NOAA FISHERIES

Pacific Islands Fisheries Science Center

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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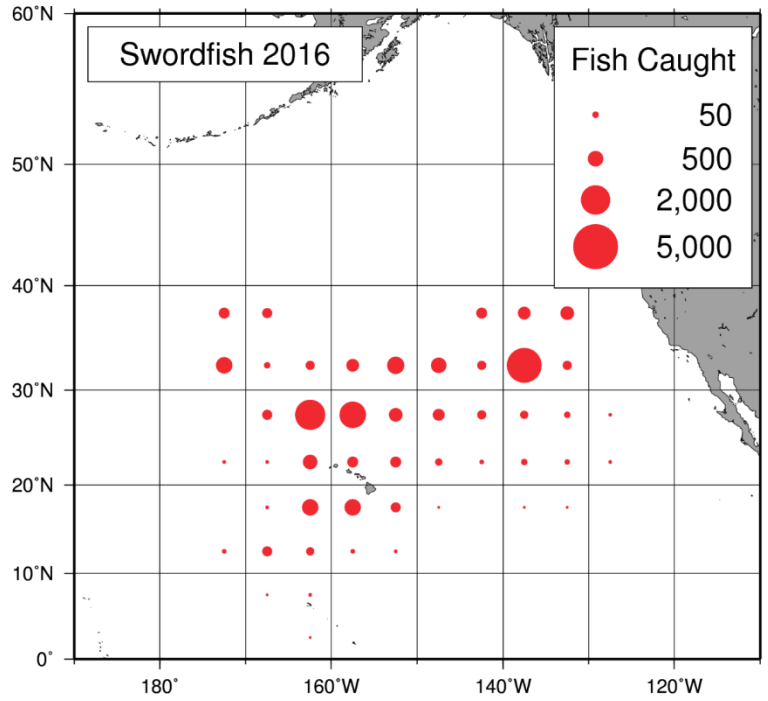
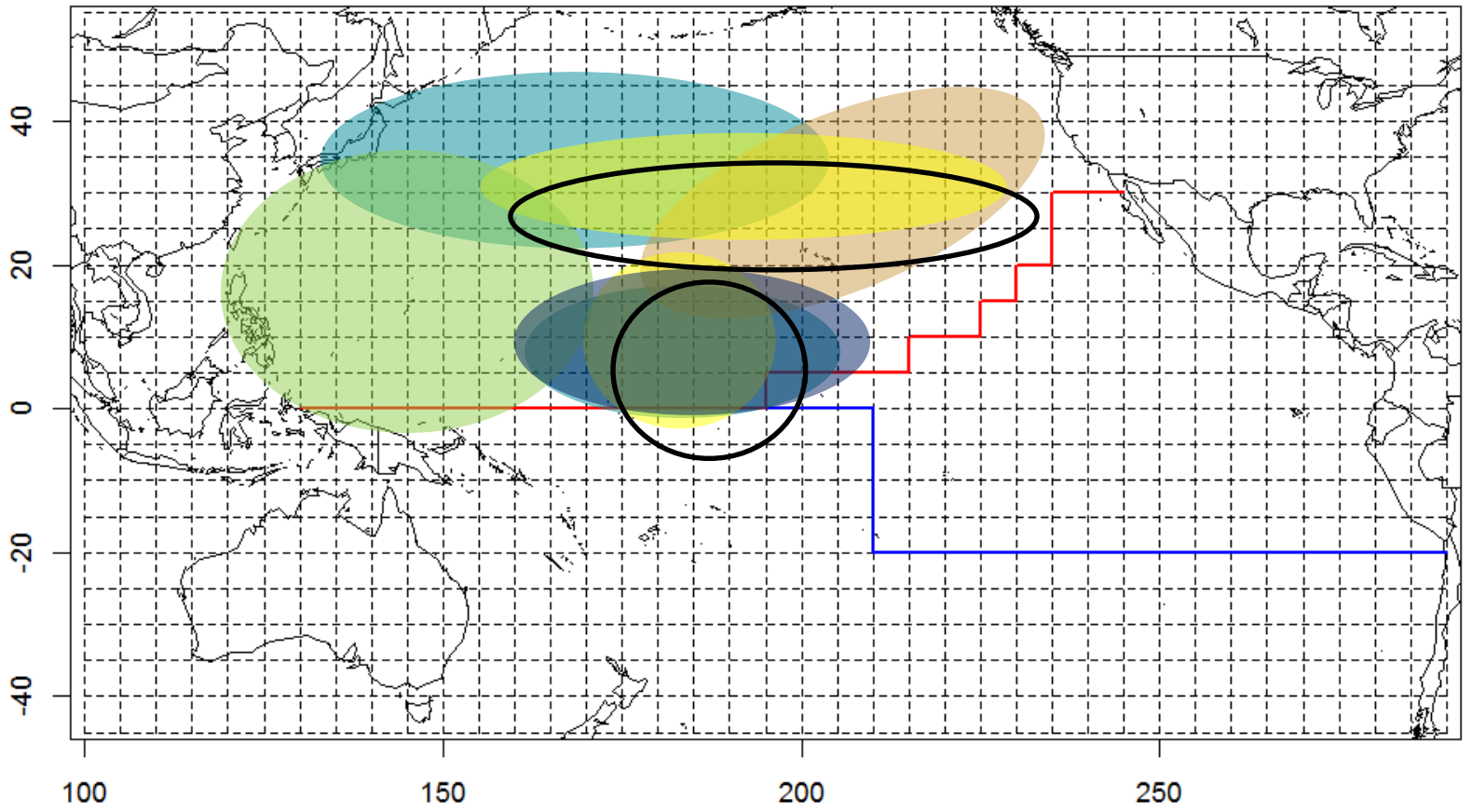
North Pacific Swordfish



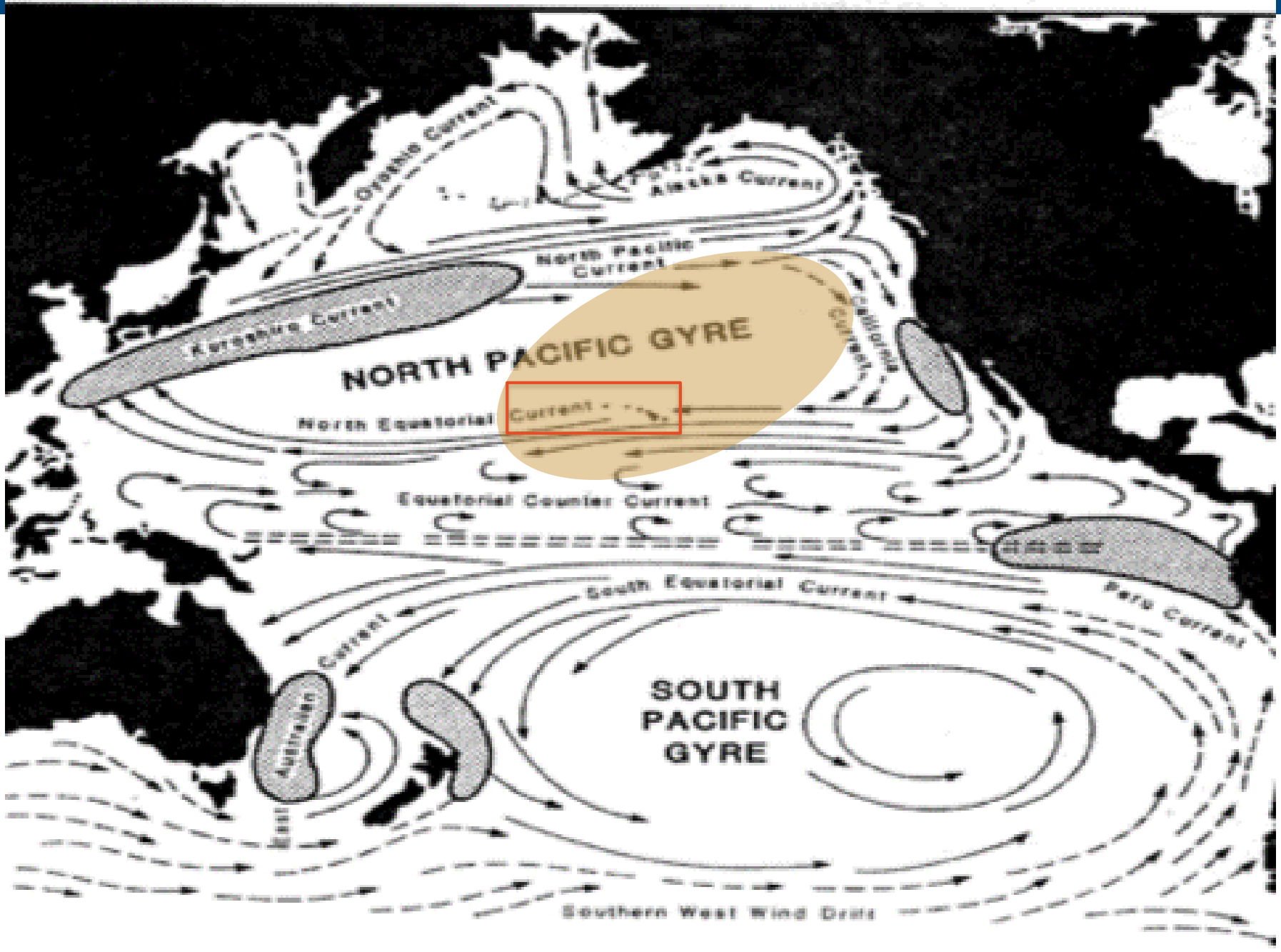
- U.S. fisheries for swordfish in the NPO accounted for 53% of the national harvest
- Longline fishery is the largest commercial fishery
- There are differences in effort, area fished, CPUE & size of fish between the shallow- & deep-set longline fisheries.
- Limited access fishery with a maximum number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

Japan DW&OS LL | TW DW LL | Other countries

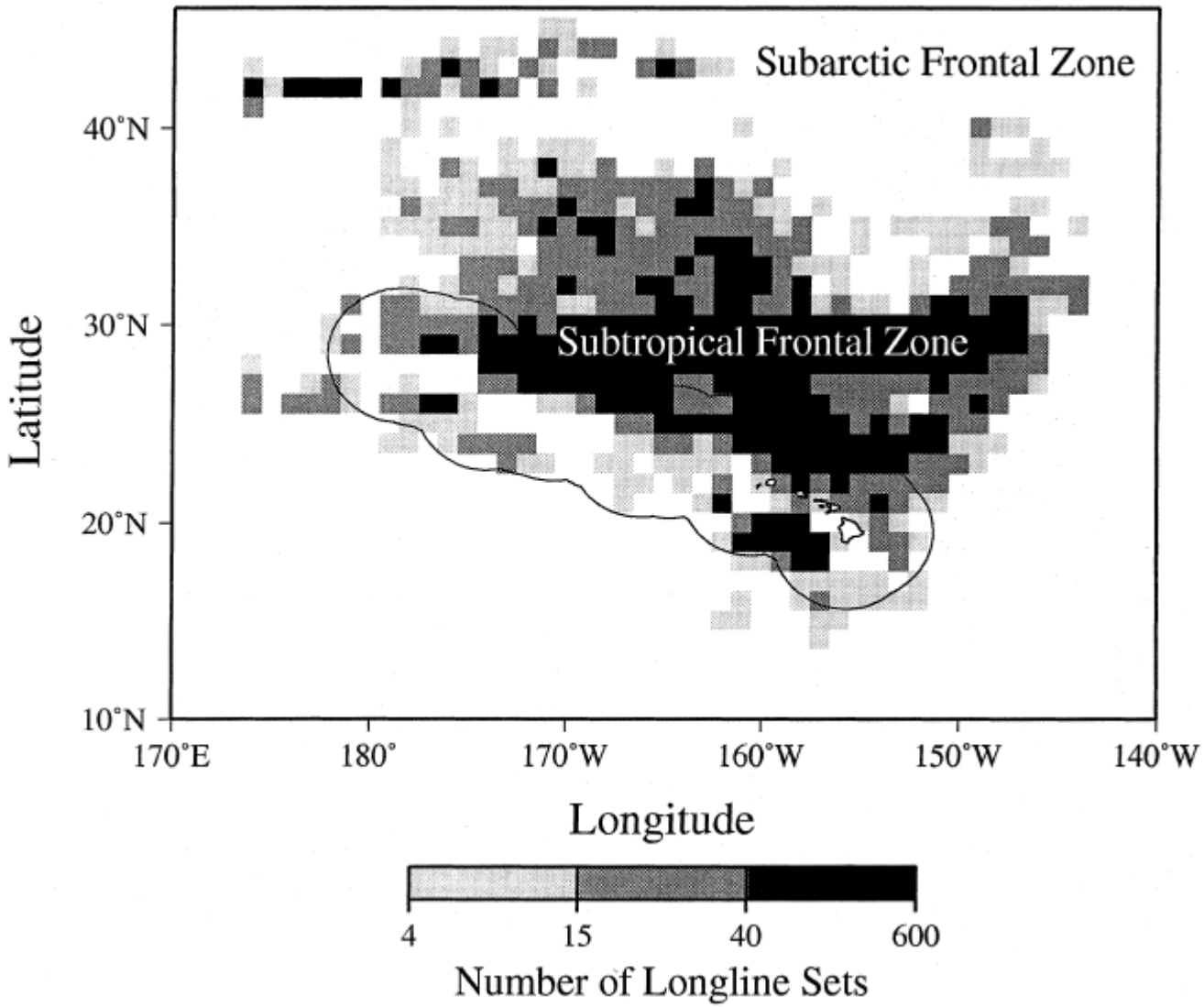
USA HW LL | KR LL | TW OS LL (STLL)



Main fishing areas


Oyashio Current
Alaska Current
North Pacific Current
Kuroshio Current
NORTH PACIFIC GYRE
California Current
North Equatorial Current
Equatorial Counter Current
South Equatorial Current
Peru Current
Australian Current
SOUTH PACIFIC GYRE
Southern West Wind Drift

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
  - ≥15 hooks per float
  - Catches small swordfish as bycatch
  - 3-10% observer coverage prior to 2004, 20% after 2004

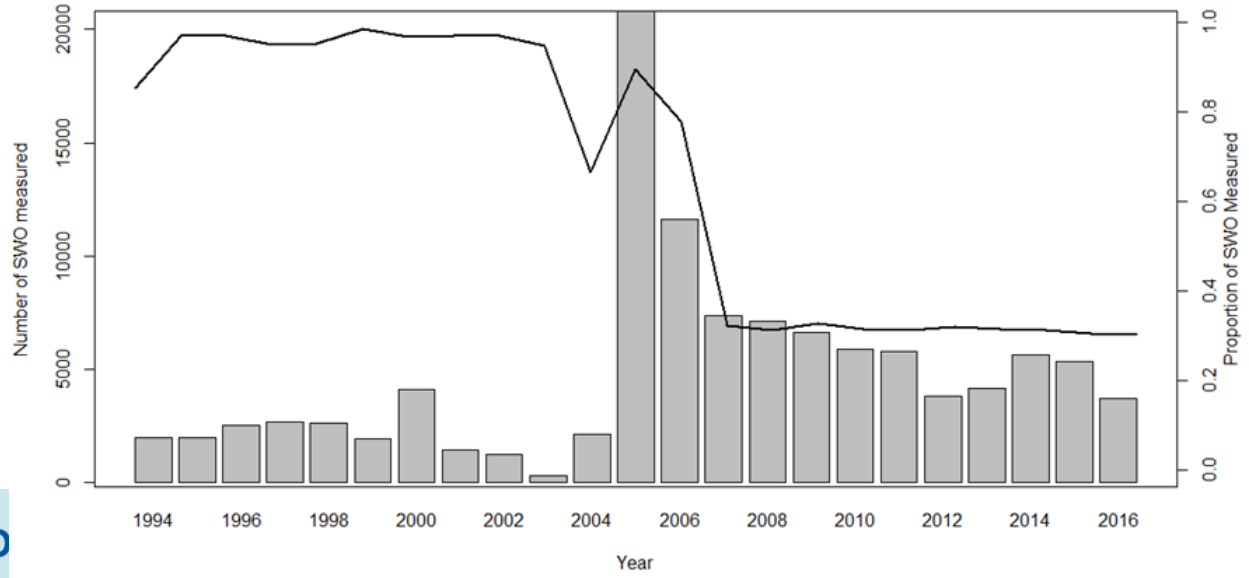
- Shallow Set:
  - Targets Swordfish
  - <15 hooks per float
  - Catches large swordfish
  - Fishery closed from 2001-2004
  - 100% observer coverage after 2004

Methods for standardizing and analyzing data

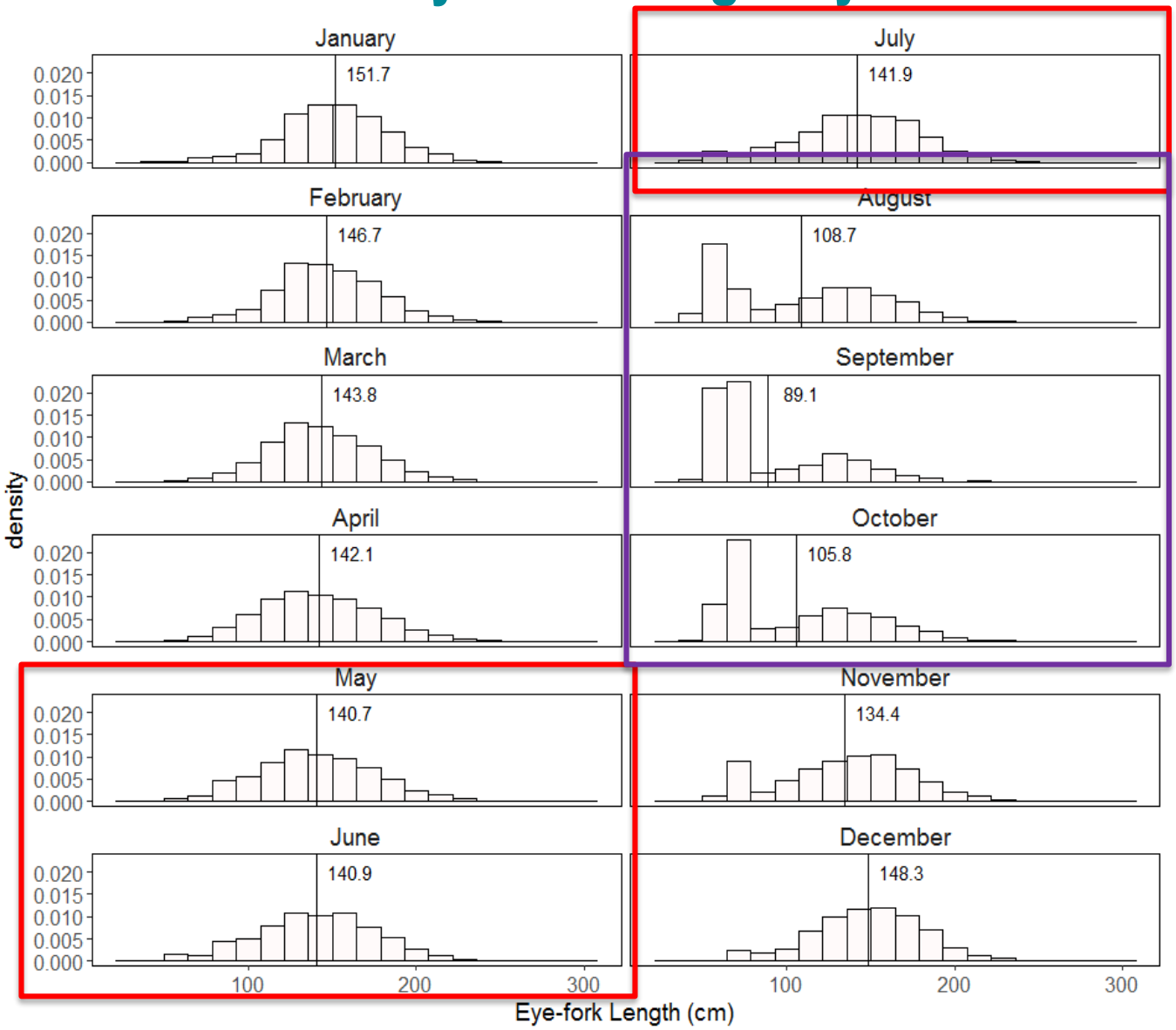
- GAM for Swordfish length data
  - Using spline smoothing function for continuous variables
  - Using Lat and Lon, Year, Cluster, Sex, MLD, SST, PDO, SOI as explanatory variables
- Delta-lognormal GLMM for Swordfish CPUE data
  - With vessel as a random effect
  - Using Lat, Year, Quarter, MLD, SST, 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)

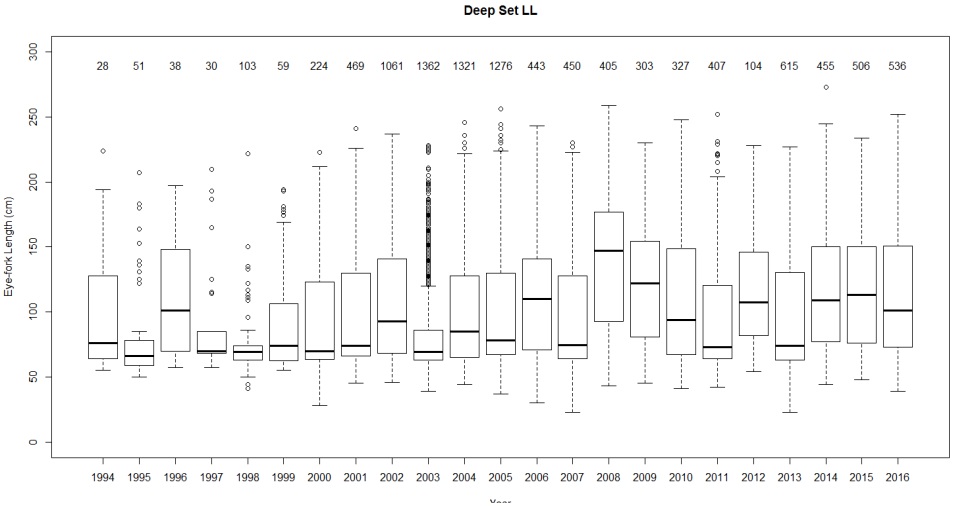
Length Frequency Analysis

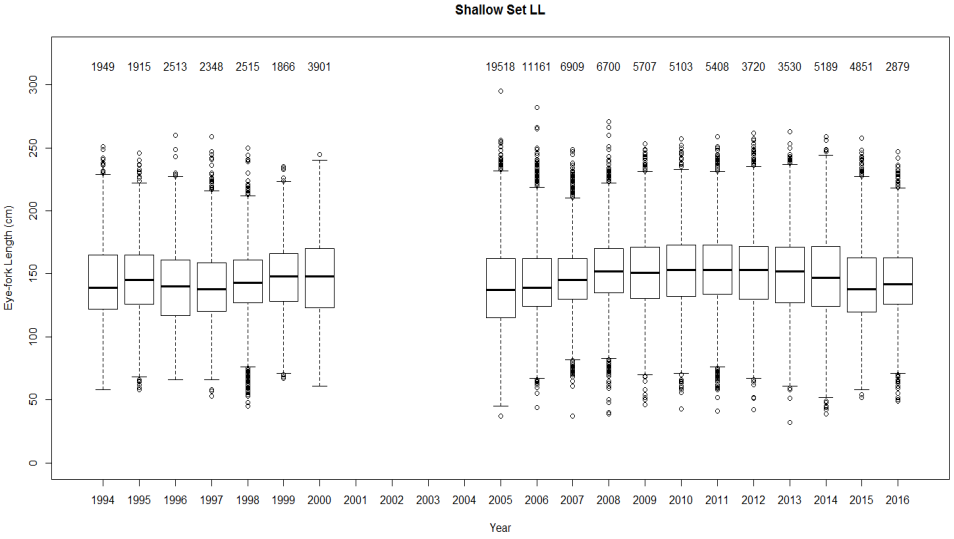
- GAM models for deep and shallow set sectors
- Deep set sector spatial distribution analyzed in two clusters:
  - May-July where larger fish are caught
  - August-April where small fish are caught
- Within each fishery sector:
  - Males vs Female spatial distribution
  - Juvenile vs Adult spatial distribution

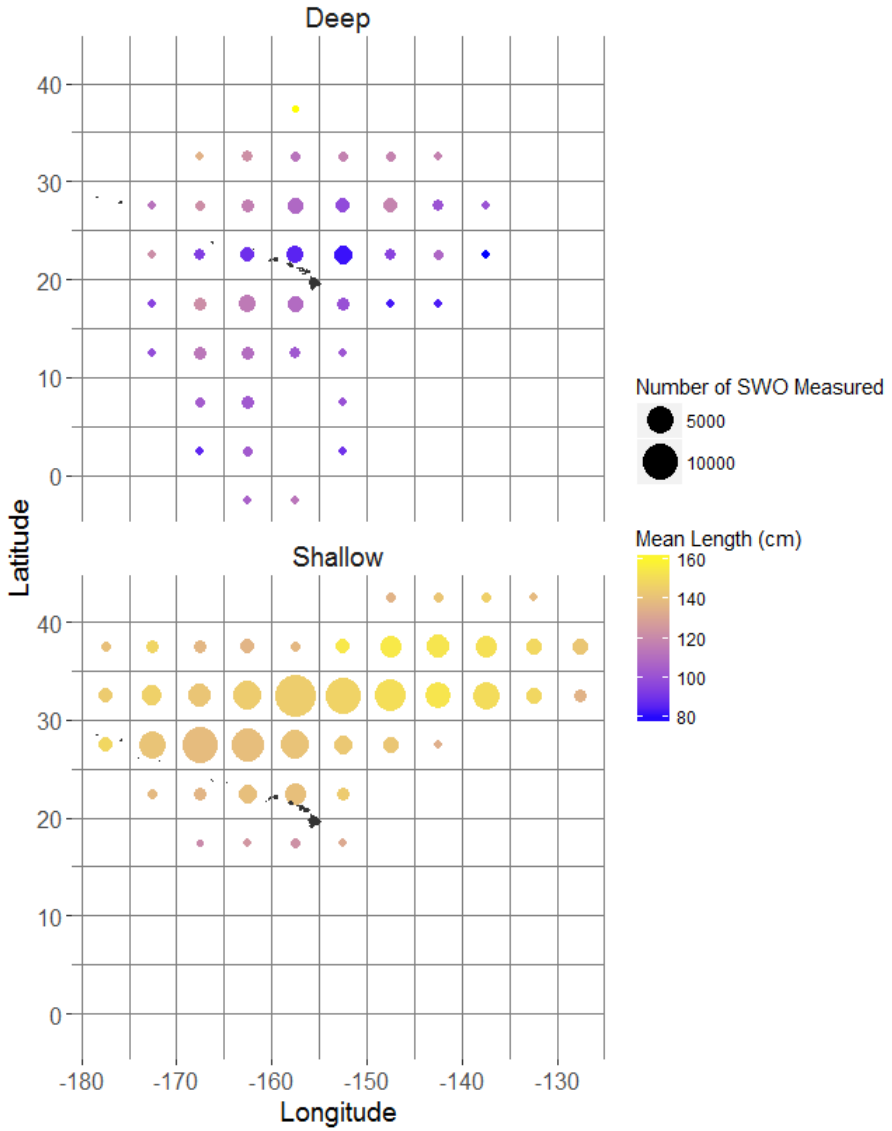


Swordfish Eye-fork Length by month



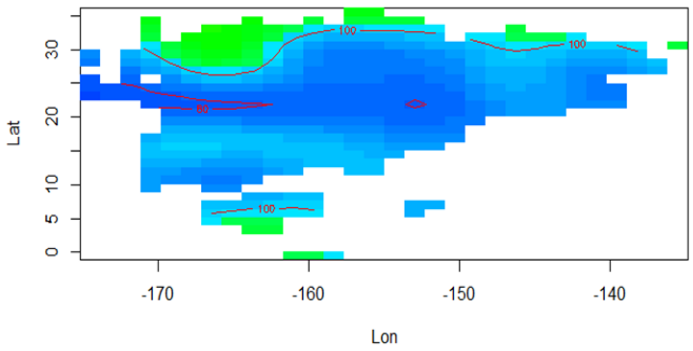

Deep Set LL
28 51 38 30 103 59 224 469 1061 1362 1321 1276 443 450 405 303 327 407 104 615 455 506 536
Eye-fork Length (cm)
0 50 100 150 200 250 300
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


Shallow Set LL
1949 1915 2513 2348 2515 1866 3901 19518 11161 6909 6700 5707 5103 5408 3720 3530 5189 4851 2879
Eye-fork Length (cm)
0 50 100 150 200 250 300
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Year

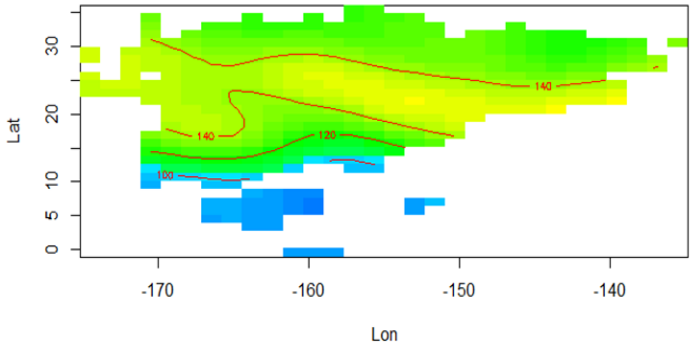

Deep
Shallow
Latitude
40 30 20 10 0
-180 -170 -160 -150 -140 -130
Longitude
Number of SWO Measured
5000
10000
Mean Length (cm)
160
140
120
100
80

Deep

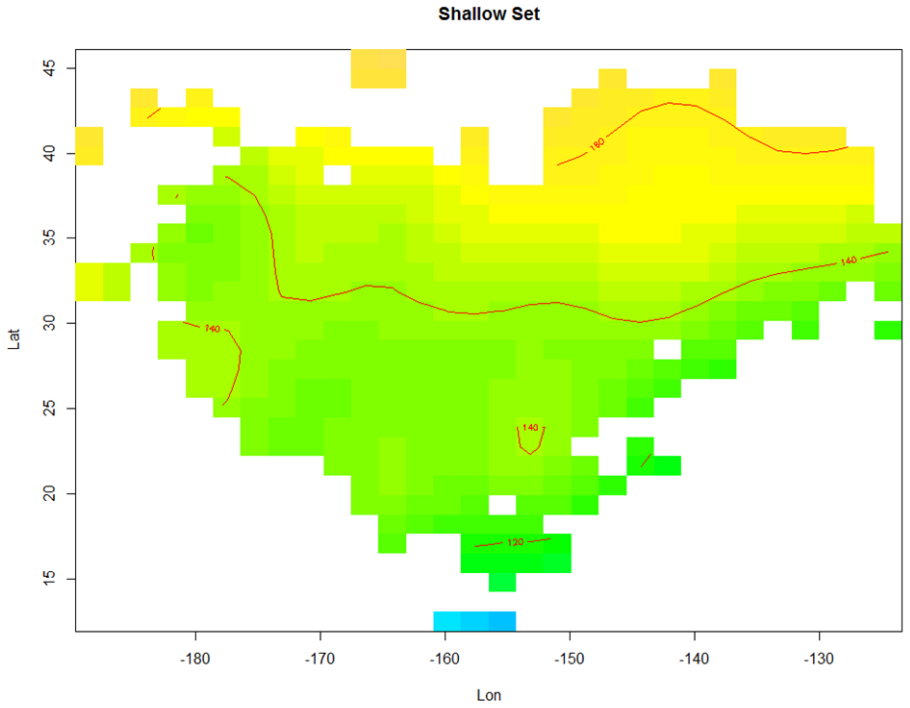
August-April



May-July

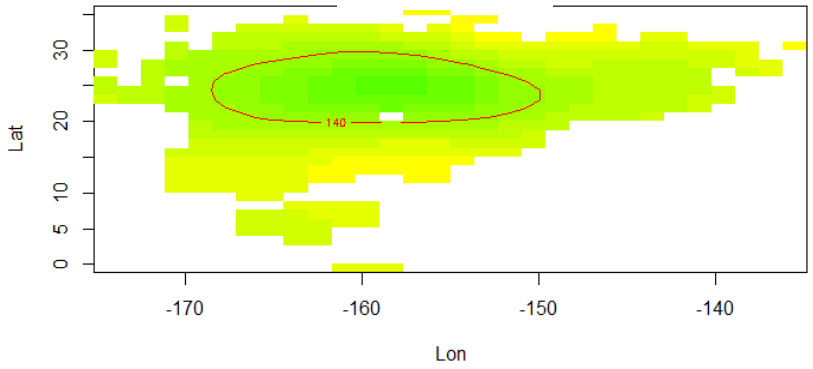


Shallow

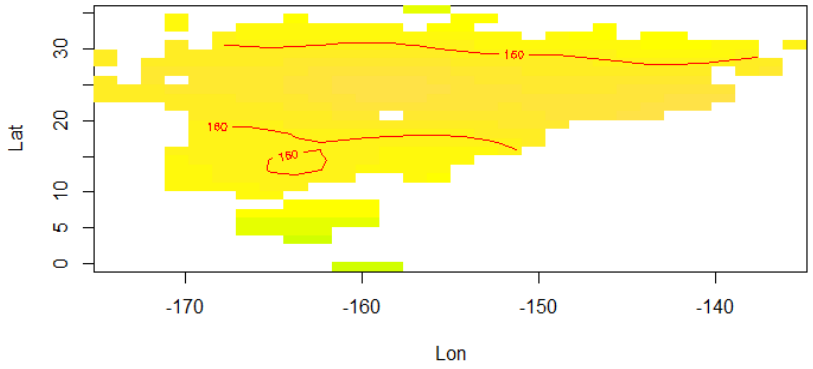


Adults

August-April

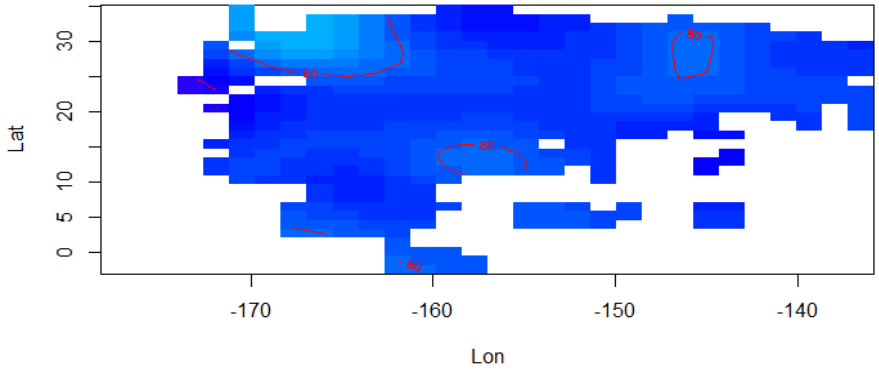


May-July

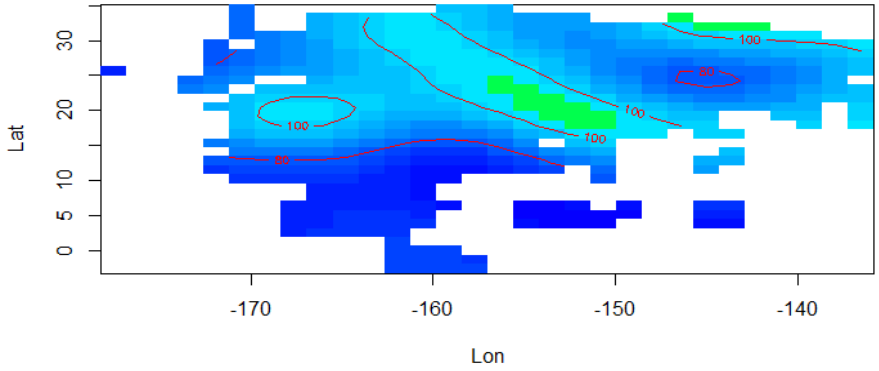


Juveniles

August-April

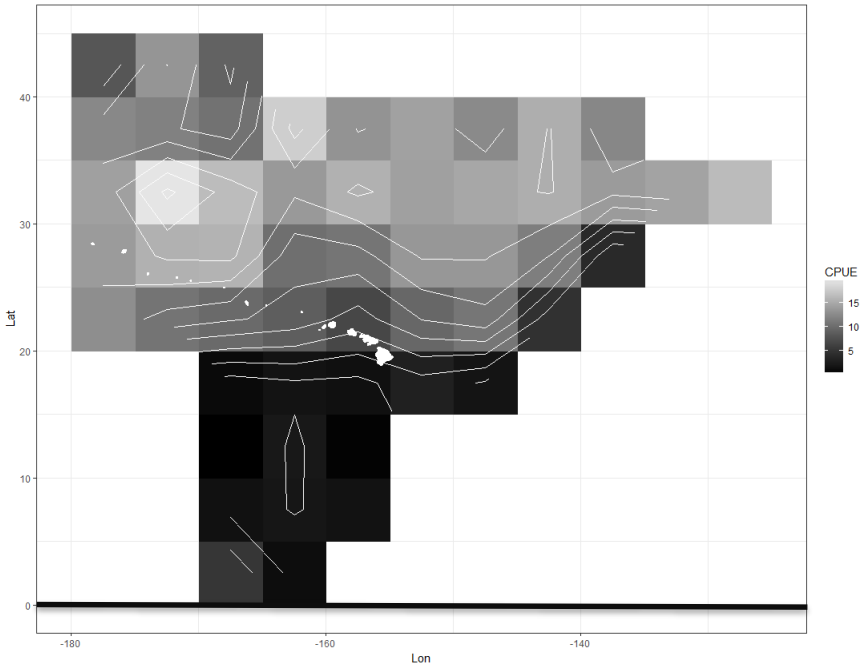


May-July

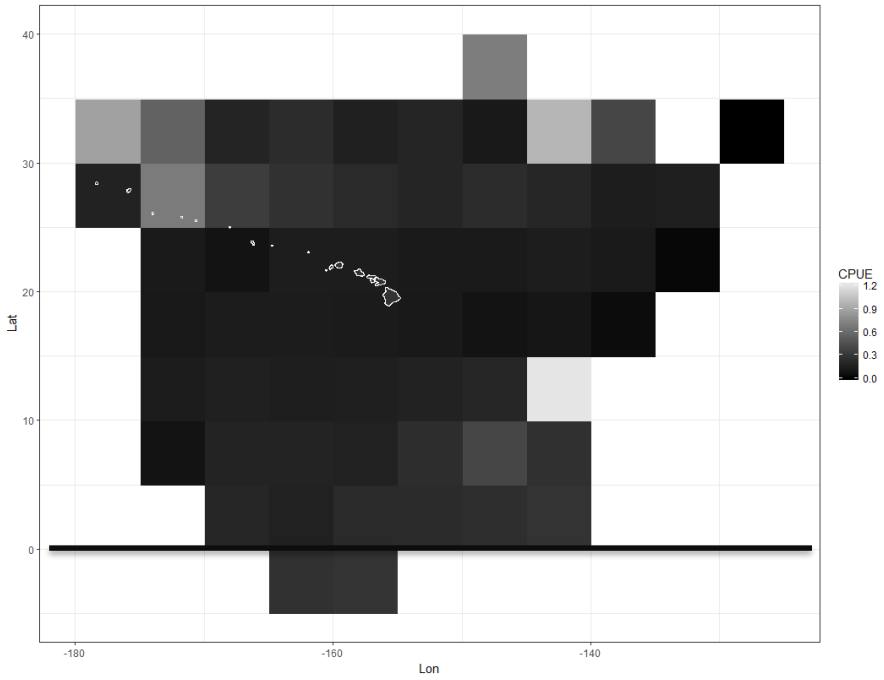


Length Composition Analysis

- 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



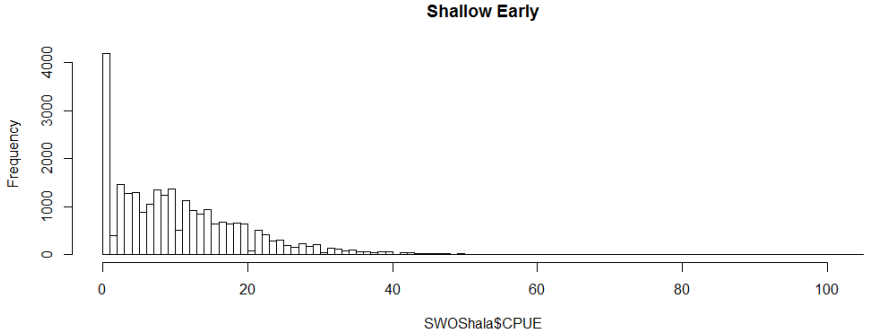
Nominal CPUE – Shallow set Fishery
1995-2000 and 2005-2016
Contours are indicate a CPUE change of 2

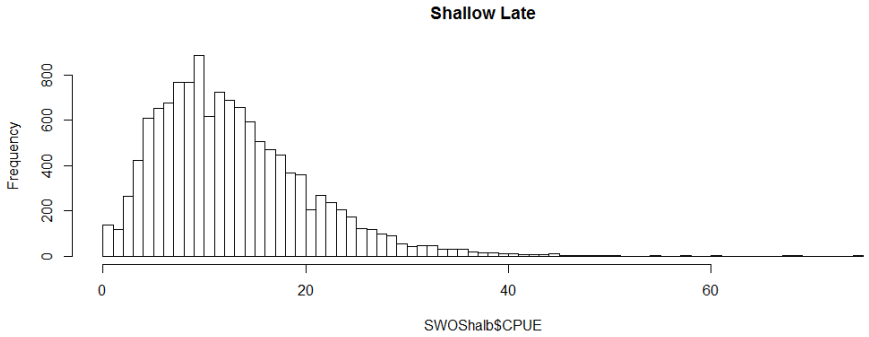


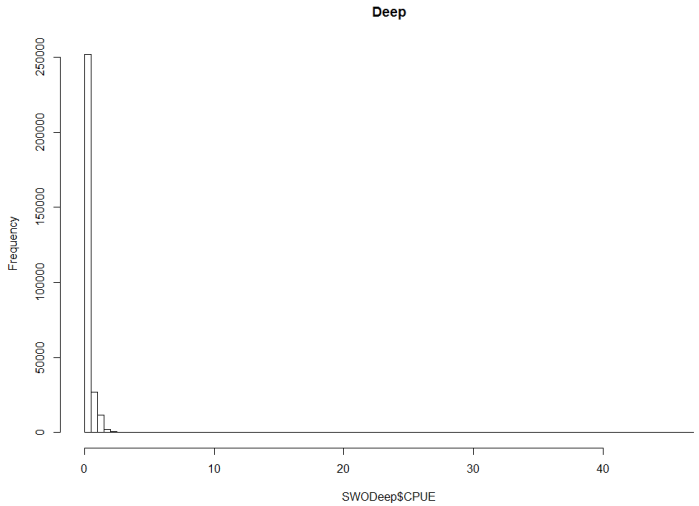
Nominal CPUE – Deep set Fishery
1995-2016

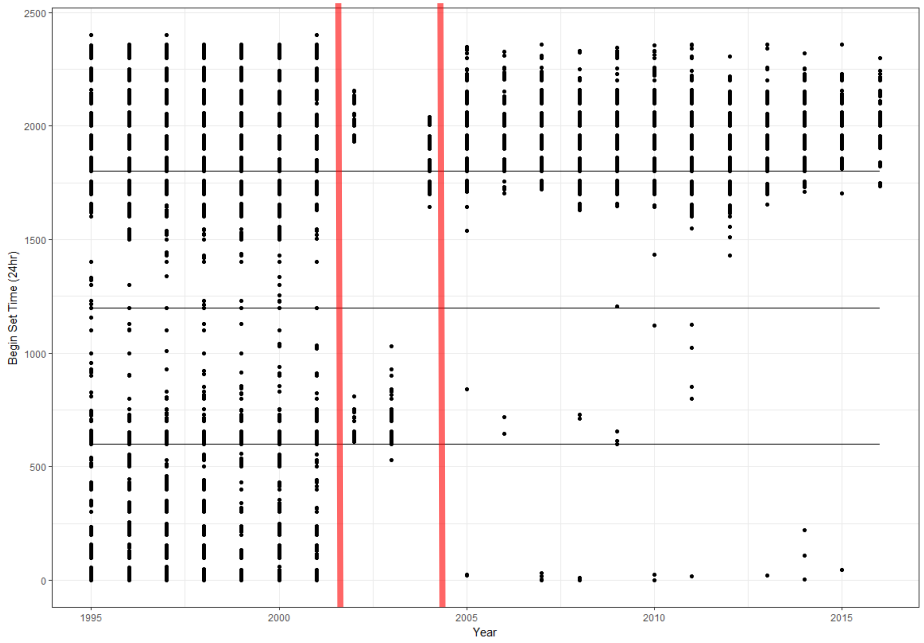
Incorporating Spatial Information to Standardized CPUE

- 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

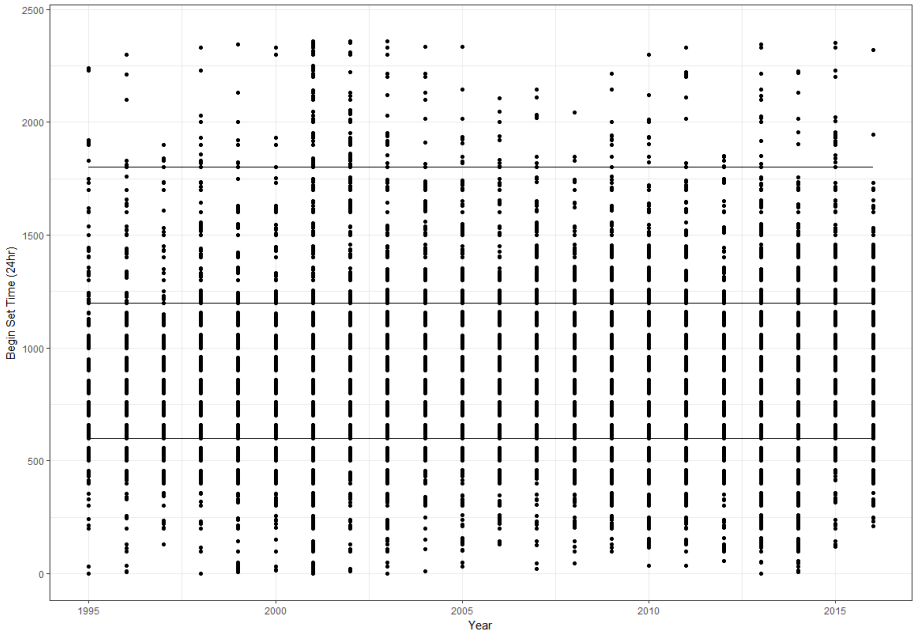






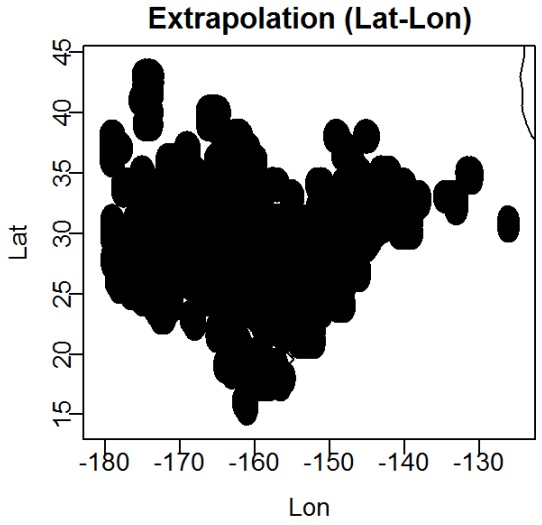


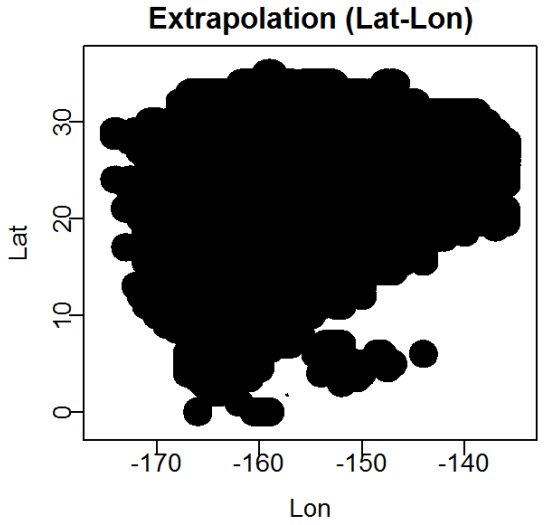
Shallow set Begin Set Time by Year

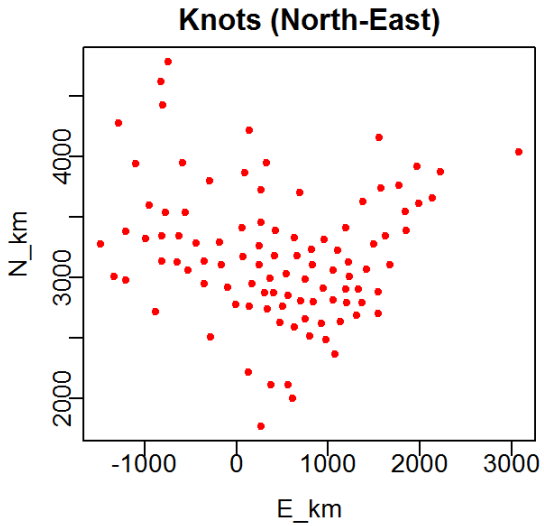


Deep set Begin Set Time by Year

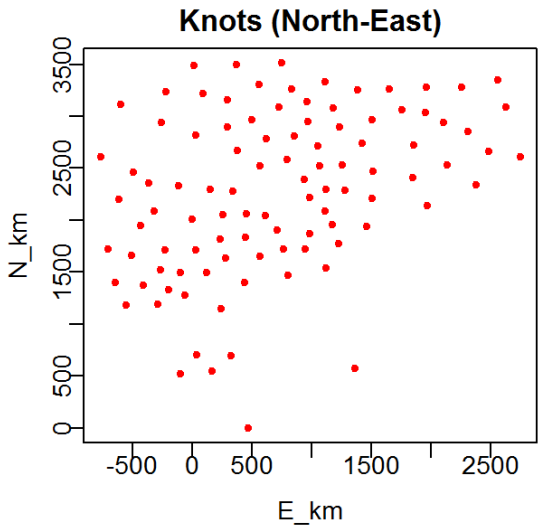
Exploring VAST with Swordfish CPUE data





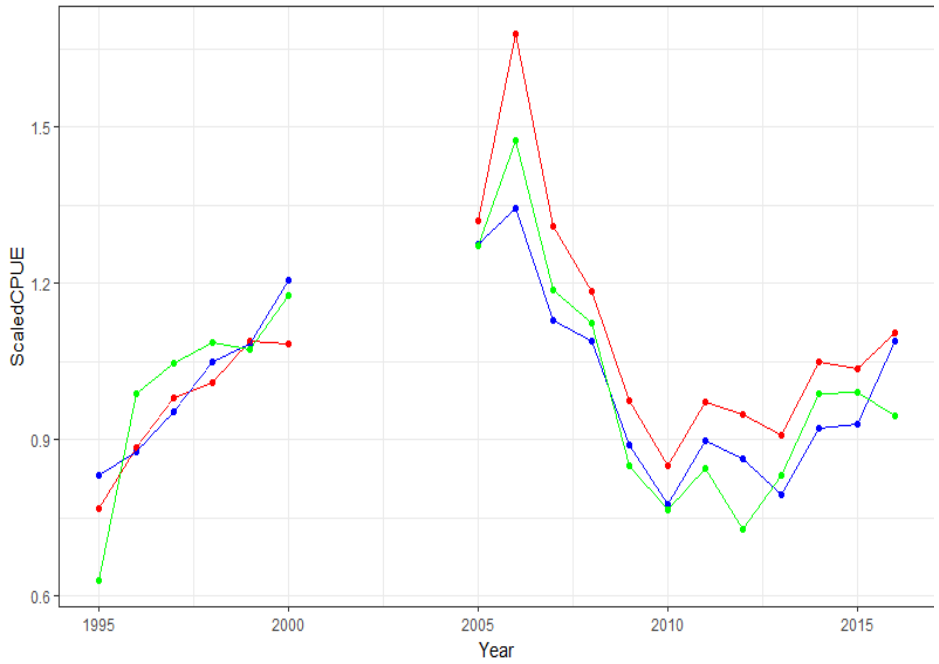


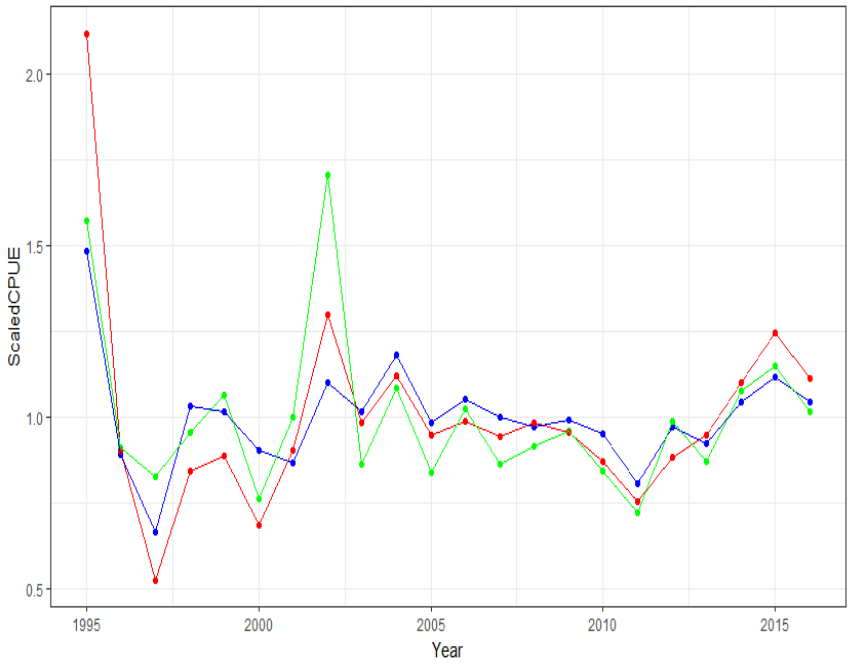
Shallow Set



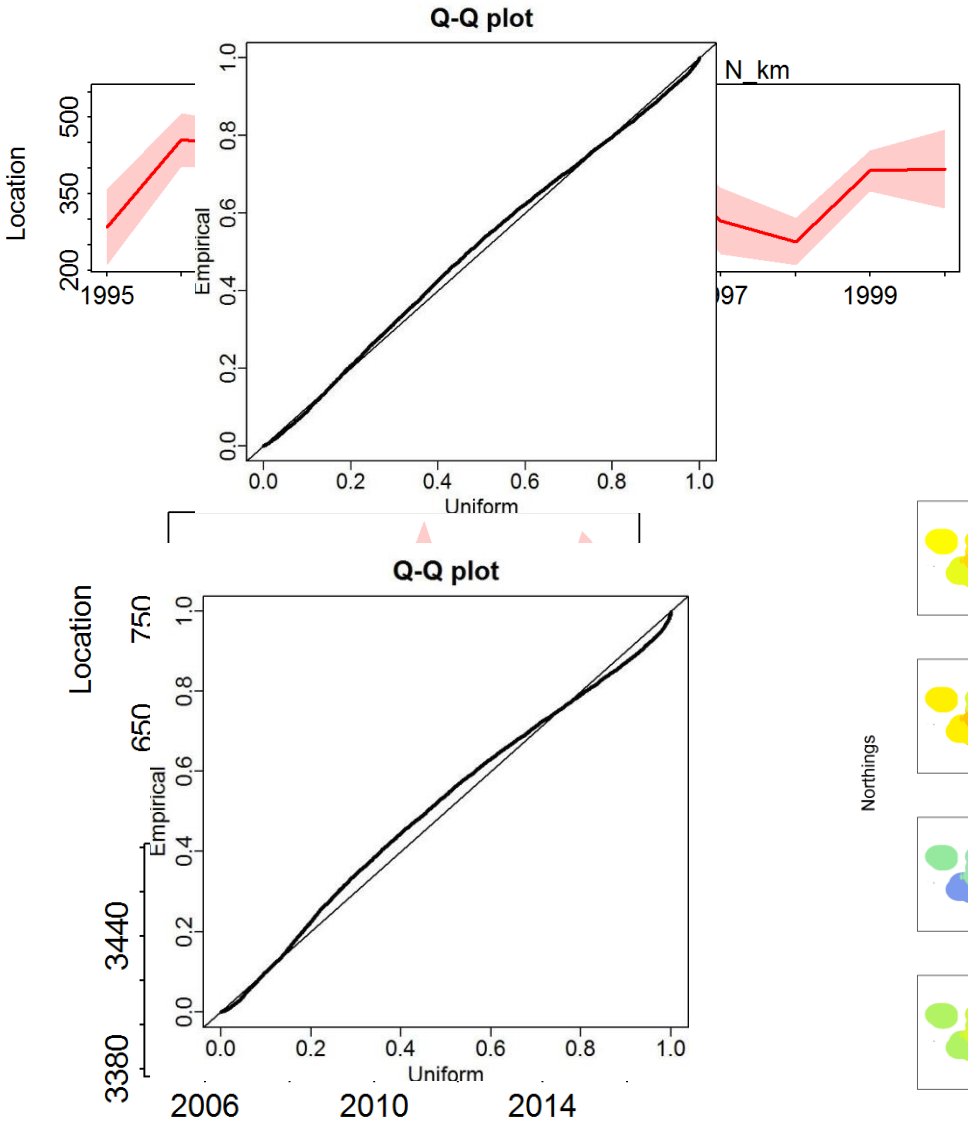
Deep Set

CPUE Comparison

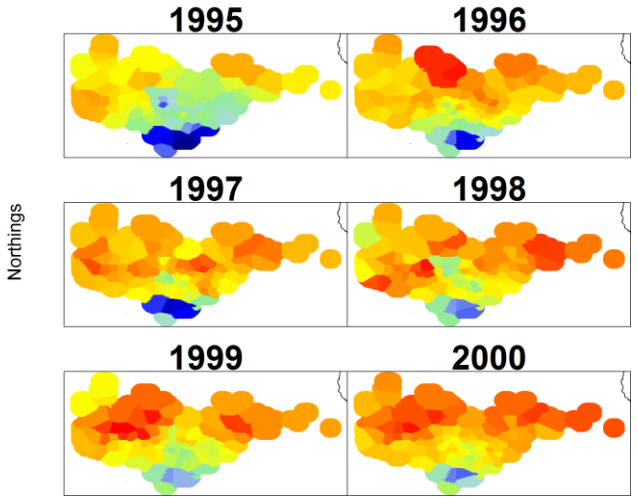


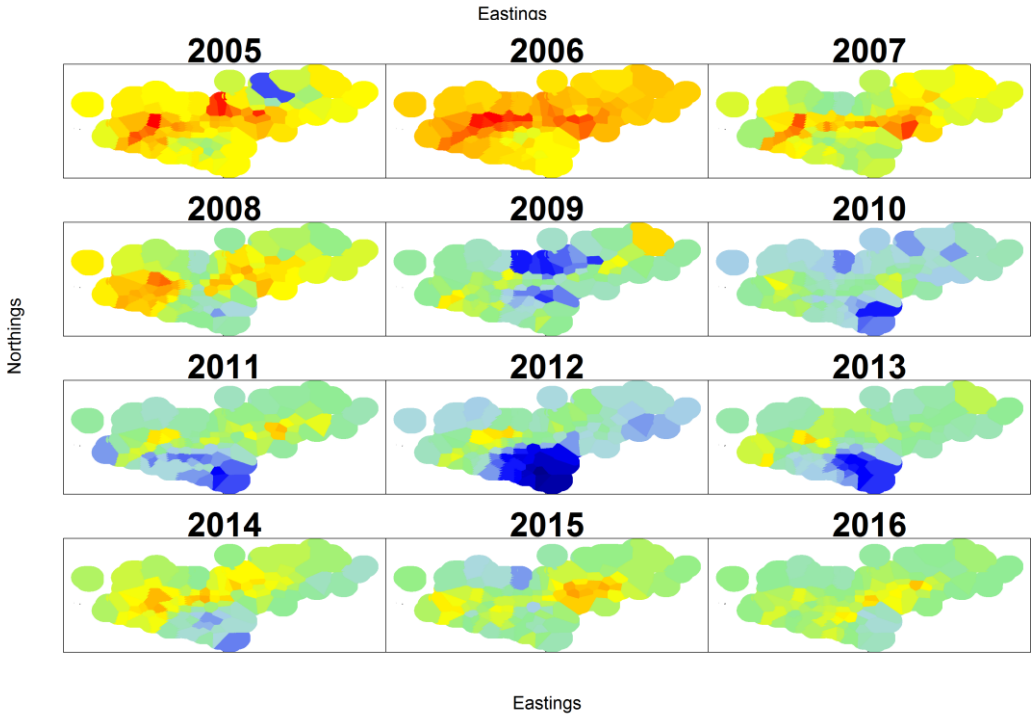


Shallow Set

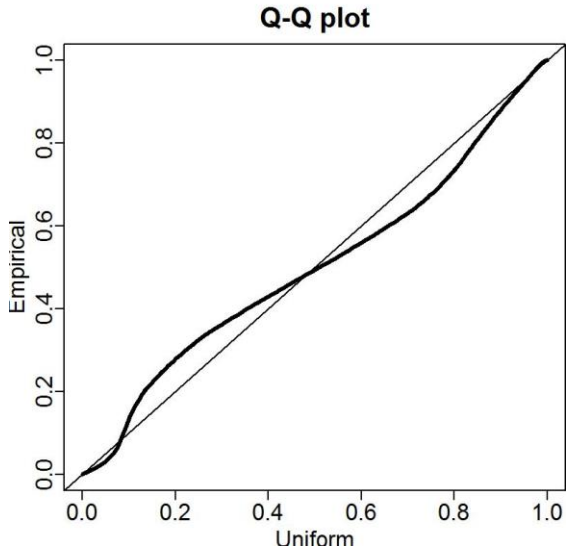

Q-Q plot
Location
N_km
Empirical
Uniform
200
350
500
1995
1999
0.0
0.2
0.4
0.6
0.8
1.0

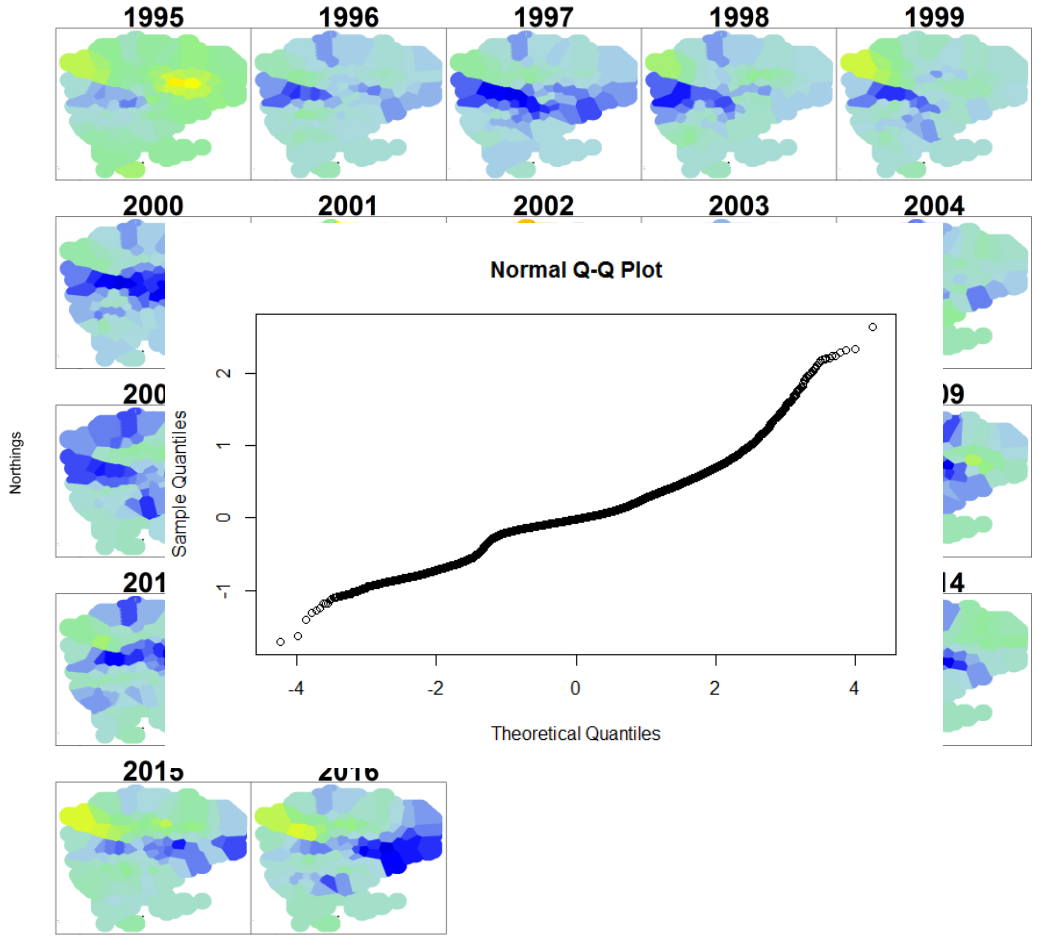
Q-Q plot
Location
Empirical
Uniform
3380
3440
650
750
2006
2010
2014
0.0
0.2
0.4
0.6
0.8
1.0

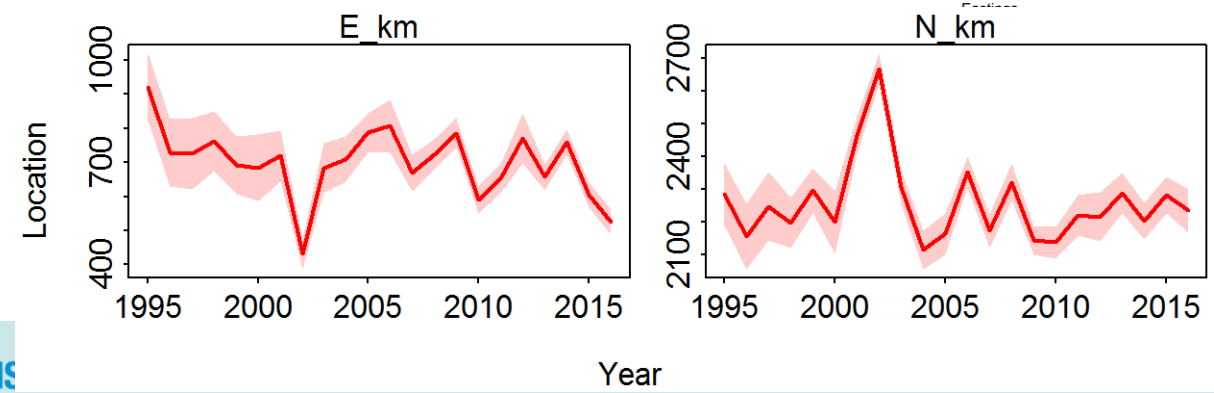

1995
1996
1997
1998
1999
2000
Northings


Eastings
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Northings
Eastings

Deep Set


Q-Q plot
Empirical
Uniform
0.0
0.2
0.4
0.6
0.8
1.0


1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Normal Q-Q Plot
Sample Quantiles
Theoretical Quantiles
Northings
-4
-2
0
2
4
-1
0
1
2


E_km
N_km
Location
Year
400
700
1000
2100
2400
2700
1995
2000
2005
2010
2015

Challenges to using VAST

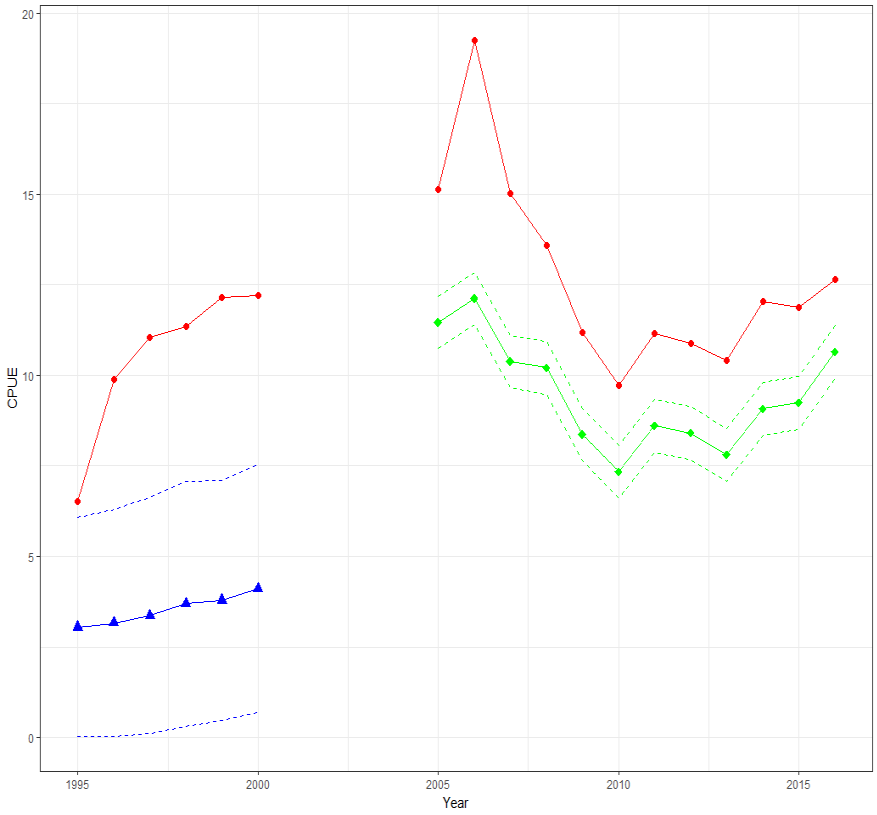
- Adding Covariates for Catchability
  - Operational Data, Lunar Illumination, etc.
- Adding Covariates for Density
  - Oceanographic features: SST, MLD, Frontal Energy
- Unbalanced sampling
  - >95% shallow set catch in Q1 and Q2
- Shallow Set Fishery
  - >99% Positive Encounters after 2005
- Shallow Set Fishery Closures

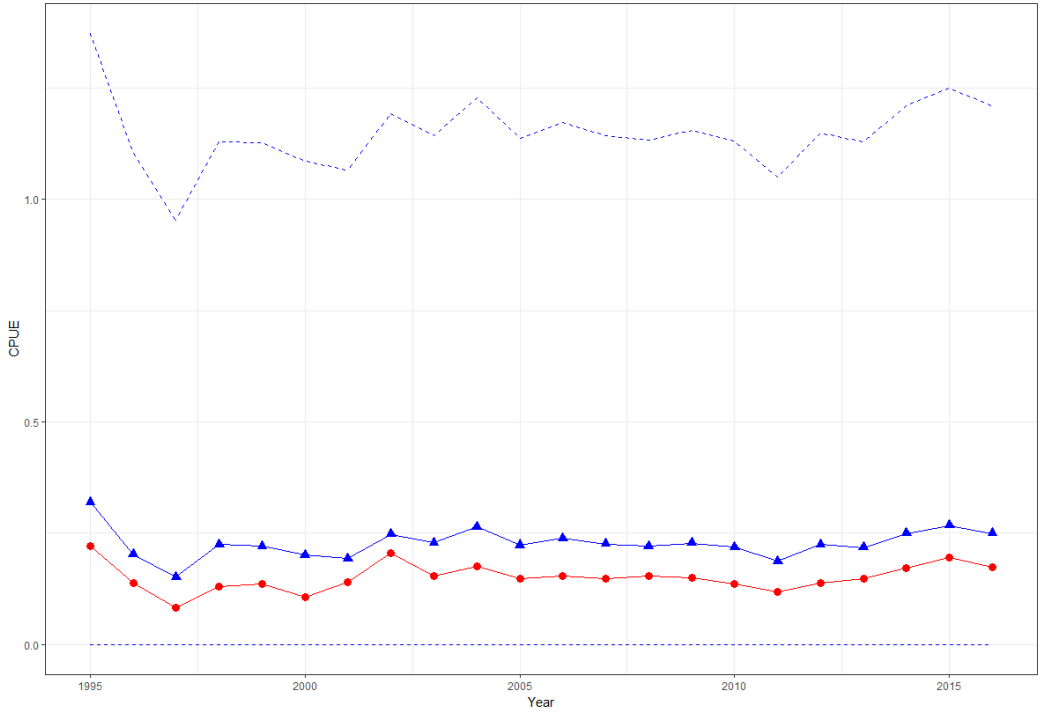
Future of VAST for swordfish?

- 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