Integration of multiannual climate predictions in the estimation of stock status and rebuilding time frames for highly migratory species

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Management of Highly Migratory Species (HMS) in the North Pacific

The Pew Charitable Trust

Stock Status Determination of Highly Migratory Species in the North Pacific

Stock Assessment
Reconstruction of Historical Conditions
Estimation of Current Biomass and Reference Points

Future Projections
Project population forward with constant catch rate
Probability of biomass > reference points or rebuilding target

Management Decision
Stock Projections

• Sensitive to assumptions of future recruitment

• Often future recruitment is simulated as random noise around average stock-recruitment based on historical patterns

• Environment can drive substantial variability in recruitment (e.g. Szuwalski et al. 2015)

• Can lead to biased estimates of stock status or rebuilding probabilities
Stock Projections

- Informative to know if recruitment over the next 10 years will be likely to be
- Less bias?
- Narrower window of probable outcomes?
Pacific Bluefin Tuna Case Study

- SST-informed recruitment model skillful
- $R^2 = 0.72$ for training (1982-2005)
- $R^2 = 0.51$ for out of sample prediction (2006-2012)
Pacific Bluefin Tuna Case Study

Multi-Annual Climate Predictions for Fisheries: An Assessment of Skill of Sea Surface Temperature Forecasts for Large Marine Ecosystems

- skillful multiannual predictions in spawning region LMEs
Pacific Bluefin Tuna Catch by Country

Catch by country

Calendar year

Calendar year

Catch in weight (t)


Japan  Korea  Taiwan  United States  Mexico

PBT 2018 Stock Assessment
http://isc.fra.go.jp/pdf/ISC18/ISC_18_ANNEX_14_Pacific_Bluefin_Tuna_Stock_Assessment_2018_FINAL.pdf
Pacific Bluefin Biomass

PBT 2018 Stock Assessment
http://isc.fra.go.jp/pdf/ISC18/ISC_18_ANNEX_14_Pacific_Bluefin_Tuna_Stock_Assessment_2018_FINAL.pdf
Pacific Bluefin Tuna Harvest Control

• If the SSB projection indicates that the probability of achieving the initial rebuilding target by 2024 is less than 60%, management measures will be modified...

• If the SSB projection indicates that the probability of achieving the initial rebuilding target by 2024 is at 75% or larger, the WCPFC may increase their catch limits
• Probabilities of achieving rebuilding target depend on stock projections

• Stock projections are sensitive to recruitment assumption

• Projections are run with average and low recruitment scenarios (resampling from 1980-1989 low recruitment period)
Pacific Bluefin Tuna Case Study

- Are multi-annual, probabilistic recruitment forecasts skillful?
- Focused on probability of recruitment being below average (lower tercile)
Pacific Bluefin Tuna Case Study

SST predictions 1 to 10 years into the future for 1991 to 2012 from GFDL CMIP5 decadal experiment
Initialized between Jan 1st 1982 to Jan 1st 2012
10 ensemble members

Probabilistic prediction 1 to 10 years into the future of recruitment being below average
Retrospective skill assessment

Brier Score = 0.22
(0 to 1, lower better)

Brier Score = 0.22
(0 to 1, lower better)
Perfect SST Brier Score = 0.13
(0 to 1, lower better)
Forecast SST vs. Average Recruitment

The upper graph shows the log of recruits over time, with data points scattered from 1990 to 2010. The lower graph depicts the probability of low recruitment, comparing forecasted and random types. The forecasted probability shows a higher variation, while the random type maintains a lower and more consistent probability.
Impact on estimate of stock status

• Forced age structured population dynamics model with 5 recruitment scenarios:
  1. Actual recruits
  2. Resampling from entire recruitment time series
  3. Resampling from low recruitment period
  4. Perfect SST
  5. Forecast SST

• Compared probability of achieving rebuilding target over 8 random years across 100 simulations, each with 500 iterations per recruitment replicate
Impact on estimate of stock status

- In SST scenarios probability of low recruitment event every year influences # of iterations forced by low recruitment period
  - 500 recruitment iterations per year
  - If probability is 0.8
  - 80% of 500 recruits sampled from low recruitment period
Impact on estimate of stock status

The chart shows the probability of achieving rebuilding target for different scenarios:
- **ForecastT**
- **PerfectT**
- **LowR**
- **AverageR**
- **Actual**

The box plots indicate variability around the median, with the Actual scenario showing the highest probability range.
Conclusions

- Skillful recruitment forecasts informed by SST
- Larger forecast error from physical rather than biological forecast
- Mechanisms of SST predictability in the region need to be investigated
- Use of SST informed forecast may reduce bias in stock status estimate
- However, SST-informed projections of stock status appear over-confident
Thank you!

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