Modeling Recruitment Responses of Striped Marlin (*Tetrapturus audax*) and Swordfish (*Xiphias gladius*) to Environmental Variability in the North Pacific

**Jon Brodziak, Dean Courtney, Kevin Piner,
Hui-Hua Lee, and Gerard DiNardo**

**Pacific Islands Fisheries Science Center
2570 Dole St., Honolulu, HI 96816**

Jon.Brodziak@NOAA.GOV

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Western Pacific Regional Fishery Management Council
ECOSYSTEM-BASED MANAGEMENT OF FISHERIES IN THE U.S. PACIFIC ISLANDS

Western and Central Pacific Fisheries Commission

Overview

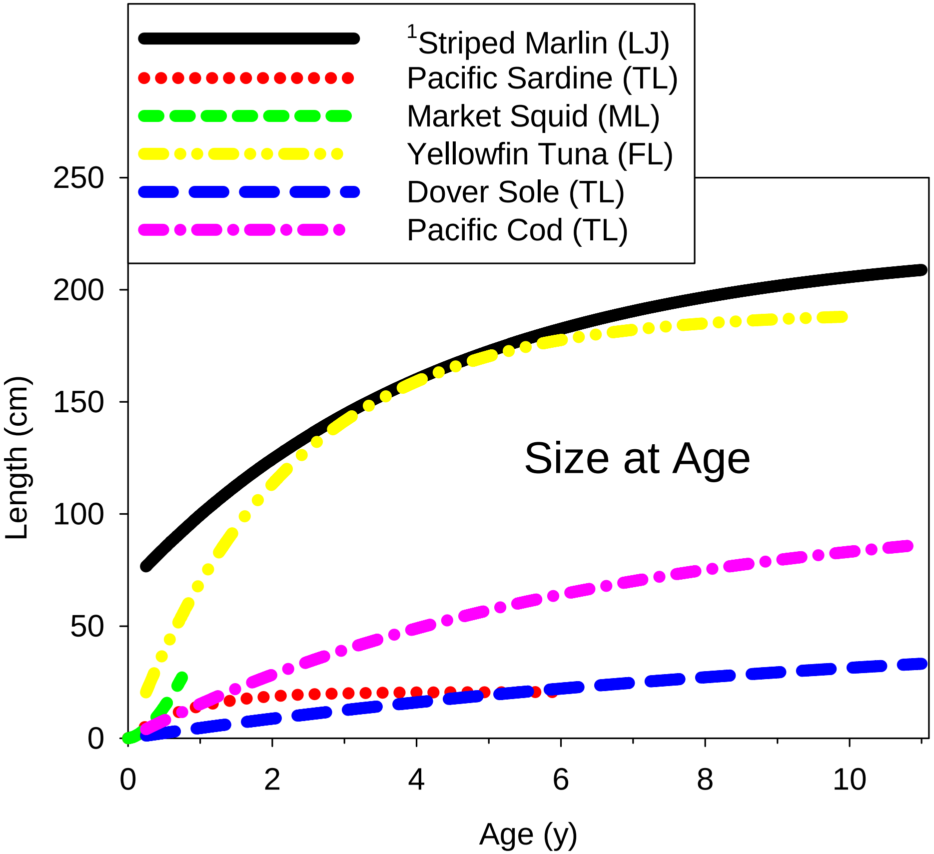
- Current North Pacific Stock Assessments
  - Striped Marlin
  - Swordfish

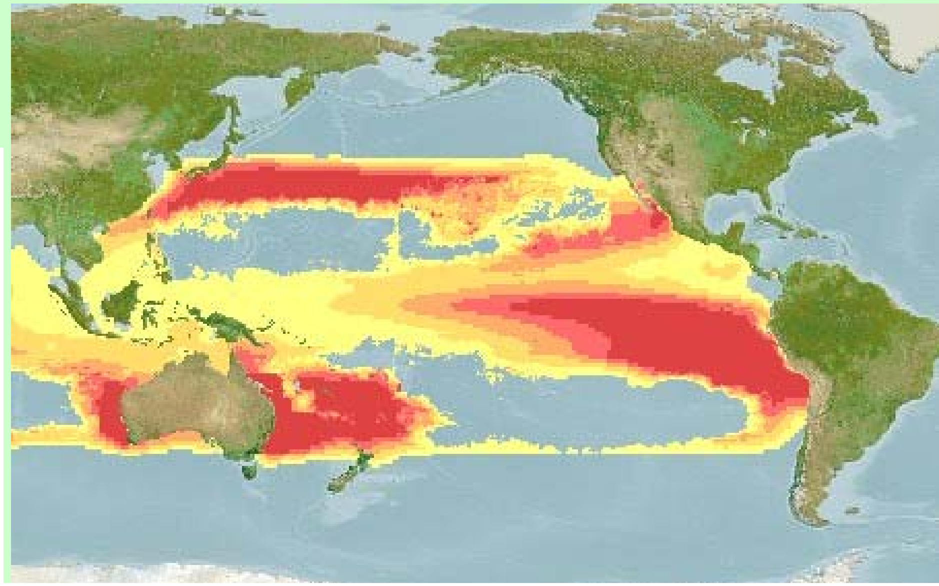
- Evidence of Environmental Forcing
  - Early Life History Survival is Important Process
  - Consider Effects of Key Climate Processes:
    - Pacific Decadal Oscillation Index
    - Southern Oscillation Index

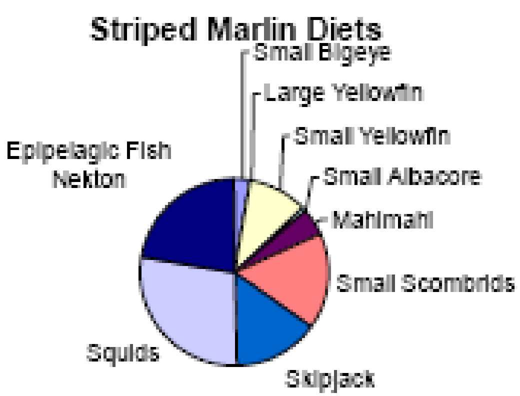
- Results and Future Research
  - Are There Significant Effects ?
  - How Can We Address Model Uncertainty?

Striped Marlin Growth, Distribution, and Food Habits

- Inhabits surface waters ≥20°C with 75% of time <10 m depth
- Generalist predator (scombrids, squids,...) with rapid growth
- Highly vulnerable to shallow set longline gear

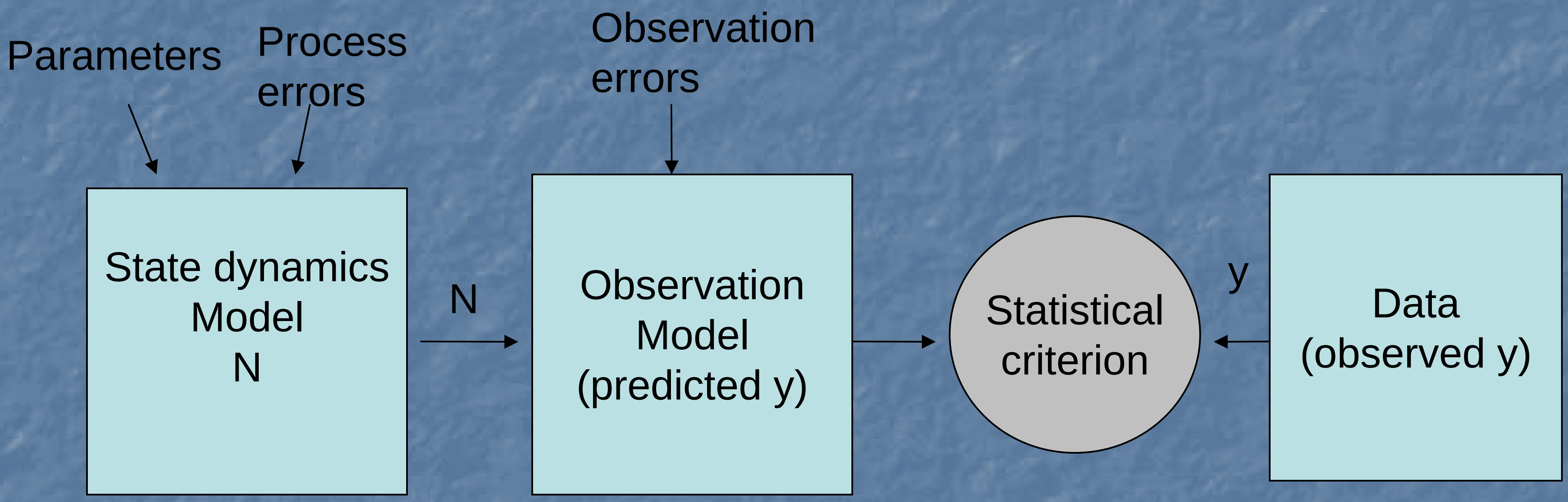






[1]Melo Barrera et al. 2003. Ciencias marinas 29(3):305-313.

Parameter estimation and state dynamics for integrated assessment models (Stock Synthesis)



$N_{t+1}=N_t-C_t$

$y_t=qN_t$

$$-\frac{n}{2}\ln[\sum(y_t-\hat{y}_t)^2]$$

Parameter N_o

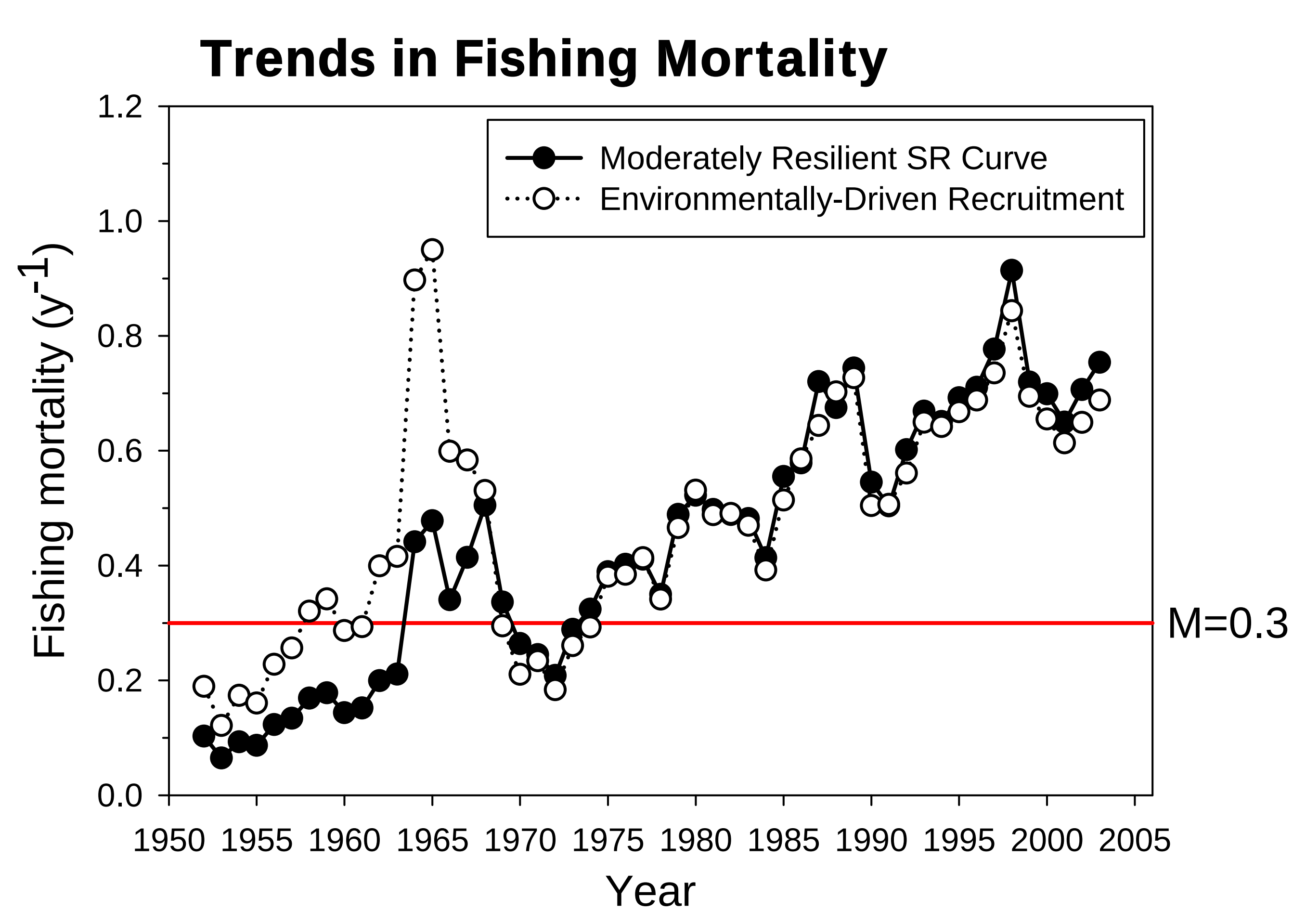
Parameter q

Log-likelihood function

Striped Marlin Assessment Scenarios and Results

Recruitment dynamics modeled using 2 hypotheses

- **Moderately Resilient SR Curve, Steepness is *h*=0.7**
- **Environmentally-Driven Recruitment, Steepness is *h*=1**

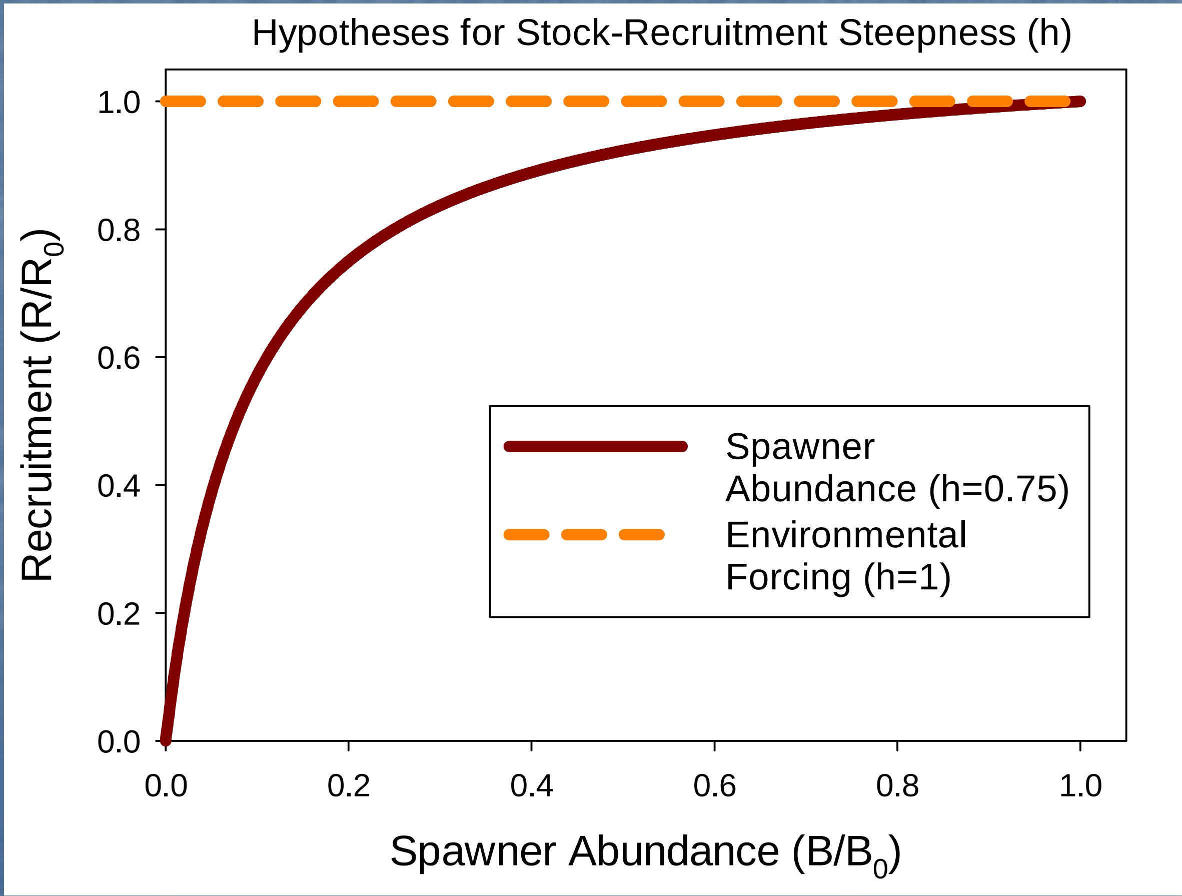


Alternative Stock Assessment Scenarios: What is the value of steepness, the fraction of unfished recruitment expected at 20% of unfished biomass?

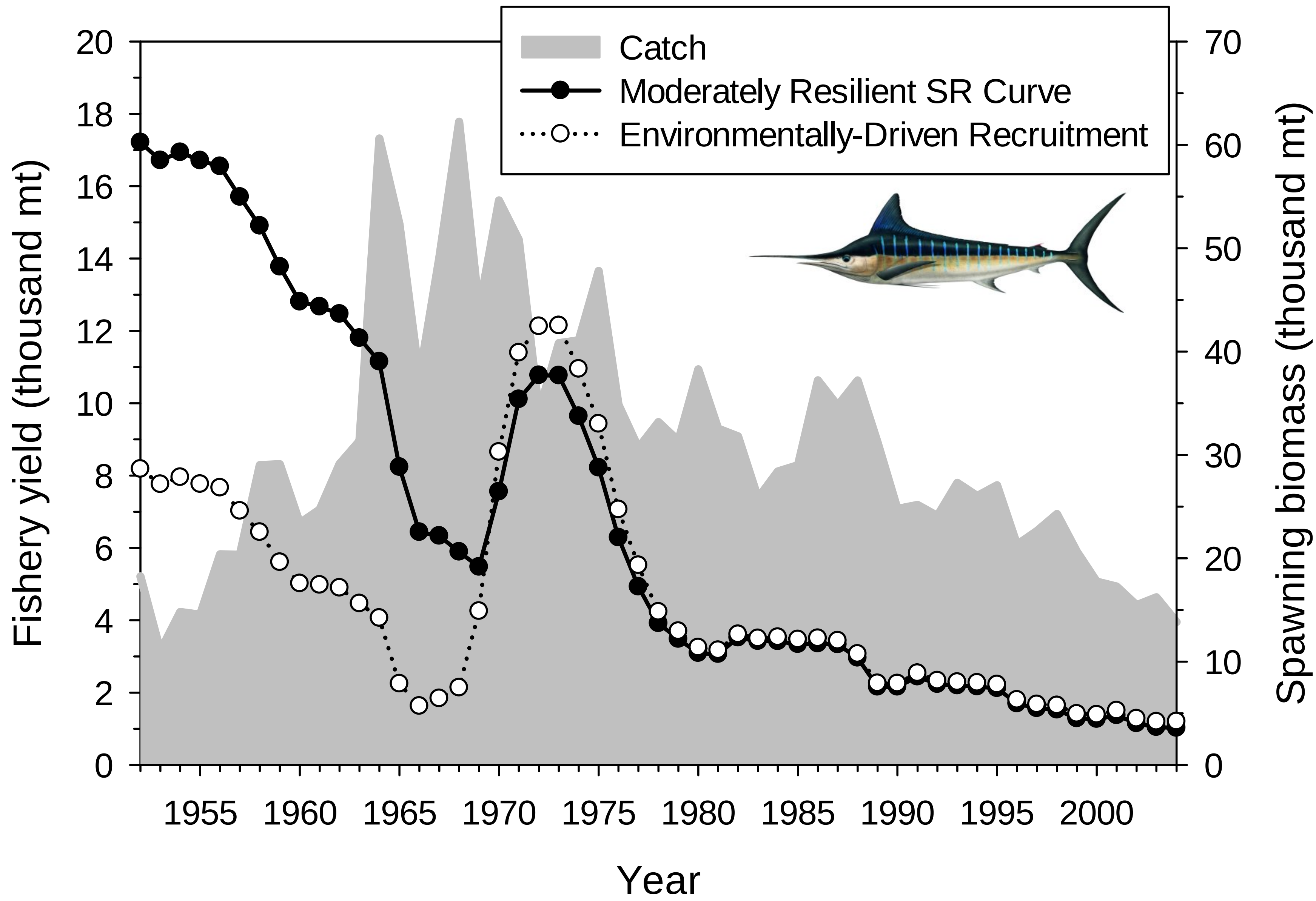
- **Formulate multiple working hypotheses about how alternative causal factors influence recruitment**

- **Select best hypothesis using model selection criteria or if multiple hypotheses are supported use model averaging**

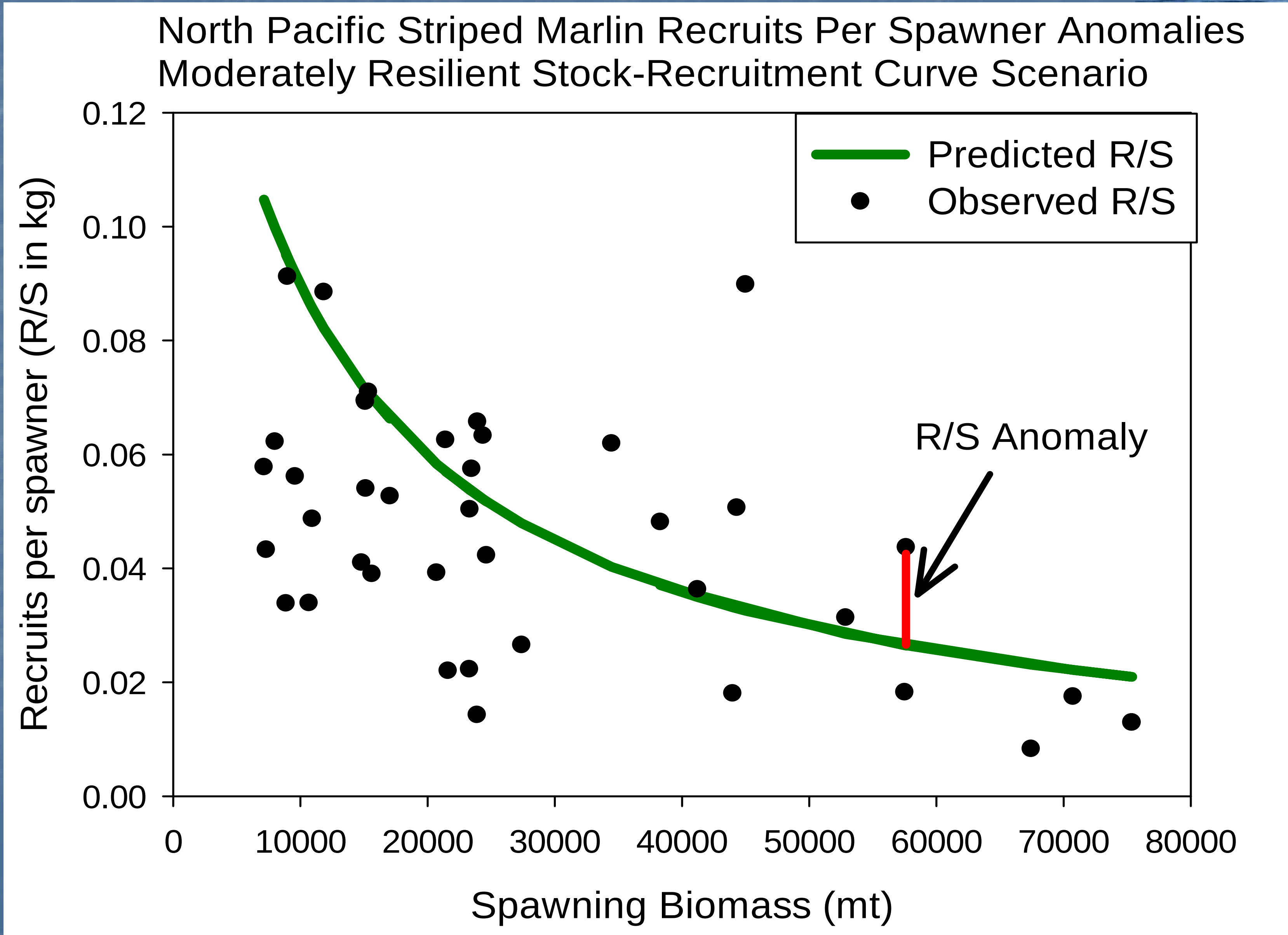
$$R = \frac{4hR_0B}{B_0(1-h)+B(5h-1)}$$



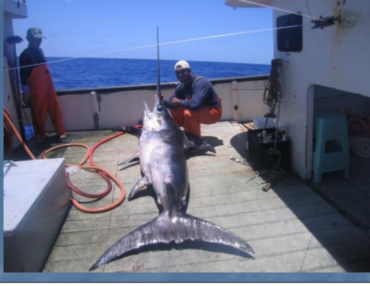
Results: Trends in Spawning Biomass

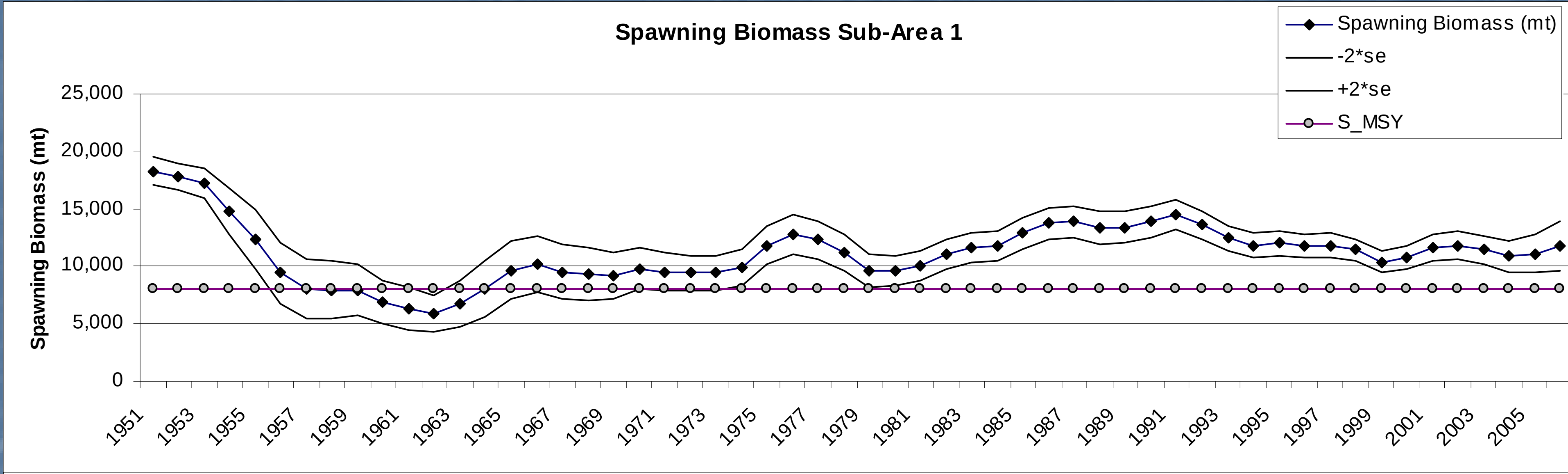


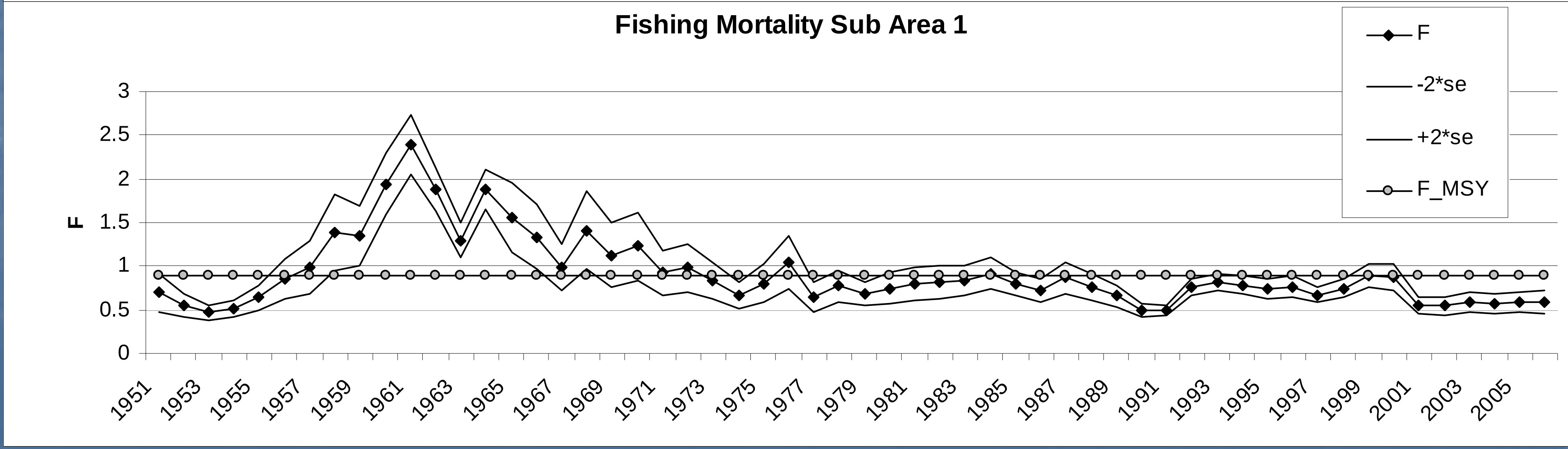
Measuring Recruitment Success: Accounting for Maternal Effects



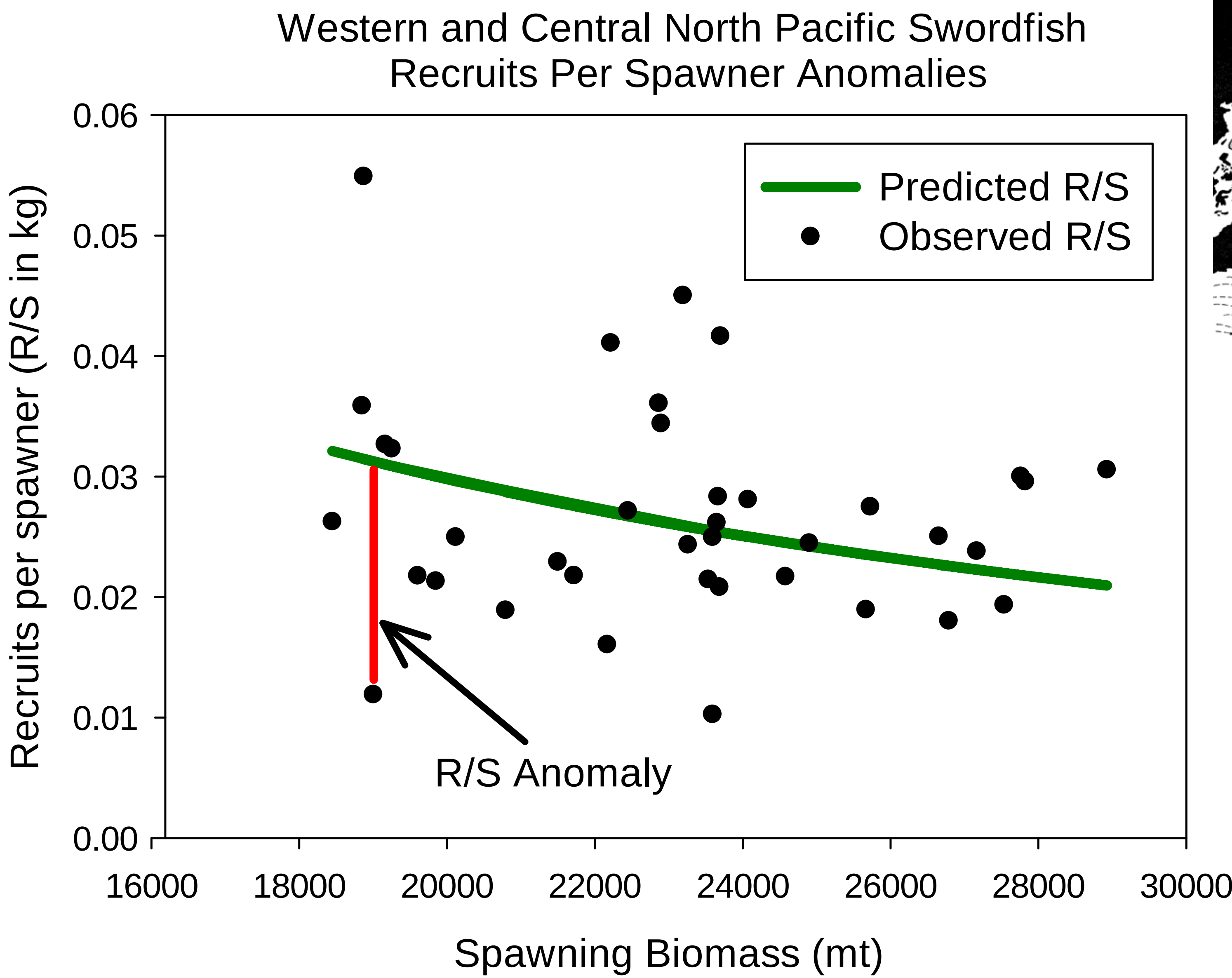
Western and Central North Pacific Swordfish Relative Stock Status

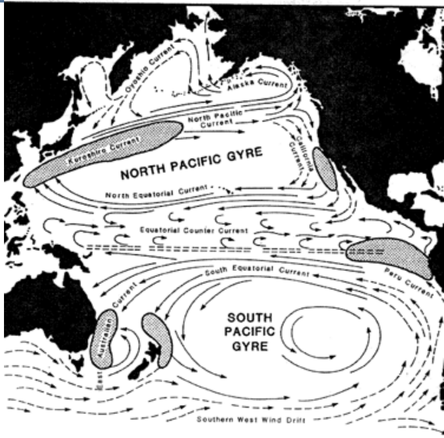




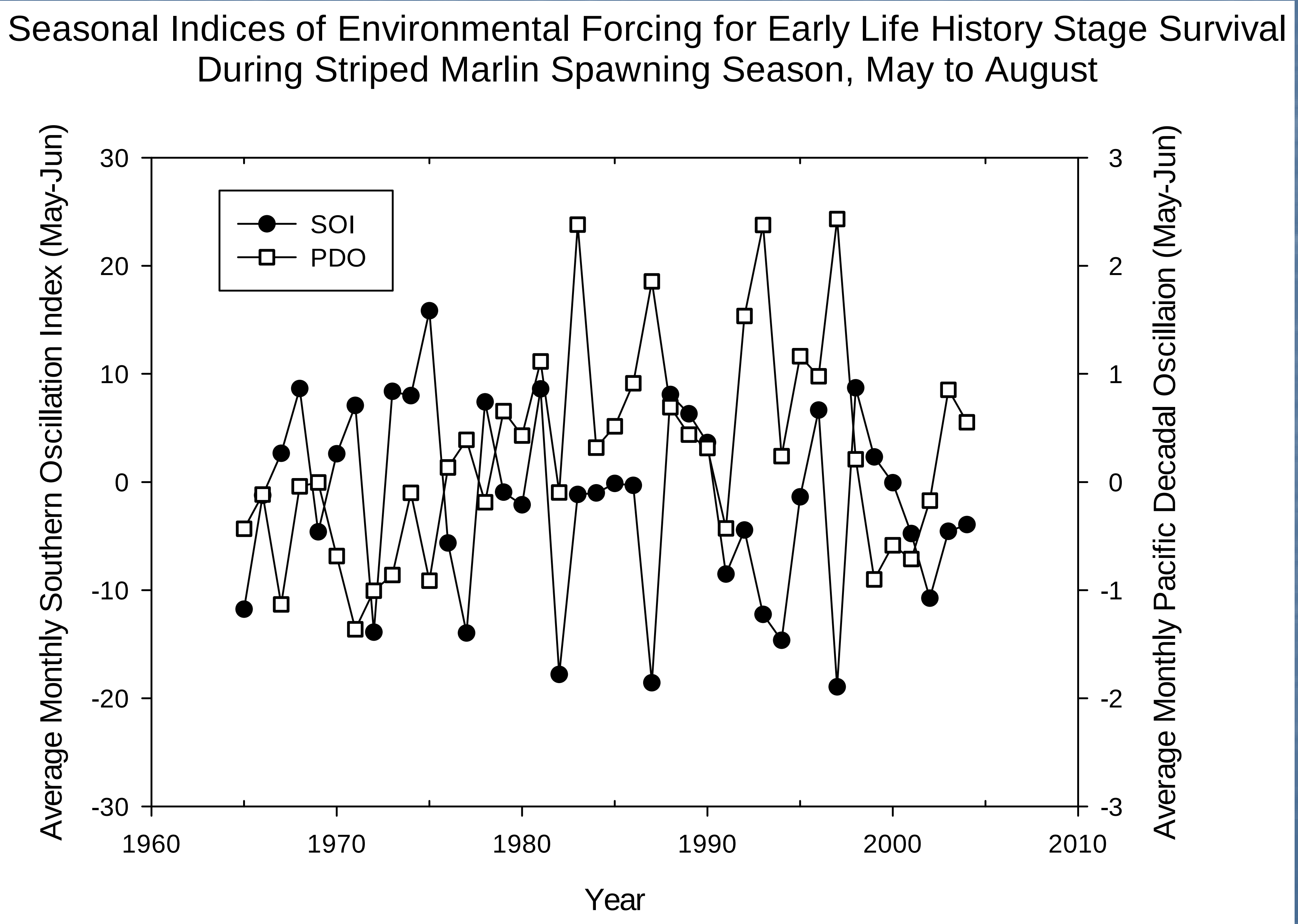


Measuring Swordfish Recruitment Success: Accounting for Maternal Effects

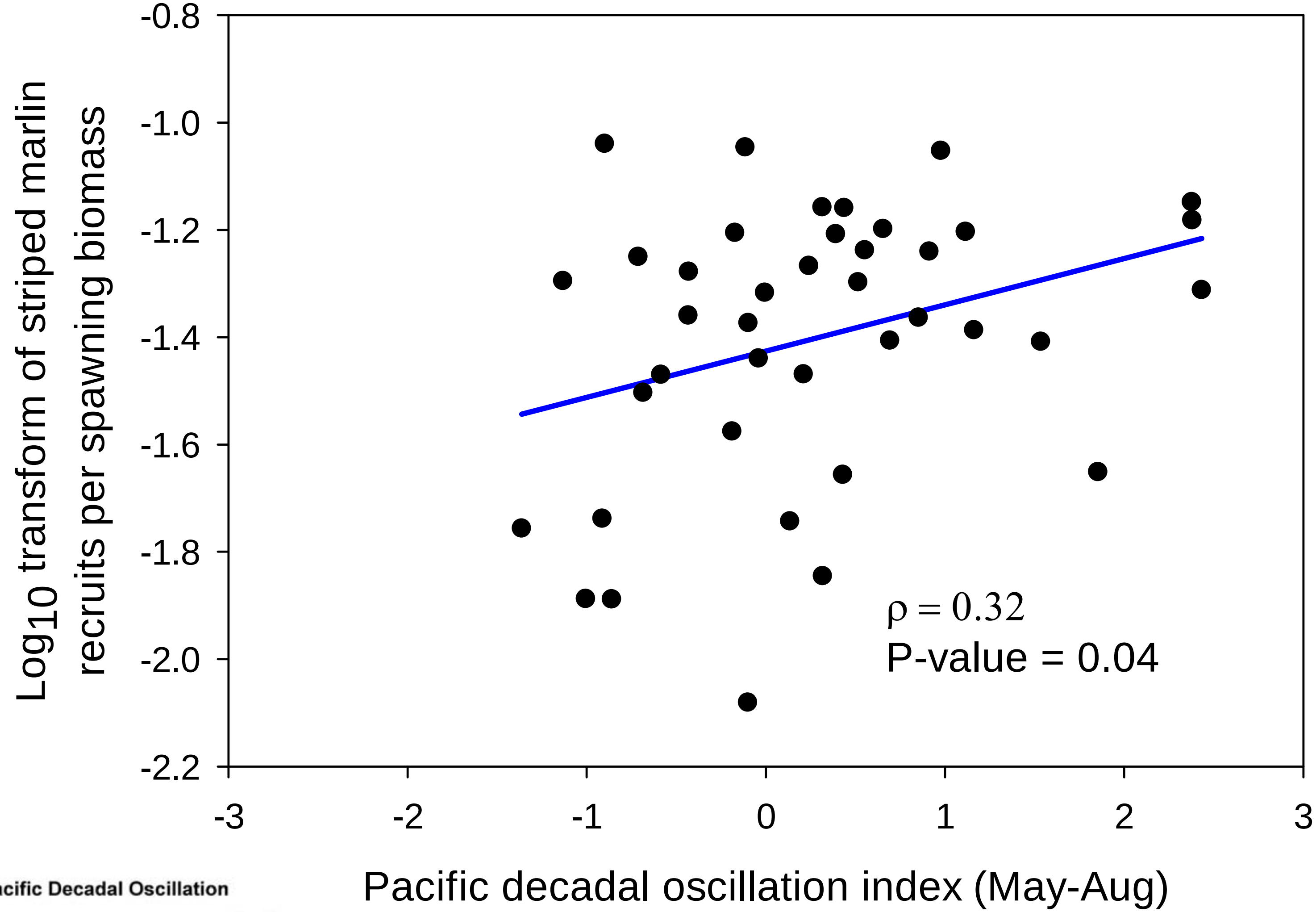


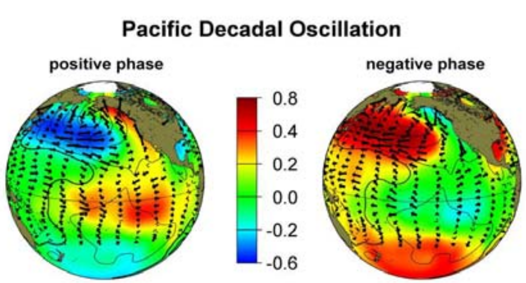


Indices of Environmental Forcing Effects on Striped Marlin Recruitment Success

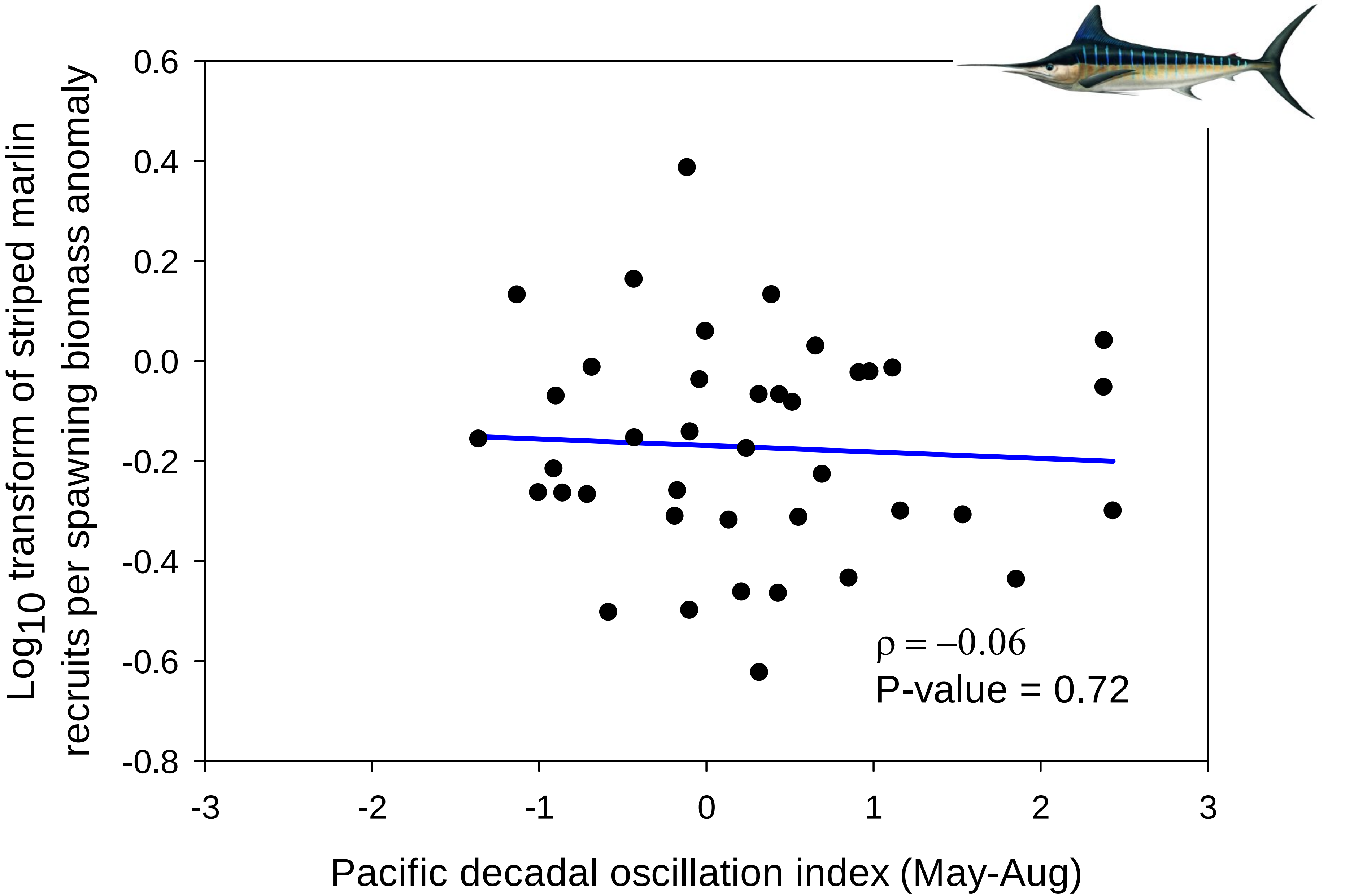


Striped Marlin Moderately Resilient Stock-Recruitment Steepness Scenario
Association Between PDO and Recruits Per Spawner Ratio

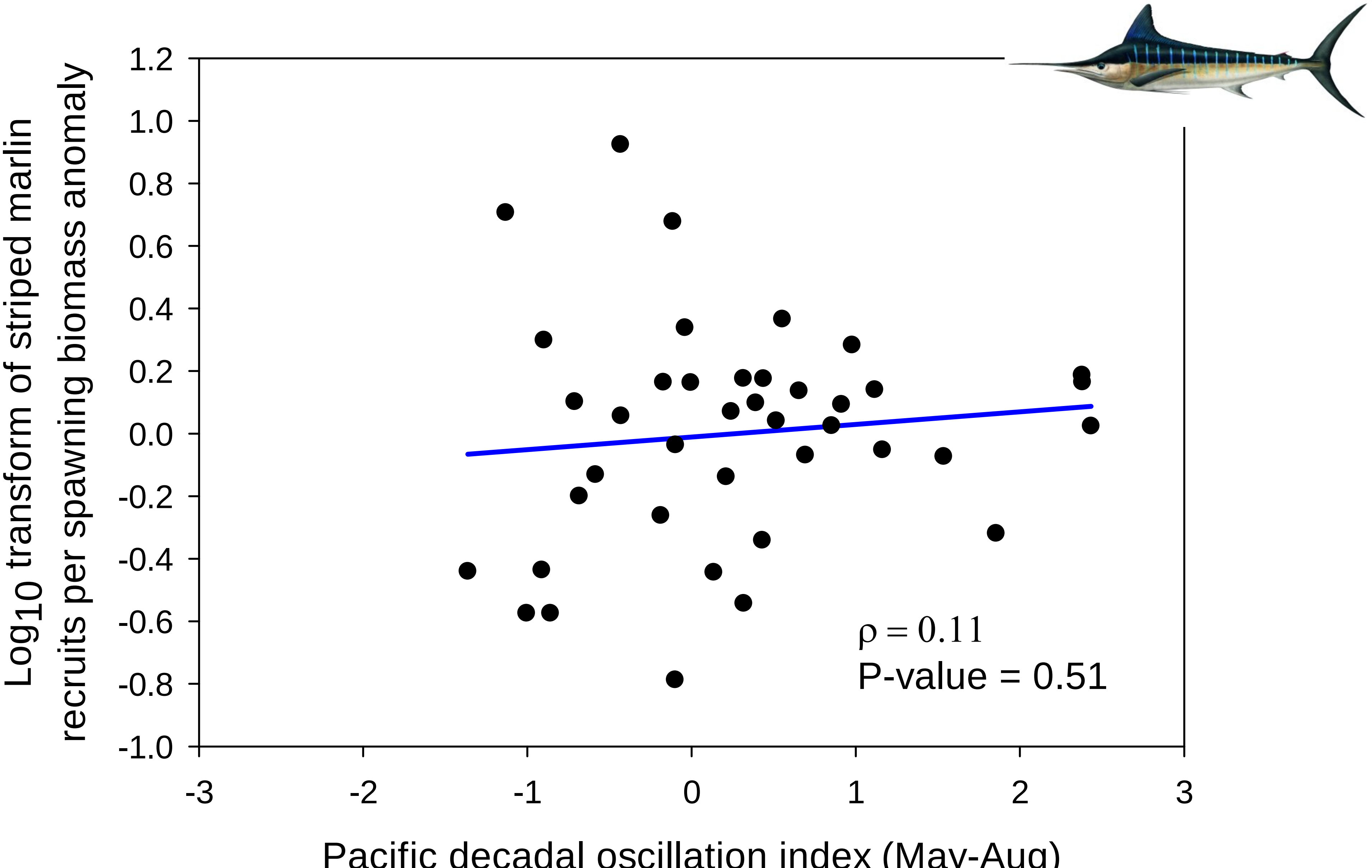




Striped Marlin Moderately Resilient Stock-Recruitment Steepness Scenario
Association Between PDO and Recruits Per Spawner Anomaly Ratio

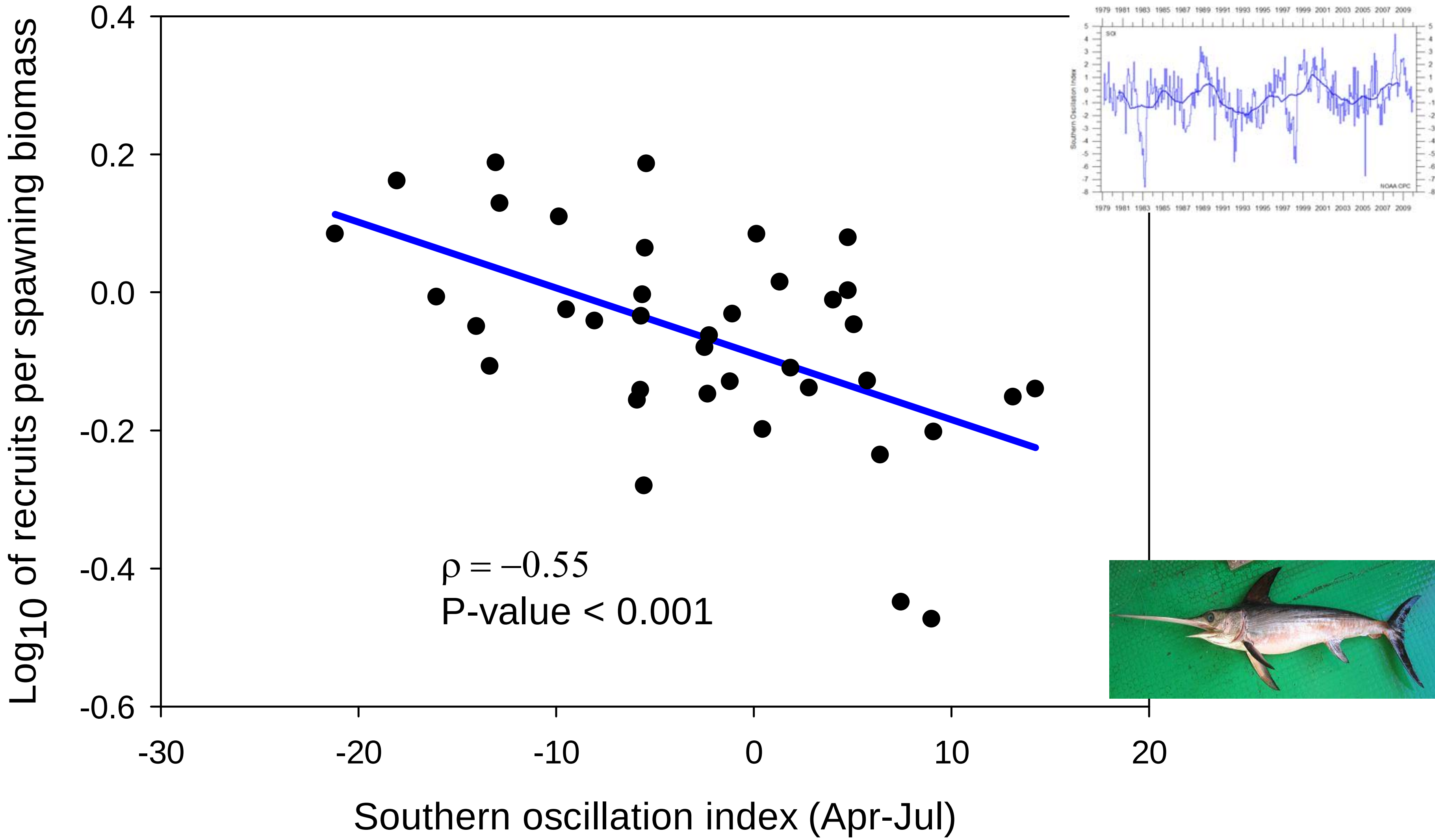


Striped Marlin Environmental Forcing Stock-Recruitment Steepness Scenario
Association Between PDO and Recruits Per Spawner Anomaly Ratio



Western and Central North Pacific Swordfish

Association of Recruits Per Spawner Anomalies and Southern Oscillation Index



$$\left(R/S\right)^{PREDICTED} = 25.589 \cdot 10^{-3} - 5.085 \cdot 10^{-4} \cdot SOI_{Apr-Jul} \qquad \Delta_{AIC} \approx 10^{2}$$

Results and Conclusions

- Limited Evidence for Strong Environmental Effects on Striped Marlin Recruitment Success
- Evidence Exists That the Southern Oscillation Index Influences Swordfish Recruitment Success Was Found
- Striped Marlin Will Likely Be More Vulnerable to Climate Change Than Swordfish Due to More Intensive Fishery Exploitation and Lower Stock-Recruitment Resilience

Future Work

- How Can Stock Forecasts Include Model Uncertainty for Recruitment Predictions ?
  - Use Fitted Environmental Forcing Functions
  - Use Fitted Stock-Recruitment Curves
    - Resample Fitted Error Distributions
    - Resample Empirical CDF of Residuals
  - Use Empirical Cumulative Distribution Functions
    - Recruitment
    - Recruits Per Spawner
    - Recruits Per Spawner Anomalies
  - Apply Model Averaging When Several Scenarios are Supported by the Data

Thank You Very Much