
<td>0.4719</td>
<td>70.26</td>
</tr>
<tr>
<td>+ current direction Zone 1</td>
<td>0.5052</td>
<td>66.00</td>
</tr>
<tr>
<td>+ current v average Zone 2</td>
<td>0.5409</td>
<td>64.81</td>
</tr>
<tr>
<td>+ SST depth range Zone 2</td>
<td>0.5705</td>
<td>64.42</td>
</tr>
<tr>
<td>+ SST average Zone 2</td>
<td>0.5987</td>
<td>63.89</td>
</tr>
</tbody>
</table>
Yellowfin recruitment estimates from final GLM (blue line) and from stock assessment model (points & dashed line). Light blue area: 95% confidence intervals around recruitment estimates from GLM.
What now?

Hindcasting of recruitment GLM for period 1948-1980; compare with recruitment estimated by the assessment model.

If the GLM series is considered to be more robust than recruitment estimated in the stock assessment model, then use it to improve estimation of biomass.
Conclusions

The ‘regime shift’ concept appears to be overly simplistic as an explanation of observed variability in oceanographic time series and tuna diet data.

Long-term environmental variability exists but is somewhat buffered in the western Pacific and patterns are not coherent among sub-regions.

Nevertheless, it has been possible to develop a statistical model relating observed variability to tuna recruitment, which may be used to refine recruitment estimates throughout the assessment period, thereby improving estimates of stock status.