Regime shifts in Western and Central Pacific Ocean tuna fisheries

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General comments on regime shifts:

deYoung et al. (2004):
‘...an abrupt change from a quantifiable ecosystem state’
'The determination of ecosystem state remains an unresolved and imprecise, oceanographic problem’

Scheffer & van Nes (2004):
‘...mechanistic explanations for [regime shifts] remain scarce’

Steele (2004):
‘...so far there is no convincing evidence that changes in ocean climate such as El Nino, Pacific Decadal Oscillation or the North Atlantic Oscillation induce bi-stable modes in marine ecosystems’
**Main objectives:**

- Establish whether the regime shifts* documented for the North Pacific in the late 1970s, 1980s and 1990s are seen in the WCPO
- Investigate operational metrics** to identify such shifts

**Data:**

- recruitment estimates from most recent MFCL stock assessments
- sea-surface temperature (SST) and primary productivity estimates from a physical-biogeochemical ocean model
- climate indices based on SST and atmospheric pressure

**Methods:**

- non-linear regression to determine functional form of long-term variability, i.e. fit to sigmoid curves or sine waves
- calculation of Fisher Information as an ecosystem indicator

*discontinuities and/or low-frequency periodic variability in data characteristic of the system*
Sea-surface temperature (ESSIC) – North Pacific

Sea-surface temperature (deg C)

- winter
- spring
- summer
- autumn

Year: 1950 to 2000
Climate & biological variables – North Pacific

Hare & Mantua 2000
First two principal component scores from an empirical orthogonal function analysis of the 100 environmental time series
Fisher Information (Fath et al. 2003: J Theor Biol)

\[ I = \frac{1}{T} \int_{0}^{T} \frac{(R''(t))^2}{(R'(t))^4} \, dt \]

\[ R'(t) = \sqrt{\sum_{i=1}^{n} \left( \frac{dy_i}{dt} \right)^2} \]

\[ R''(t) = \frac{1}{R'(t)} \left[ \sum_{i=1}^{n} \frac{dy_i}{dt} \frac{d^2 y_i}{dt^2} \right] \]
Environmental data extracted from ESSIC model
**Sea surface temperature**

![Graph showing sea surface temperature over time.](image)

**Primary production**

![Graph showing primary production over time.](image)
Functional approximations for albacore recruitment
Sea surface temperature
Primary production
Climate indices & recruitment estimates

(a) **PDO**

(b) **BET-YFT-SKJ**

(c) **NPI-ALB**

PDO: Pacific Decadal Oscillation (sea-surface temperature)
NPI: North Pacific Index (atmospheric pressure)
Functional approximations for PDO

Long-period (ca. 50 yr) oscillation

Regime Shift: late 1940s

Regime Shift: late 1970s
Functional approximations for recruitment estimates

Yellowfin

Bigeye
Fisher Information for WCPO (excluding SKJ)
Fisher Information for WCPO (including SKJ)
Conclusions re: WCPO & tuna recruitment:

Fisher Information from recruitment estimates and basin-scale climate indices detects regime shifts in the WCPO in the 1970s & late 1980s, consistent with North Pacific.

These shifts were positive for the tropical tunas (bigeye, yellowfin, skipjack) and negative for albacore.

No evidence (yet) in WCPO for a regime shift post-1998, documented for the North Pacific*; functional approximation and wavelet analysis (Minobe 1999) suggests imminent negative changes in both 50 yr and 20 yr cycles.

If this occurs we would expect a prolonged period of below-average recruitment for bigeye, yellowfin and skipjack (cf. 1960s/1970s) with increased productivity for albacore.