Incorporating the Spatiotemporal Distribution in the Standardization of Swordfish (*Xiphias gladius*) Catches in the North Pacific Ocean Hawaii-based Longline Fishery

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North Pacific Swordfish

- U.S. fisheries for swordfish in the NPO accounted for 53% of the national harvest.
- Longline fishery is the largest commercial fishery.
- There are differences in effort, area fished, CPUE & size of fish between the shallow- & deep-set longline fisheries.
- Limited access fishery with a maximum number of vessels set at 167
  - 2016: 141 permitted vessels
  - 13 targeted swordfish
Main fishing areas
HI LL fishing effort 1991-1995

Bigelow, et al. 1999
Hawaii-Based Longline Fishery

- Data from 1995 - 2016 from the Pacific Islands Regional Observer Program (PIROP)

Deep Set:
- Targets tuna
- At least 15 hooks per float
- Catches small swordfish as bycatch
- 3-10% observer coverage prior to 2004, 20% after 2004

Shallow Set:
- Targets Swordfish
- Less than 15 hooks per float
- Catches large swordfish
- Fishery closed from 2001-2004
- 100% observer coverage after 2004
Methods for standardizing and analyzing data

• GAM for Swordfish length data
  - Using spline smoothing function for continuous variables
  - Using Lat and Lon, Year, Cluster, Sex, MLD, SST, PDO, SOI as explanatory variables
• Delta-lognormal GLMM for Swordfish CPUE data
  - With vessel as a random effect
  - Using Lat, Year, Quarter, MLD, SST, Lunar Illumination, HPF, Begin Set Time, Bait Type as explanatory variables
• VAST for Swordfish CPUE Data
  - Initial runs with vessel as a random effect but no other covariates (yet)
Length Frequency Analysis

• GAM models for deep and shallow set sectors
• Deep set sector spatial distribution analyzed in two clusters:
  − May-July where larger fish are caught
  − August-April where small fish are caught
• Within each fishery sector:
  − Males vs Female spatial distribution
  − Juvenile vs Adult spatial distribution
Swordfish Eye-fork Length by month

January: 151.7
February: 146.7
March: 143.8
April: 142.1
May: 140.7
June: 140.9
July: 141.9
August: 108.7
September: 89.1
October: 105.8
November: 134.4
December: 148.3
Adults

August-April

Juveniles

August-April

May-July

May-July
Length Composition Analysis

• Size composition data shows clear spatial patterns
  – Large fish further north and small fish further south
  – Clear movement of large fish into the fishing area during spawning season
• A strong recruitment signal in the deep set size data
• Potentially some difference in spatial distribution between adult and juvenile fish
Nominal CPUE – Shallow set Fishery
Contours are indicate a CPUE change of 2

Nominal CPUE – Deep set Fishery
1995-2016
Incorporating Spatial Information to Standardized CPUE

• Current method: Include Latitude as an explanatory variable in GLMM
  – Delta-lognormal GLMM model for shallow set early and deep set
    ▪ Spatial and temporal variables, environmental variables, operational variables
  – Lognormal GLMM on positive catches only for late shallow set data
Exploring VAST with Swordfish CPUE data

Shallow Set

Deep Set
CPUE Comparison

![Graphs showing CPUE comparison over years](image)
Deep Set

Q-Q plot

Empirical vs Uniform

Normal Q-Q Plot

Sample Quantiles vs Theoretical Quantiles

Location E_km and N_km over years 1995 to 2015
Challenges to using VAST

• Adding Covariates for Catchability
  - Operational Data, Lunar Illumination, etc.

• Adding Covariates for Density
  - Oceanographic features: SST, MLD, Frontal Energy

• Unbalanced sampling
  - >95% shallow set catch in Q1 and Q2

• Shallow Set Fishery
  - >99% Positive Encounters after 2005

• Shallow Set Fishery Closures
Future of VAST for swordfish?

• Limited documentation and debugging guides
  Warning message:
  In TMBhelper::Optimize(obj = Obj, lower = TmbList["Lower"], upper = TmbList["Upper"], :
  Hessian is not positive definite, so standard errors are not available

• Abundance index is basically the same…so why use VAST?
Red: nCPUE, blue/green sCPUE