

# California Scorpionfish 2017 Stock Assessment

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STAR Panel meeting July 24-28, 2017

## Background

## Catch

## Indices

## Composition

## Biological

## Model

## Uncertainty

## Appendix



## California scorpionfish (*Scorpaena guttata*)

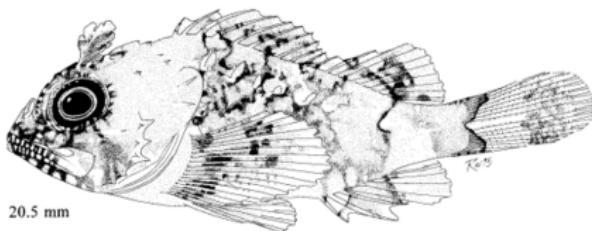
- Most common species of *Scorpaena* on the U.S. West Coast, more species in Mexico
- Venomous dorsal, anal and pelvic spines
- Demersal, found over both hard and soft bottom (anecdotal evidence suggests they prefer new structure)
- Exhibit aggregating behavior (spawning and non-spawning aggregations)



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## Early Life History

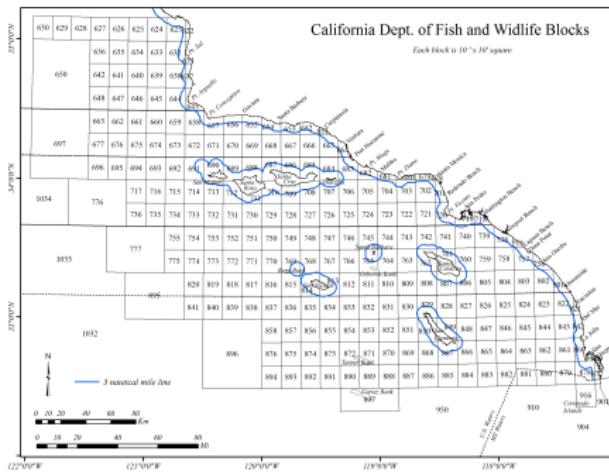
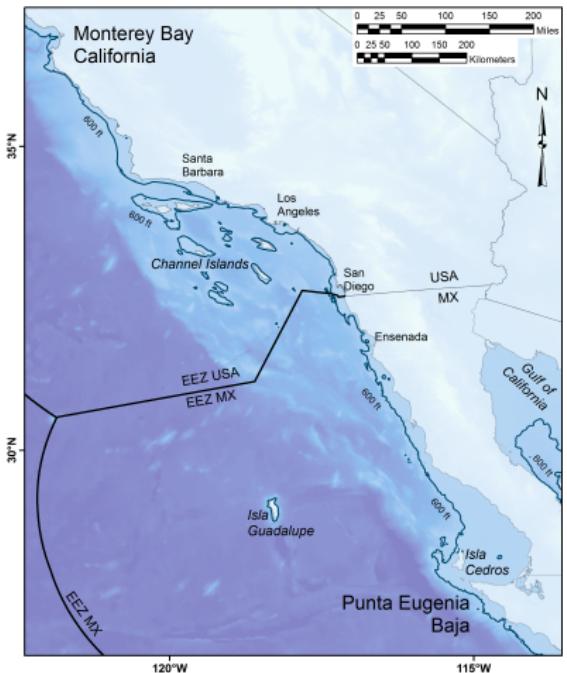
- Migration to spawning grounds, exhibit explosive breeding behavior just before dawn
- External fertilization, females produce hollow gelatinous single-layer floating egg matrix
- Eggs hatch after about 5 days
- Juveniles settle at less than 2 cm



# Distribution

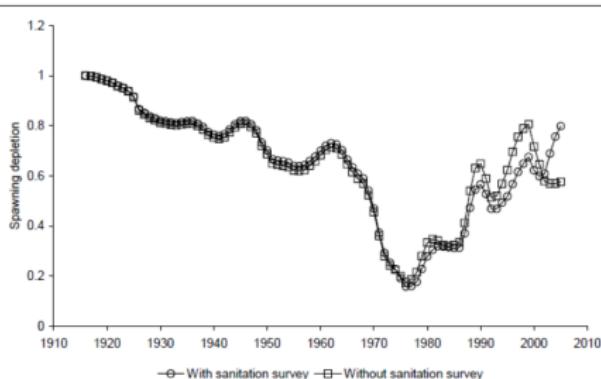
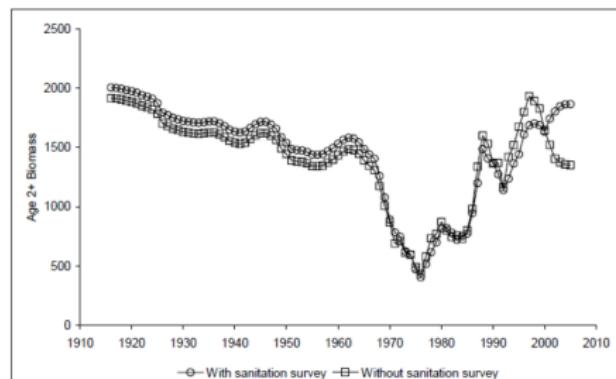
- Distributed from central California to Punta Eugenia, Baja California Sur, Mexico
- Rarely observed north of Pt. Conception
- Observed from the intertidal to 600 ft, prefer depths of 20-450 ft
- Proportion of the stock in Mexican waters unknown

# Distribution and Stock Assessment Boundary



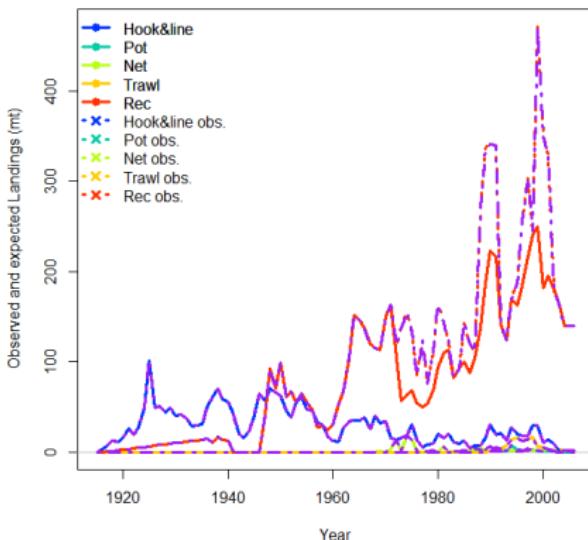
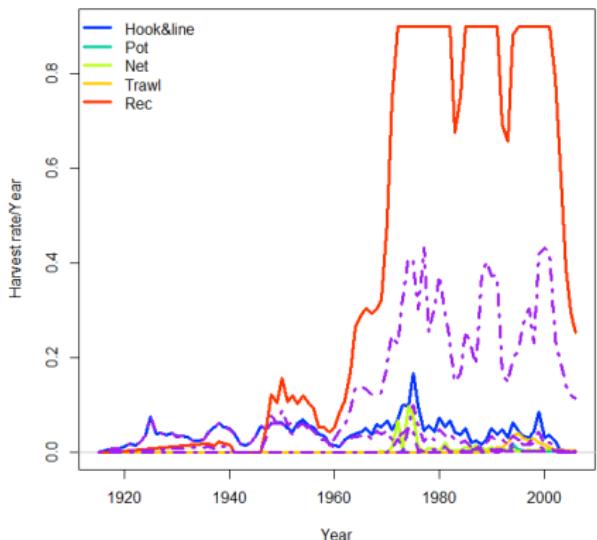
## 2005 Stock Assessment

- Stock first assessed in 2005
- South of Pt. Conception
- $M$  fixed at 0.25
- $h$  fixed at 0.7
- Publicly Owned Treatment Works (POTW) monitoring trawl survey was the axis of uncertainty in the 2005 assessment
  - POTW survey referred to as the Sanitation District Index in 2005



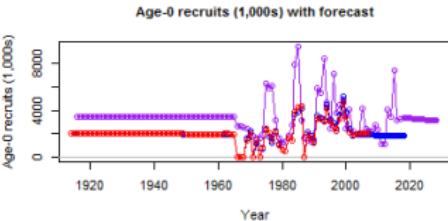
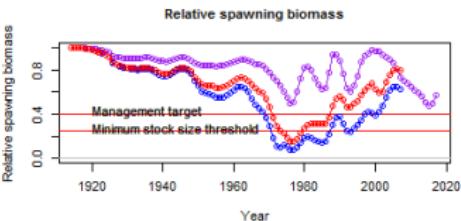
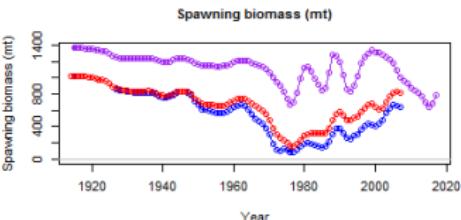
## 2005 Stock Assessment

- Transitioning from the 2005 assessment, an error was found
- Harvest rate hit the bounds for the recreational fleet
- Not all of the recreational catch was removed in the model
- Input vs. estimated catch was not standard output in SS v.1.8



# 2005 Stock Assessment

- 2005 assessment, SS v.1.8
- 2005 model in SS3.24z
- 2017 pre-STAR base model, SS3.30.0.05
- The two assessments have very similar trends over time, with  $B_0$  higher for the 2017 assessment that includes all removals



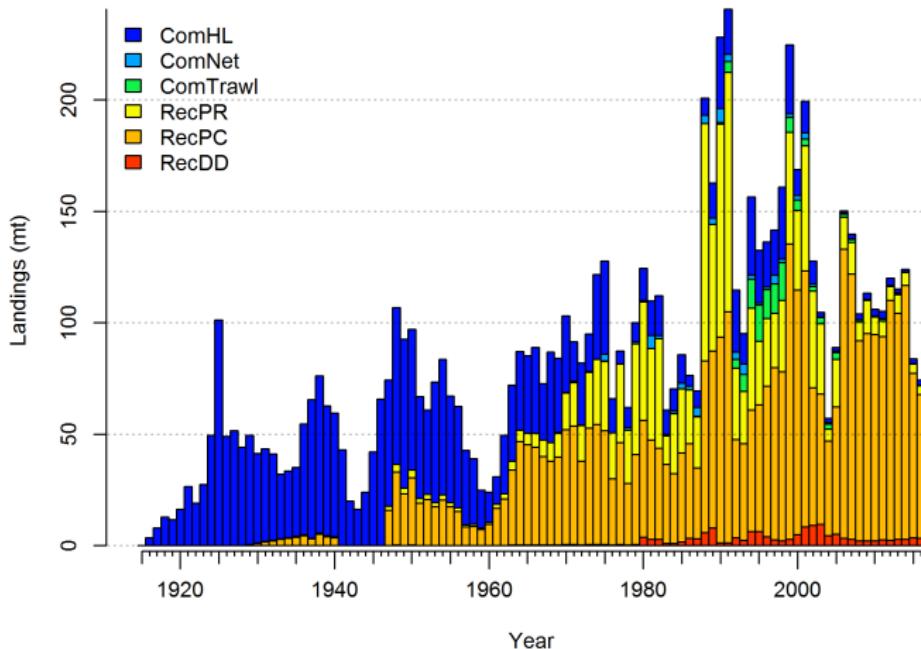
# 2017 Stock Assessment

## Pre-STAR Base Model

- One area south of Pt. Conception
  - Catches from Mexican waters excluded as in 2005
- Steepness fixed at 0.718
- Sex-specific  $M$  fixed for females, male  $M$  estimated as offset
- Re-evaluated fleet definitions
- Ages now available from the NWFSC trawl survey
- New indices and length compositions available
- Newest version of SS allows specification of the minimum sample size



# Catches by Fleet



# Regulations

## Recreational

- 2000** 10-in min. size limit, 3 hooks and 1 line
- 2001** 2 hooks and 1 line, Cowcod conservation area
- 2002** Various season length restrictions
- 2003** 20-30 fm depth restriction in 2003, otherwise post-2001 unrestricted or 50 or 60 fm, 5 fish bag limit

## Commercial

- 1999** 10-in min. size limit, Nearshore fishery permit with restricted access at 1100 permits
- 3003** Nearshore fishery permit with restricted access at 200 permits



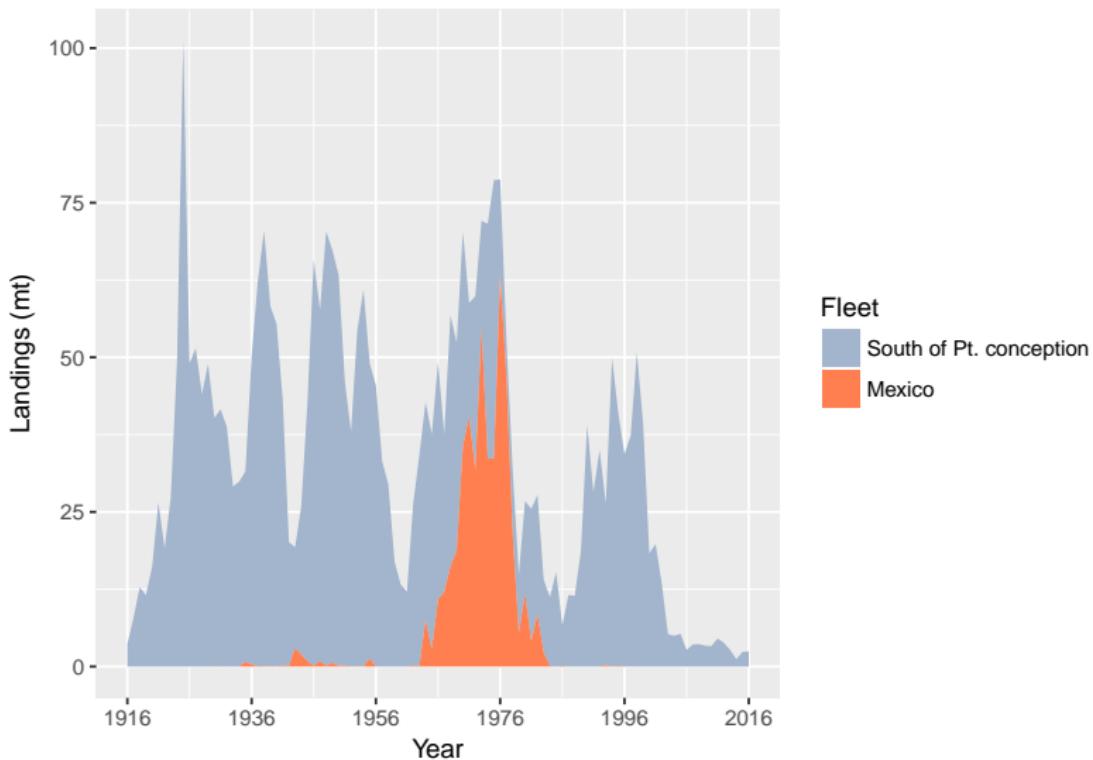
# Regulations - depth and closures

## Commercial (left) and Recreational (right)

Year	JAN-FEB	MAR-APR	MAY-JUN	JUL-AUG	SEP-OCT	NOV-DEC
1994						
1995						
1996						
1997					LE = 80,000 lb/month; OA = 40,000 lb/month	
1998						
1999						
2000	CLOSED					
2001	CLOSED					
2002	CLOSED					
2003	800	CLOSED	800	800	CLOSED	CLOSED
2004	300	CLOSED	300	400	400	300
2005	300	CLOSED	300	400	400	300
2006	300	CLOSED	300	400	400	300
2007	600	CLOSED	600	800	800	600
2008	600	CLOSED	600	800	800	600
2009	600	CLOSED	600	1,200	1,200	1,200
2010	600	CLOSED	600	1,200	1,200	1,200
2011	600	CLOSED	1,200	1,200	1,200	1,200
2012	1,200	CLOSED	1,200	1,200	1,200	1,200
2013	1,200	CLOSED	1,200	1,200	1,200	1,200
2014	1,200	CLOSED	1,200	1,200	1,200	1,200
2015	1,200	CLOSED	1,200	1,200	1,200	1,200
2016	1,200	CLOSED	1,200	1,200	1,200	1,200
2017	1,500	CLOSED	1,500	1,500	1,500	1,500

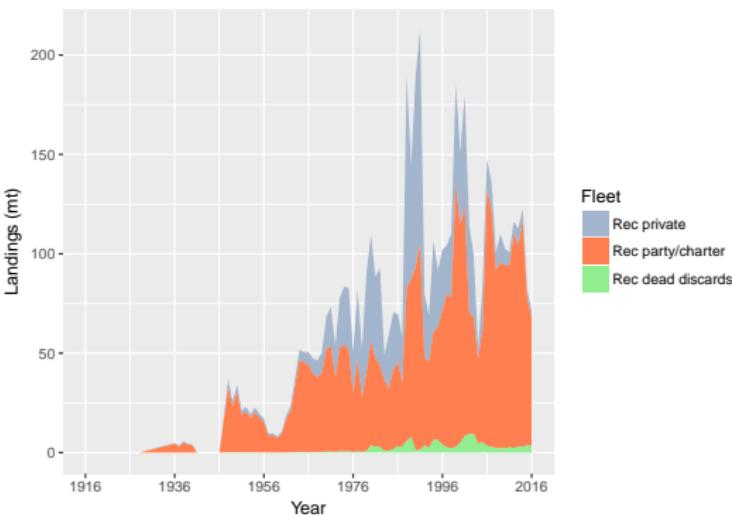
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1999	open											
2000	open											
2001	20	20	open	20	20							
2002			open	open	open	open	20	20	20	20		
2003	20	20					20	20	30	30	30	
2004			60	60							60	60
2005											30	60
2006			60	60	60	60	60	60	60	60	60	60
2007	40	40	60	60	60	60	60	60	60	60	60	60
2008	40	40	60	60	60	60	60	60	60	60	60	60
2009	40	40	60	60	60	60	60	60	60	60	60	60
2010	40	40	60	60	60	60	60	60	60	60	60	60
2011	60	60	60	60	60	60	60	60	60	60	60	60
2012	60	60	60	60	60	60	60	60	60	60	50	50
2013	50	50	50	50	50	50	50	50	50	50	50	50
2014	50	50	50	50	50	50	50	50	50	50	50	50
2015	60	60	60	60	60	60	60	60	50	50	50	50
2016	60	60	60	60	60	60	60	60	50	50	50	50*

# U.S. and Mexico Catch



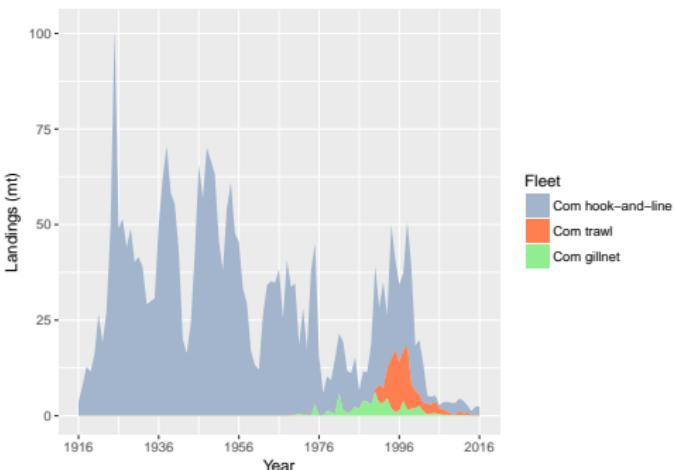
# Recreational Catch

- 2005 assessment used number of fish for recreational catches
- 2017 assessment includes one recreational discard fleet
  - Discard mortality rate of 7%
  - Discard biomass accounts for <3% of recreational mortality



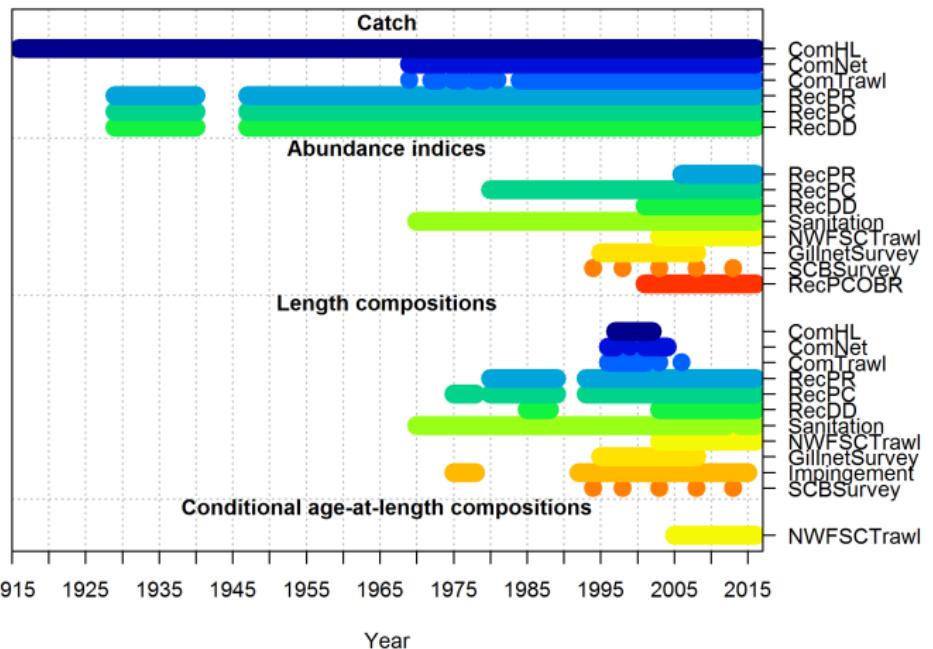
# Commercial Catch

- Historical catches same as the 2005 assessment
- California Fisheries Information System (CFIS) landings data used to update catches from 2005-2016
- Discards assumed negligible



# Indices of Abundance

Data by type and year



# Indices of Abundance

All of the methods used to standardize indices have been endorsed by the SSC

Name	Years	Fishery ind.	Method
Recreational PR dockside CPUE	2004-2016	No	delta-GLM (bin-lognormal)
CPFV logbook CPUE	1980-2016	No	negative binomial
Onboard observer discard catch CPUE	2002-2016	No	delta-GLM (bin-lognormal)
Sanitation district CPUE	1970-2016	Yes	delta-GLM (bin-lognormal)
NWFSC trawl survey CPUE	2003-2016	Yes	VAST
CSUN/VRG Gillnet survey CPUE	1995-2008	Yes	delta-GLM (bin-lognormal)
Southern California Bight trawl survey CPUE	'94, '98, '03, '08, '13	Yes	delta-GLM (bin-lognormal)
Onboard observer retained catch CPUE	2002-2016	No	delta-GLM (bin-lognormal)

# Indices of Abundance

## Delta-GLM Approach

- Approach used for all indices except the NWFSC trawl survey and the CPFV logbook
- Two-part model
  - Binomial fit to the presence-absence data
  - Lognormal or Gamma fit to positives
- General approach
  - Filter data to identify most appropriate samples
  - Model selection
    - Gamma or Lognormal for positives
    - Covariates for each of the two models chosen using AIC
  - Uncertainty for final model estimated via jackknifing

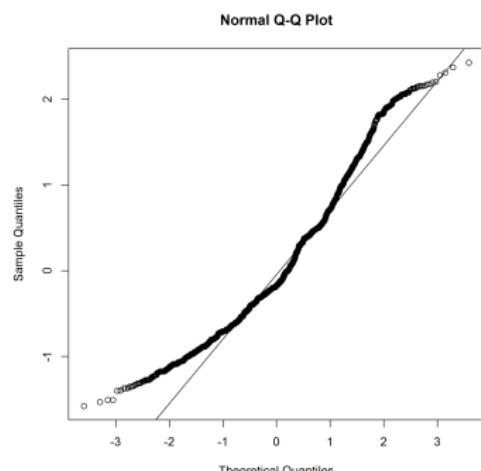


# Recreational Dockside Private Boat Index

**Sample:** California CRFS only; **Years:** 2006-2016; **Effort:** Angler days

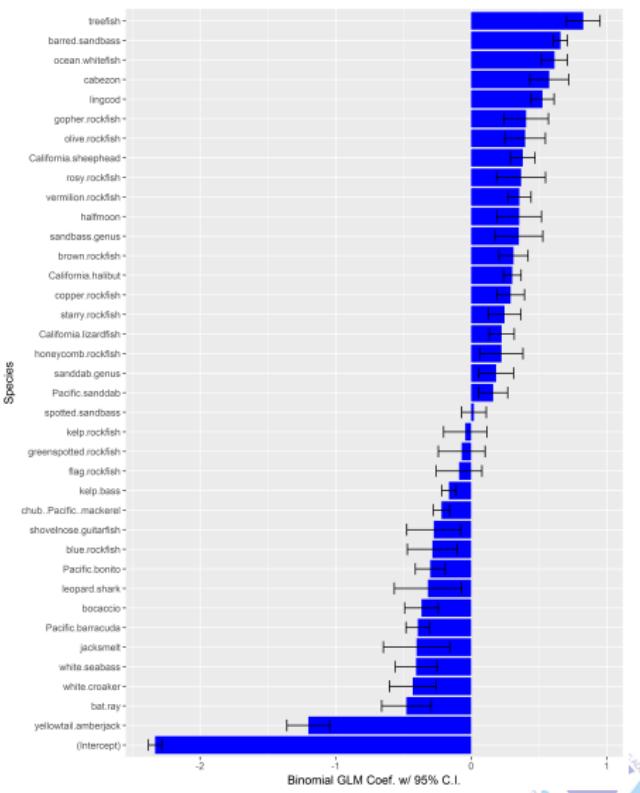
Filter	Criteria	Pos. Trips	Trips
Entire dataset		108,171	
General data filters	CRFS-PR1 survey only, Southern California only (sub_reg = 1), Hook and line gear only (geara = 'H'), Ocean only (Area_X = 1 or 2)	3,802	43,956
Region	Remove trips from Santa Barbara	3,757	42,956
Year	Remove 2004-2005; fishery closed majority of year	3,094	33,770
Closed fishery	Remove remaining trips when fishery closed	3,056	32,236
Rare and co-occurring species	Remove trips with yellowfin tuna and dolphinfish and species present in <1% of all trips and in at least 5 years of data	3,056	30,033
Stephens-MacCall	Retain all positive trips, plus "False Positives" (trips predicted to be in California scorpionfish habitat, but with no California scorpionfish retained)	3,056	<b>8,590</b>

Model	Binomial	Lognormal
Year	6182	8103
Year + County	5862	8003
Year + Wave	6091	8092
Year + County + Wave	<b>5792</b>	<b>8000</b>



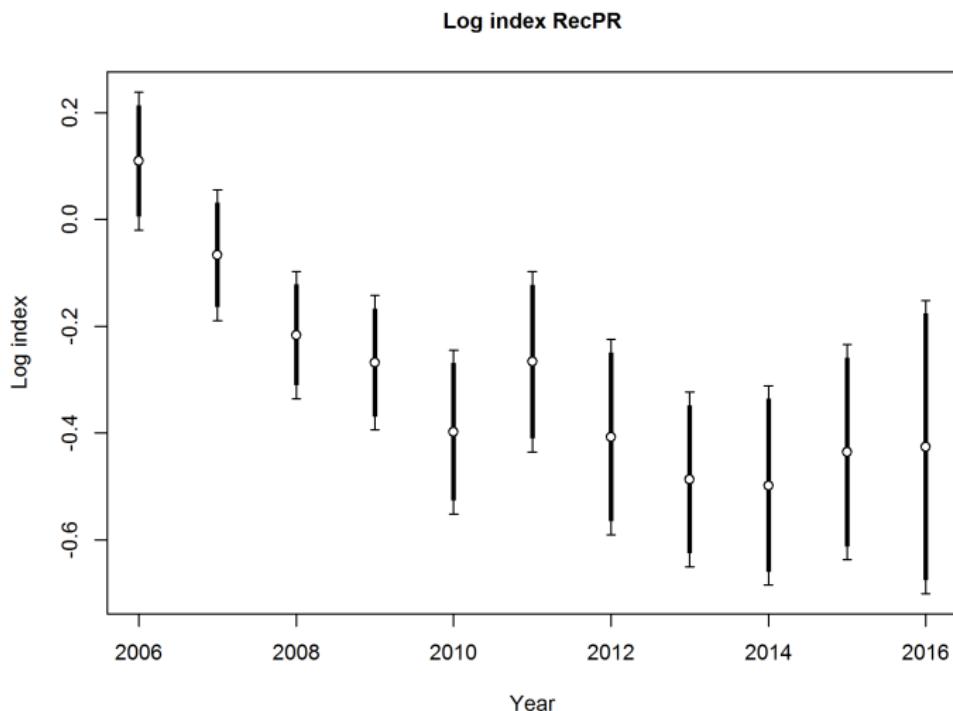
# Recreational Dockside Private Boat Index

- Positive indicators: treefish, barred sandbass, ocean whitefish, cabezon
- Negative indicators: yellowtail amberjack, bat rays, white croaker, white seabass
- Similar indicator species as in the MRFSS party/charter analysis



# Recreational Dockside Private Boat Index

## Results



# Recreational CPFV Logbook Index

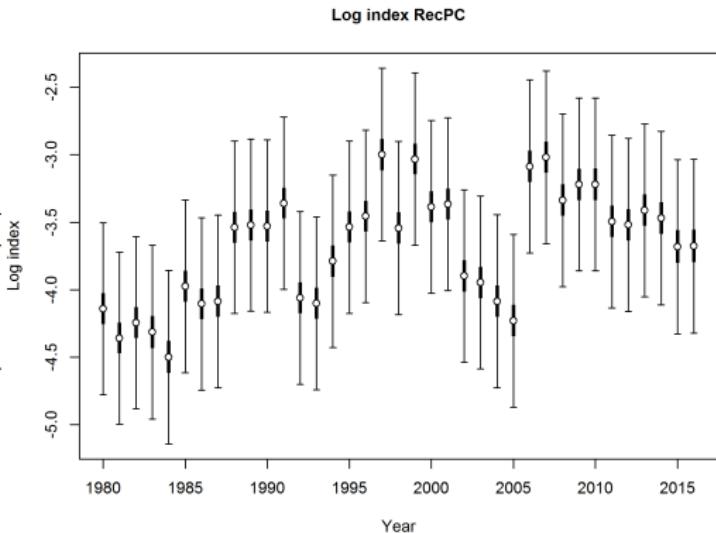
**Sample:** Captain-reported catch; **Years:** 1980-2016; **Effort:** Angler hours

Filter	Criteria	Trips
All CA data	No filter	1,164,662
Gear	Remove trips reported as diving, mooching or trolling	959,740
Effort or missing data	Remove trips with missing effort or species information	930,233
Year	Remove 2017, remaining years 1980-2016	929,781
Region	Remove trips north of Pt. Conception and in Mexico	568,222
Fish encountered	Remove trips reporting number of retained fish greater than in the 99% quantile (>325 fish)	564,433
Target species	Remove trips targeting sharks, striped bass, sturgeon, tuna, misc. bay, and potluck	558,872
Single-species trips	Filter trips reporting catches of only species and that one species in <100 trips	558,833
Offshore trips	Remove trips catching yellowtail, tunas, and dolphinfish that were not designated as offshore trips	475,492
Vessel	Remove trips by vessels that had fewer than 10 trips catching scorpionfish	466,023
Anglers	Remove trips with number of anglers < the 1% and > the 99% quantile (retain 5-75 anglers)	452,938
Depth	Remove trips in blocks with a minimum depth of >140m	443,929
Scorpionfish targets	Blocks with at least 100 scorpionfish trips	433,248
Sample size	Blocks with at least 500 trips	<b>432,868</b>

# Recreational CPFV Logbook Index

## Results

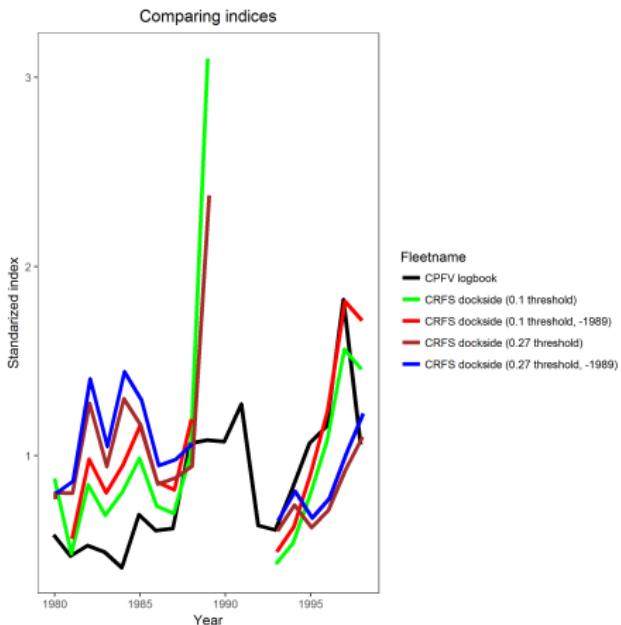
Model	Negative Binomial
Year	1918470
Year+ Month	1901592
Year + Block	1872224
Year+ Month + Block	<b>1854652</b>



# Recreational Dockside Party/Charter Boat Index

**Sample:** California MRFSS ; **Years:** 1980-2003; **Effort:** Angler hours

- *Index not used in the assessment*
- No MRFSS sampling from 1990-1992
- Index sensitive to Stephens-MacCall threshold
- Dockside index estimate for 1989 is high and anomalous
- Data redundant with the CPFV logbook index
- 1989 estimate lower if a higher threshold is used



# Recreational Onboard Indices

**Sample:** Drift-level catch **Years:** 1999-2016 **Effort:** Angler hours

- Drift-level catch data collection onboard CPFVs
- Alpha hull method used to select suitable habitat for California scorpionfish
- Assume that suitable habitat is the same for discarded and retained fish

Filter	Criteria	Pos. trips	Trips
Initial SQL filtering		6,475	59,192
Habitat filter	Remove drifts >1000 m of alpha hull buffer, remove "reefs" with <0 drifts or 5% positives, or in CCA	6,365	30,987
Exclude 1999 and 2000	Management changes (depth and gear restrictions)	5,986	29,577
Depth	Remove upper and lower 1% of data (retain 26-330ft)	5,921	29,002
Minutes Fished	Remove upper and lower 1% of data (retain 4 - 155 minutes)	5,780	28,460
Observed Anglers	Remove upper and lower 1% of data (retain 4 - 15 anglers)	5,679	27,946
Boats	Include boats encountering scorpionfish in at least 3 years; at least 30 drifts and 10 with scorpionfish	5,509	26,805
Second depth filter	Remove anything >100 m after looking at 20 m depth bins	5,507	<b>26,733</b>

# Recreational Onboard Indices

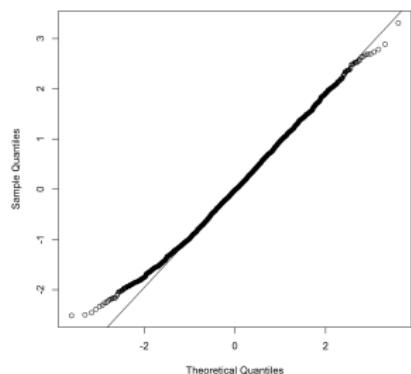
## Discarded Catch

Model	Binomial	Lognormal
Year	19619	9177
Year + Reef	18677	9177
Year + Depth	19374	8860
Year + Depth + Reef	18392	8778
Year + Month + Reef + Depth	<b>18318</b>	<b>8769</b>

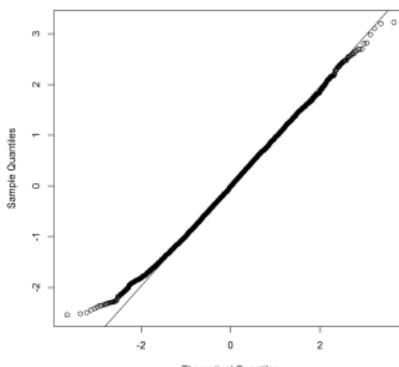
## Retained Catch

Model	Binomial	Lognormal
Year	21826	11507
Year + Reef	21192	11325
Year + Depth	21265	10704
Year + Depth + Reef	20691	10619
Year + Month + Reef + Depth	<b>20453</b>	<b>10599</b>

Normal Q-Q Plot

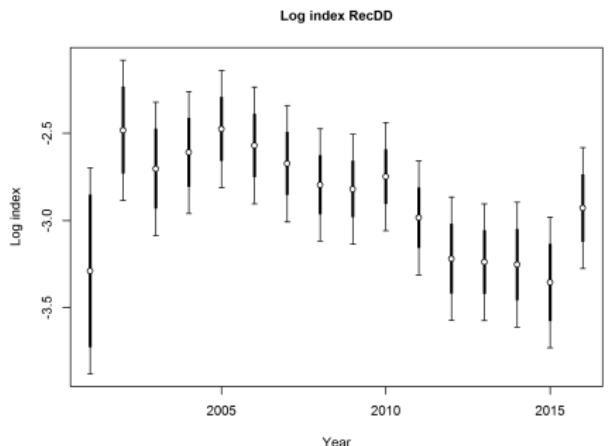


Normal Q-Q Plot

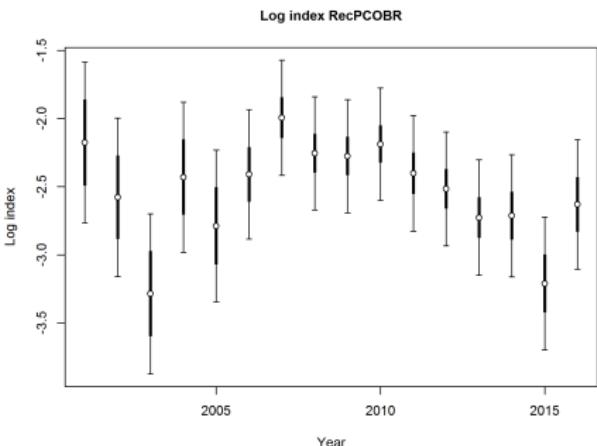


# Recreational Onboard Indices

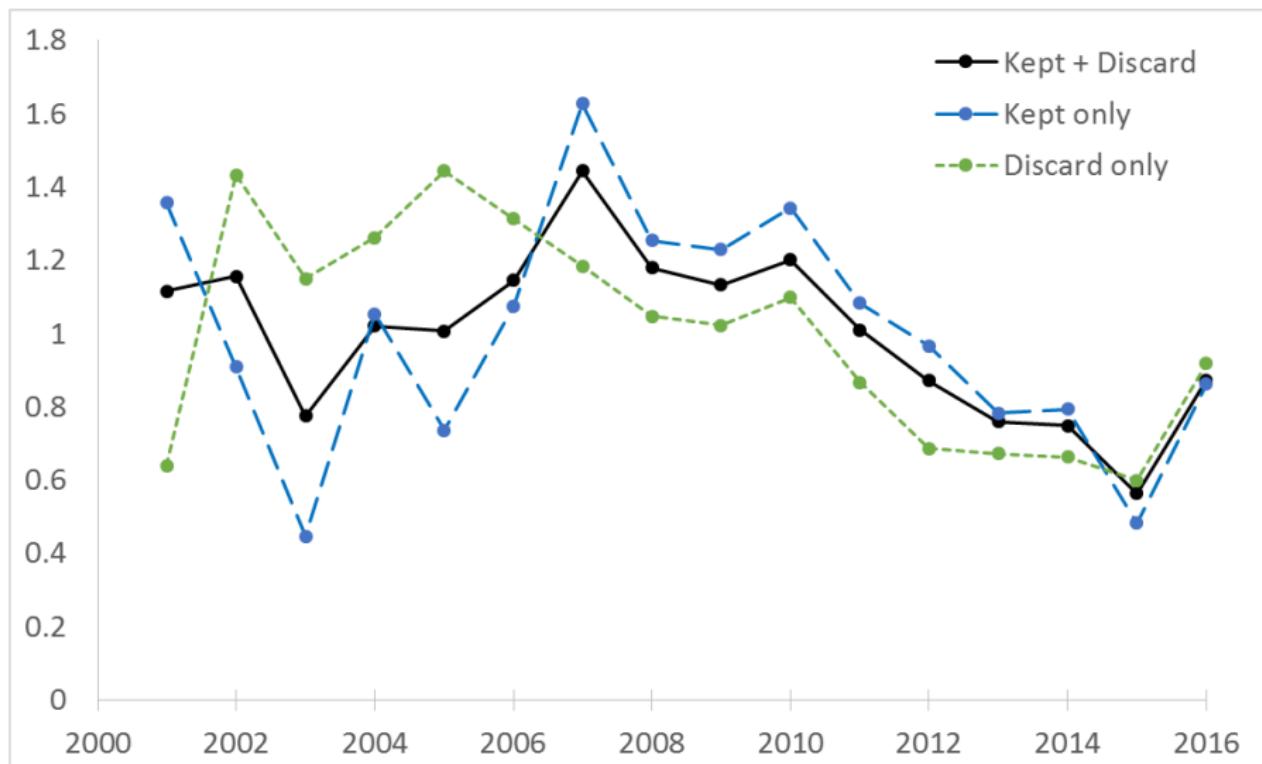
Discard catch index (left)



Retained catch index (right)



# Recreational Onboard Indices



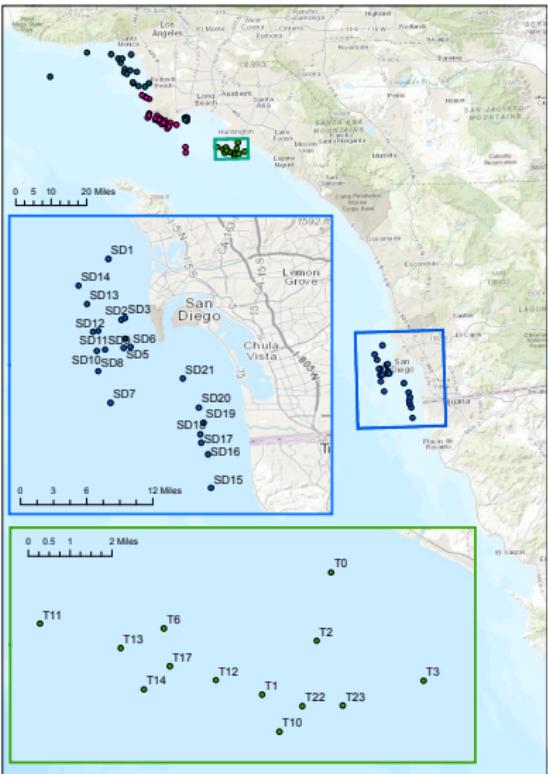
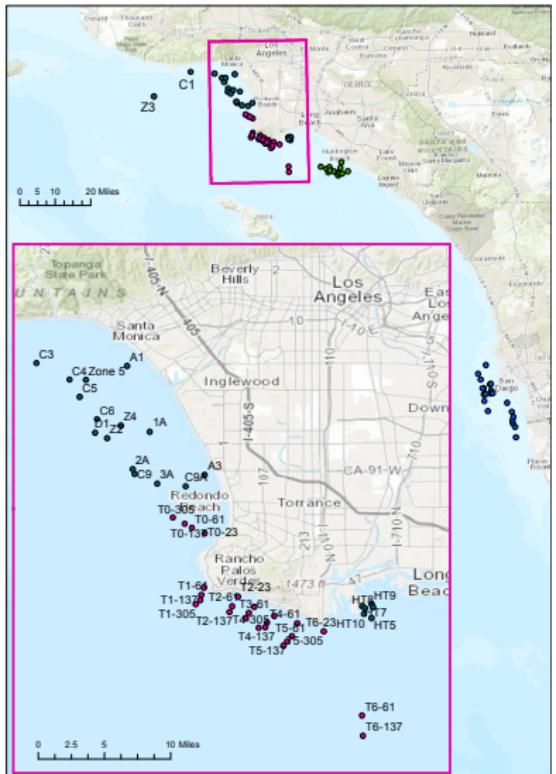
# Fishery-Independent Abundance Indices

- Publicly Owned Treatment Works (POTW) Monitoring Index
- NWFSC Trawl Survey
- California State University Northridge/Vantuna Research Group (CSUN/VRG) Gillnet Survey
- Generating Station Impingement Survey
- Southern California Bight Regional Monitoring Survey (Bight survey)

# Publicly Owned Treatment Works Survey Index

- Publicly Owned Treatment Works (POTWs) are required to have permits to discharge into state or federal waters
- Six southern California POTWs conduct trawls to monitoring fish populations (Goleta and City of Oxnard do not observe California scorpionfish)
  - Each POTW follows standardized trawl methods
  - Fixed station design, sample spring and fall, or more frequently
  - All fish encountered are measured, standard length
- Four POTWs observed California scorpionfish
  - Orange County Sanitation District (1970-2016)
  - City of Los Angeles Environmental Monitoring Division (1988-2016)
  - Sanitation Districts of Los Angeles County (1972-2016)
  - City of San Diego Public Utilities Department (1985-2016)

# POTW Survey Index



# Publicly Owned Treatment Works Survey Index

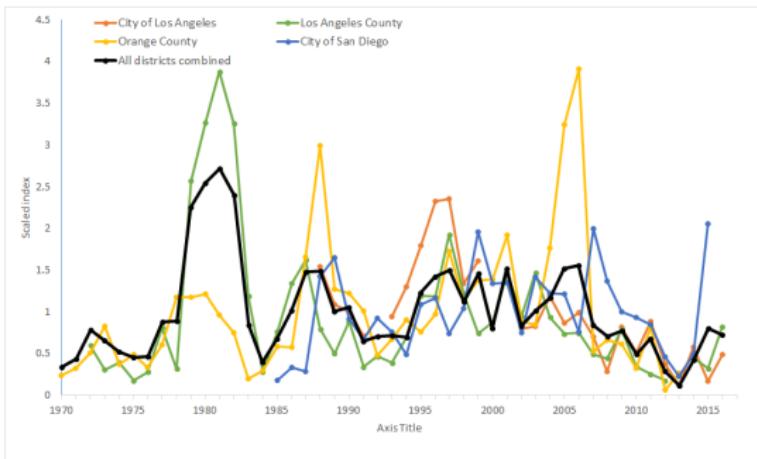
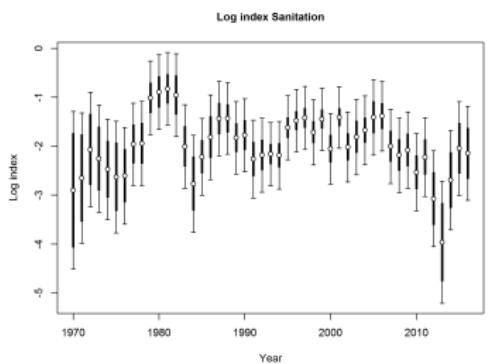
**Sample:** Four POTWs **Years:** 1970-2016 **Effort:** Tow time

Number of California scorpionfish encountered by POTW and 25 m depth bin

Program	0-24 m	25-49 m	50-74 m	100+ m	Total
City of Los Angeles	120	0	1372	0	1492
Los Angeles County	687	0	5879	450	7016
Orange County	161	669	2157	48	3035
City of San Diego	0	404	333	829	1566

# Publicly Owned Treatment Works Survey Index

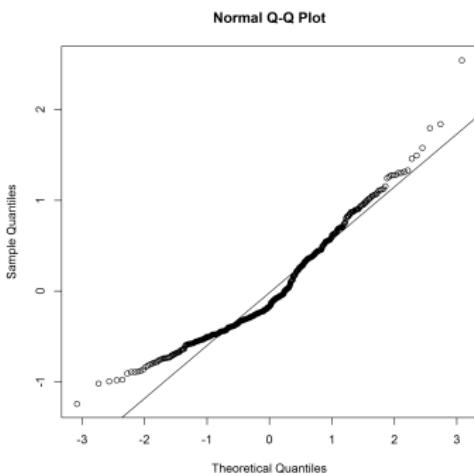
## Results



# Gillnet Survey Index

**Sample:** CSUN/VRG survey **Years:** 1995-2008 **Effort:** Soak time

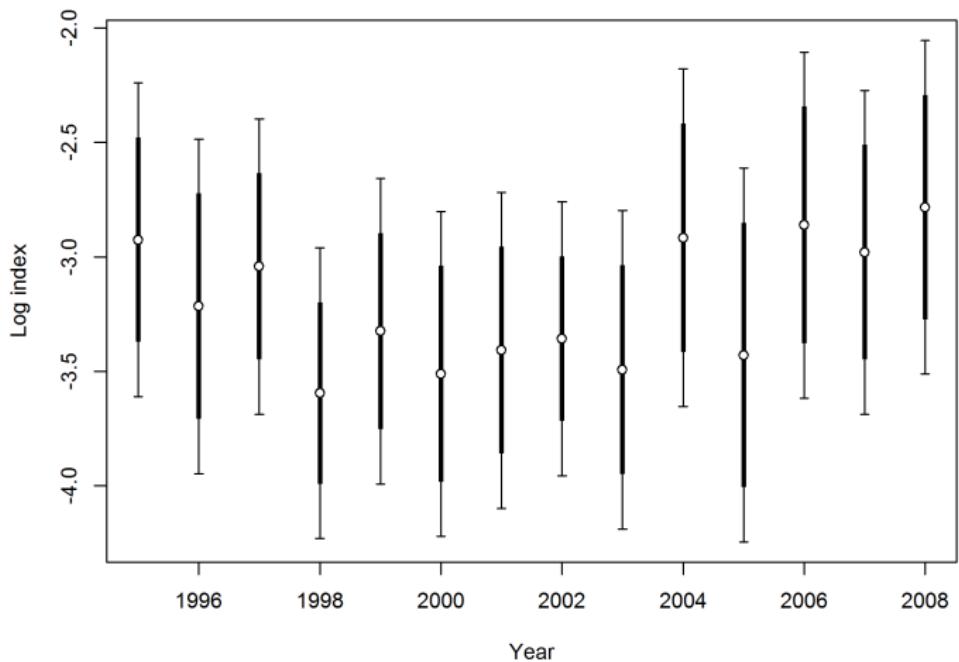
Filter	Criteria	Pos. trips	Trips
Entire dataset		325	3,558
General data filters	Samples with no net failures	269	3,515
Net type	Samples using a net type 1", 1.5" and 2" mesh	269	2,815
Sites	Sites frequently sampled	266	2,170
Month	Months sampled consistently (April, June, August, October)	259	2,019



Model	Binomial	Lognormal
Year + month + site + perp_para + floats	1983	1008
Year + site + perp_para + floats	2000	1004
Year + month + perp_para + floats	2349	1264
<b>Year + site + perp_para</b>	<b>2010</b>	<b>1004</b>

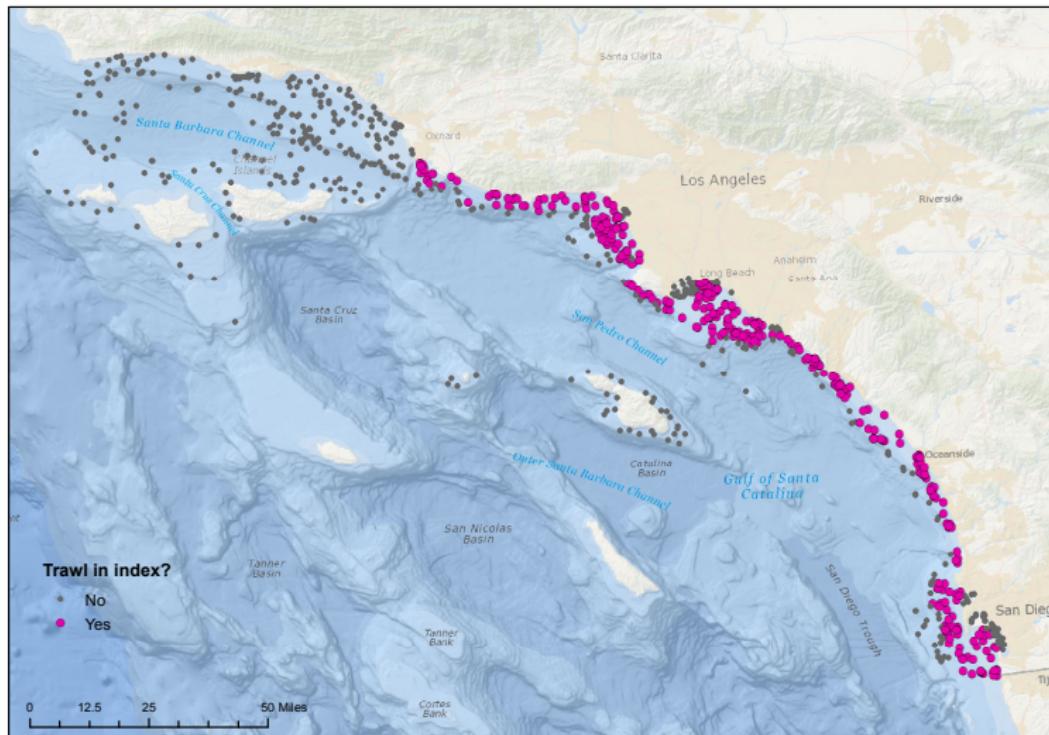
# Gillnet Survey Index

Log index GillnetSurvey



# Southern California Bight Trawl Survey Index

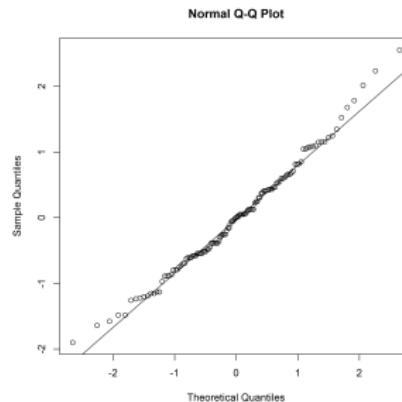
**Sample:** Bight Trawl Survey **Years:** 1994, 1998, 2003, 2008, 2013 **Effort:** Tow time



# Southern California Bight Trawl Survey Index

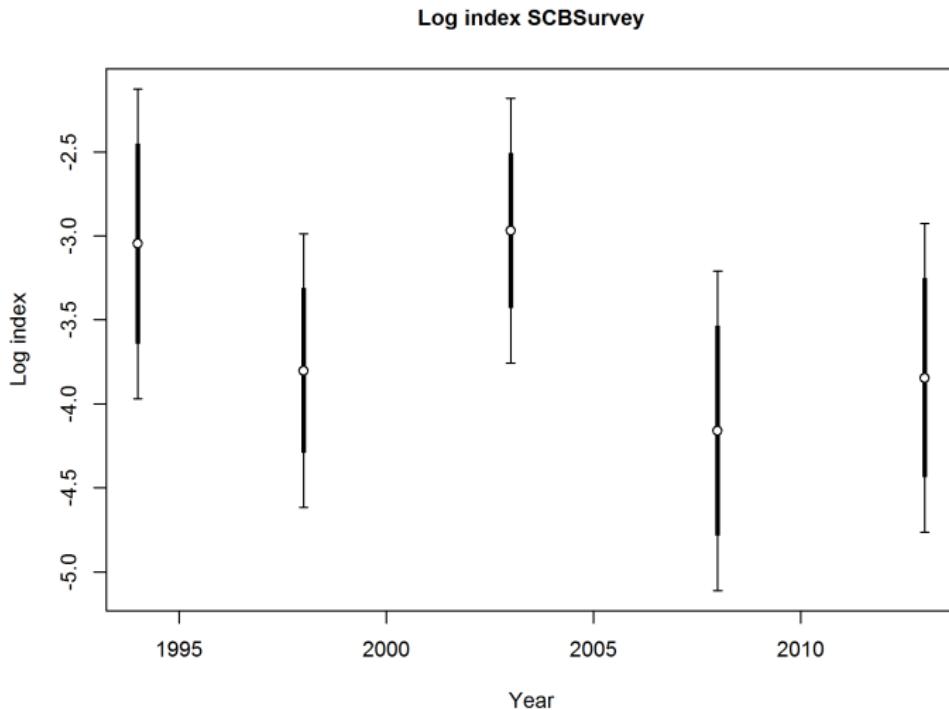
Filter	Criteria	Pos. trips	Trips
All trawls	No filter	158	944
Depth	Trawls < 98 m (retains 95% of all data)	149	662
Region	Exclude trawls in harbors, north of Ventura and islands (few scorpionfish)	129	<b>398</b>

Model	Binomial	Lognormal
Year	494.73	339.56
Year + Region	490.24	343.16
Year + Month	493.02	336.68
<b>Year + Month + Region</b>	<b>486.55</b>	<b>337.87</b>



# Southern California Bight Trawl Survey Index

## Results



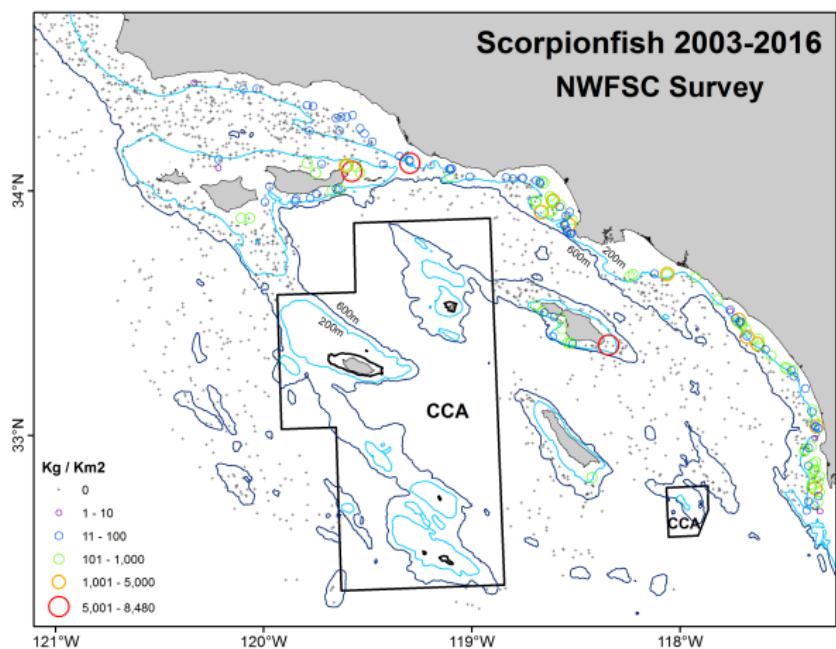
# NWFSC Trawl Survey Index

Geostatistical approach Vector Autoregressive Spatio-Temporal (VAST) model

- Uses delta-GLMM framework
  - Probability of encounters
  - Catch rates for non-zero catches
- Geostatistical approach
  - Divides survey area into fine-scale grids
  - Assumes that nearby grids have more similar fish density than those further away
  - Smooths density estimates over the landscape
  - Reduces uncertainty in the estimates

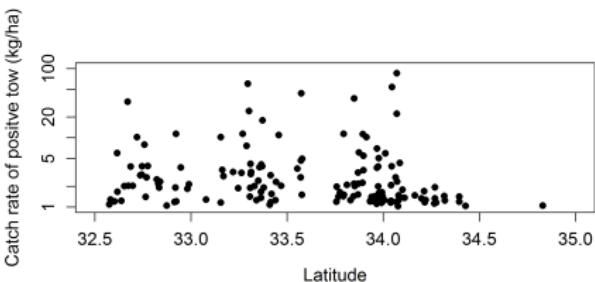
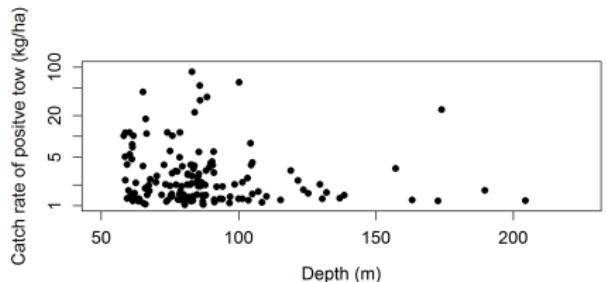
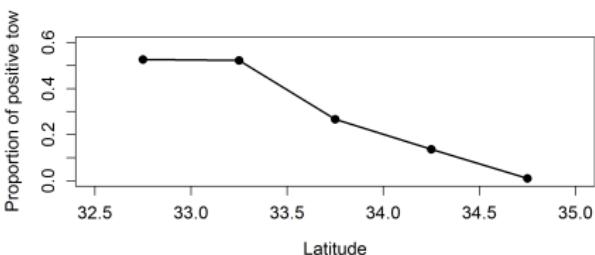
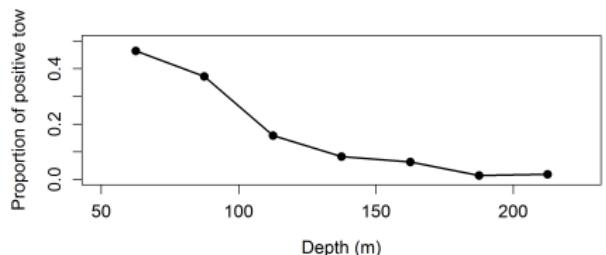
# NWFSC Trawl Survey Index

**Sample:** California MRFSS and CRFS **Years:** 1980-2003 **Effort:** Angler hours



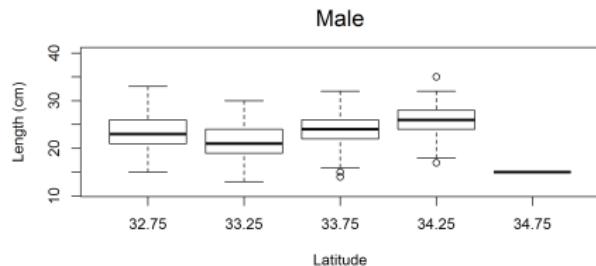
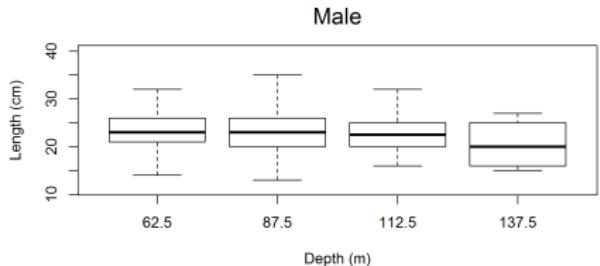
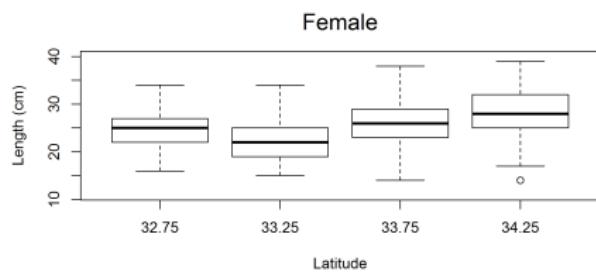
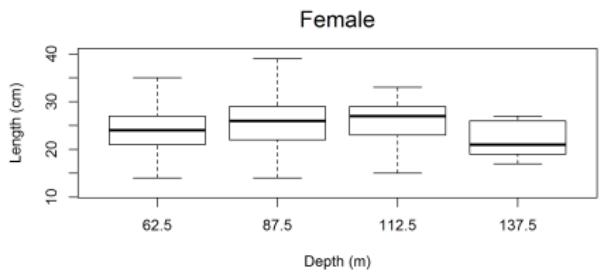
# NWFSC Trawl Survey Index

Proportion of positive tows and raw catch rate by depth (left) and latitude (right)

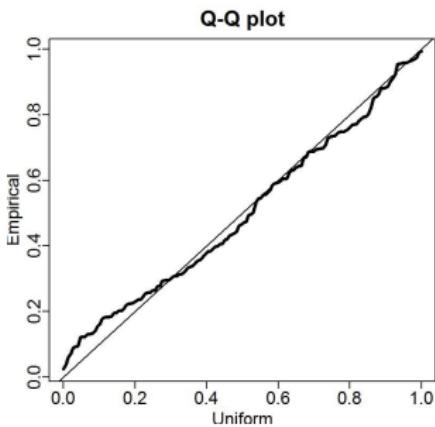
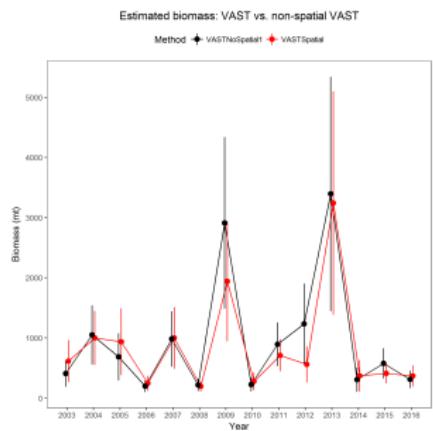


# NWFSC Trawl Survey Index

Comparison of length data by sex and depth (left) and latitude (right)



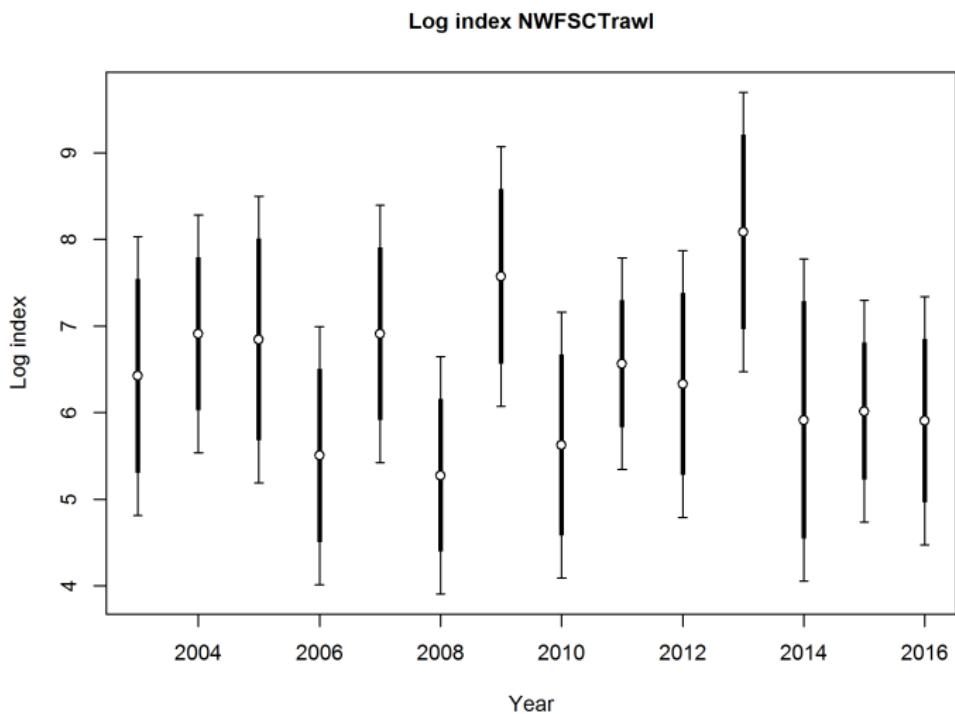
# NWFSC Trawl Survey Index



# NWFSC Trawl Survey Index

## Comparison with the GLMM

# NWFSC Trawl Survey Index

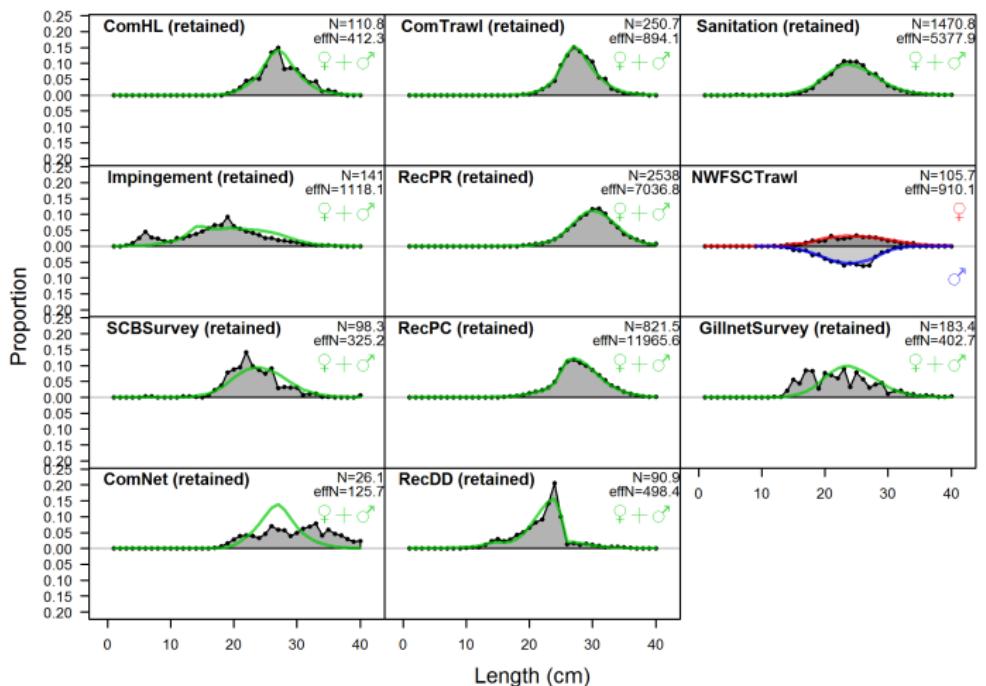


## Length compositions were provided from the following sources:

- CDFW market category study (*commercial dead fish*, 1996-2003)
- CALCOM (*commercial dead fish*, 2013-2016)
- CDFW onboard observer (*recreational charter discards*, 2003-2016)
- Collins and Crooke onboard observer surveys (1975-1978)
- Ally onboard observer study (*recreational charter kept/discards*, 1984-1989)
- MRFSS (1980-2003) and CRFS (2004-2014) (*private and party/charter, kept*)
- POTW trawl surveys (*research*, 1970-2016)
- CSUN/VRG gillnet survey (*research*, 1995-2008)
- Power plant impingement surveys (*research*, 1974-2016)
- Southern California Bight trawl survey (*research*, 1994, 1998, 2003, 2008, 2013)

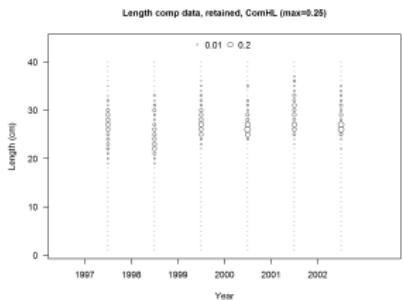
# Aggregate length composition

Length comps, aggregated across time by fleet

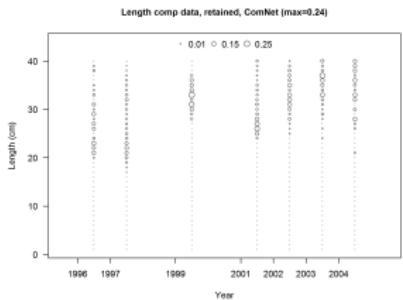


# Commercial fishery length composition

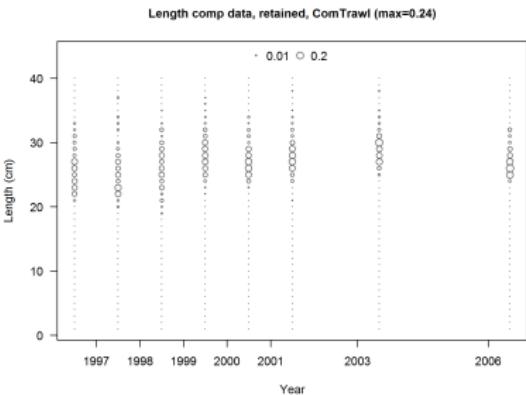
## Commercial hook-and-line



## Commercial gillnet



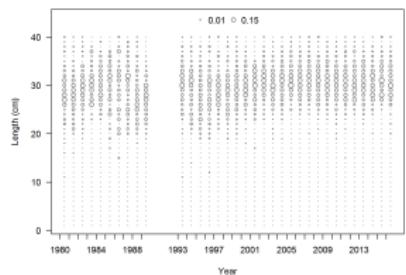
## Commercial trawl



# Recreational fishery Length Composition

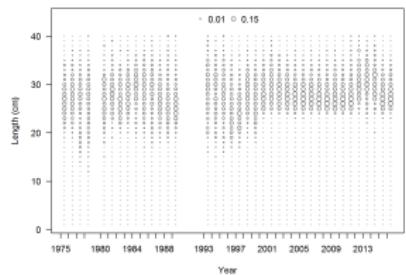
## Recreational private fleet

Length comp data, retained, RecPR (max=0.19)



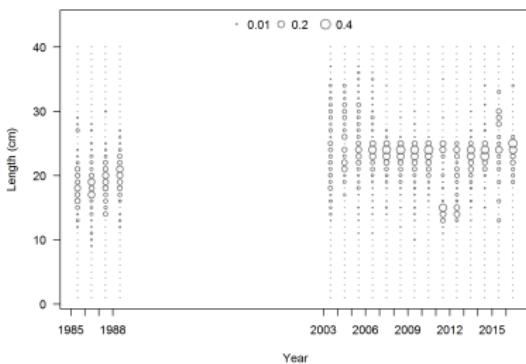
## Recreational party/charter fleet

Length comp data, retained, RecPC (max=0.18)



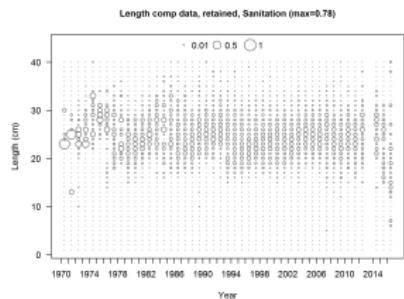
## Recreational dead discards

Length comp data, retained, RecDD (max=0.32)

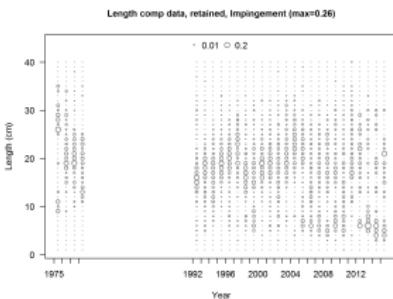


# Research Length Composition

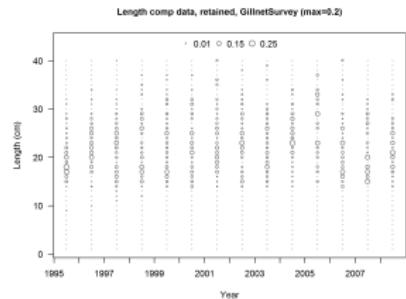
## POTW survey



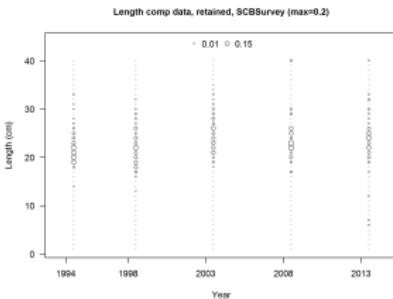
## Impingement survey



## Gillnet survey



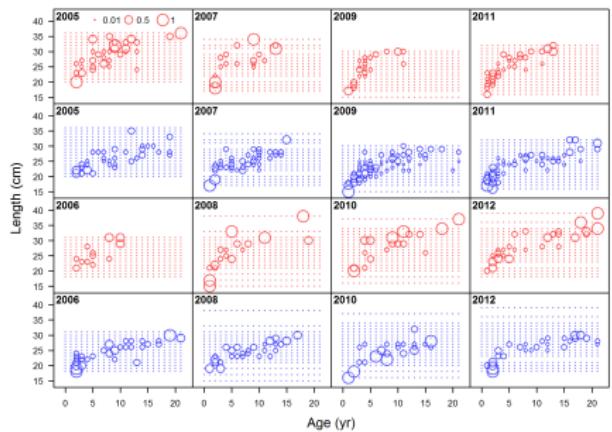
## Bight trawl survey



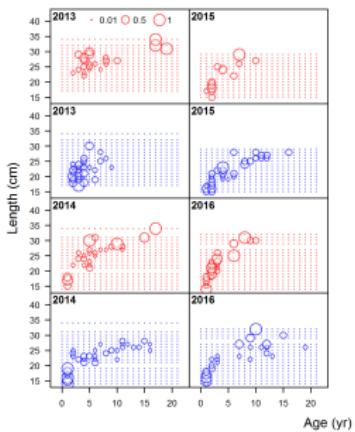
# NWFSC Length and Age Composition

Note: females in red and males in blue

Conditional age-at-length data, whole catch, NWFSC Trawl (max=1)

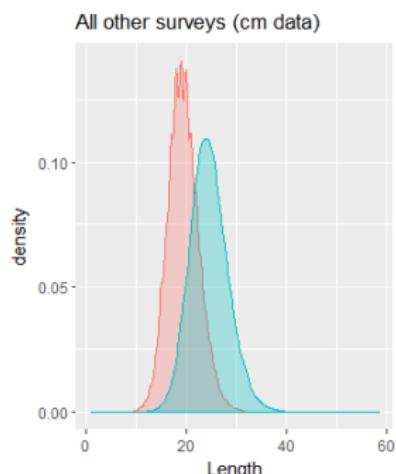
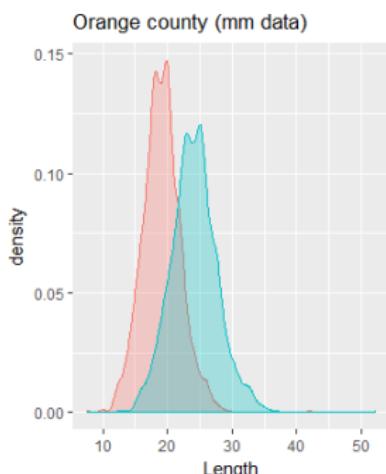


Conditional age-at-length data, whole catch, NWFSC Trawl (max=1)



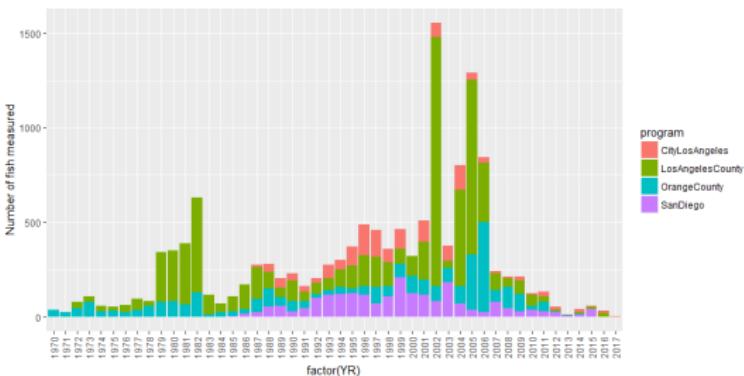
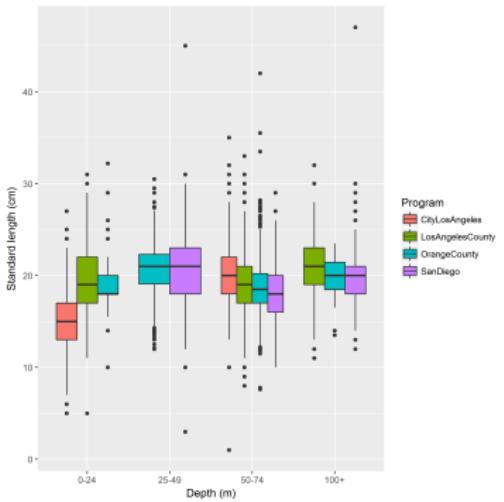
## Length data

- 2005 assessment used standard length
- Impingement, POTW, and Bight surveys measure standard length
- 2017 assessment uses total length (conversion based on a CDFW halibut trawl study; measured both SL and TL)
- To avoid gaps in TL length bins,  $TL = SL - 0.5 + U[0,1]$

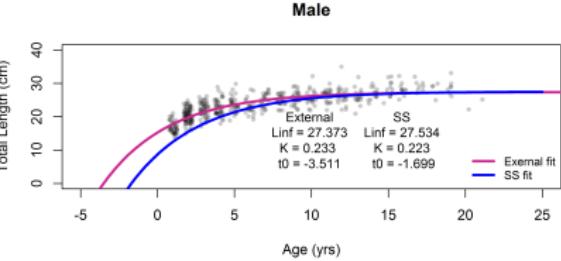
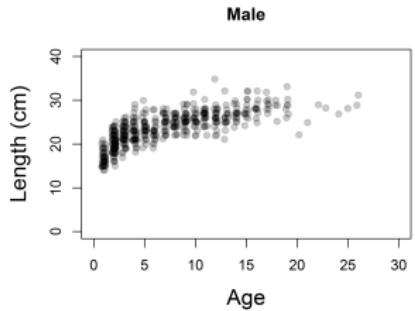
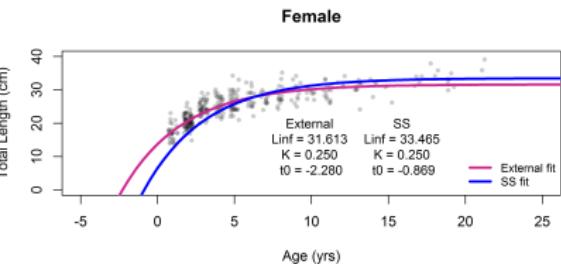
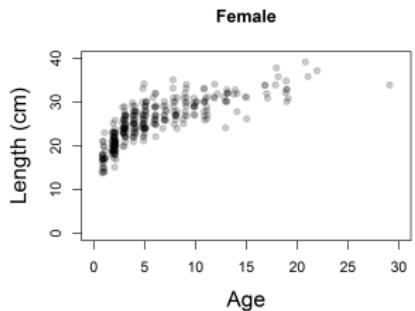


# Length data

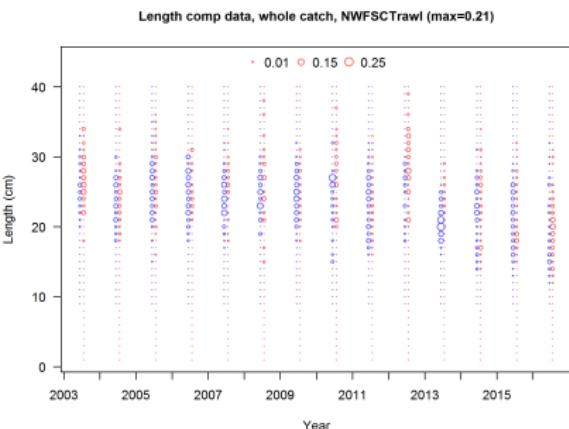
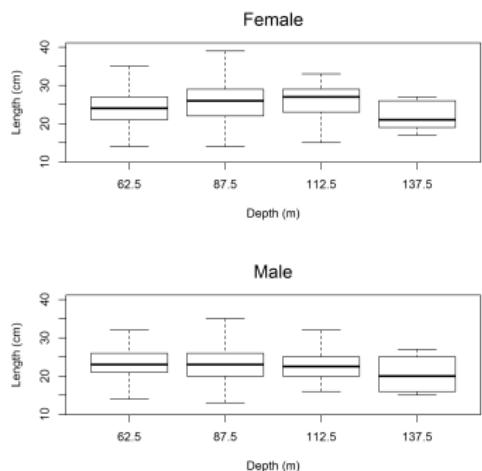
## POTW lengths



# Length-at-Age

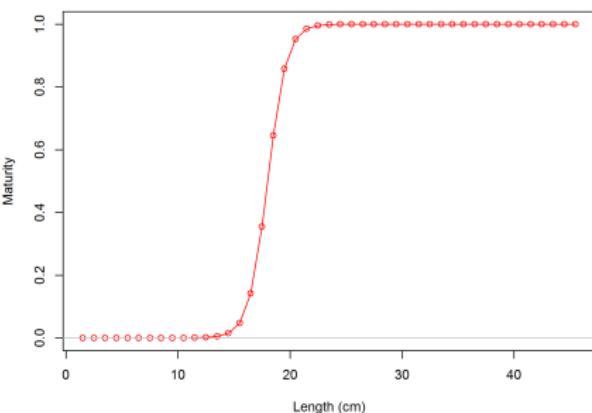


# Length-at-Age

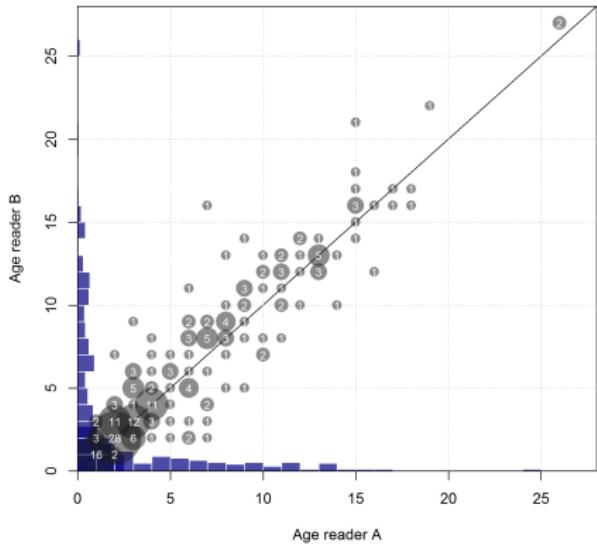
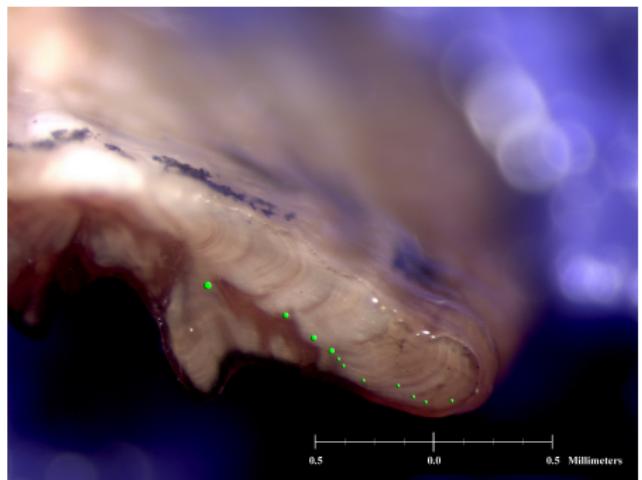


# Maturity and Fecundity

- Only information on maturity from Love et al. (1987)
- Found over 50% of females were mature by 18 cm TL, or two years of age.
- All fish were mature by 22 cm TL
- No information available on fecundity of California scorpionfish



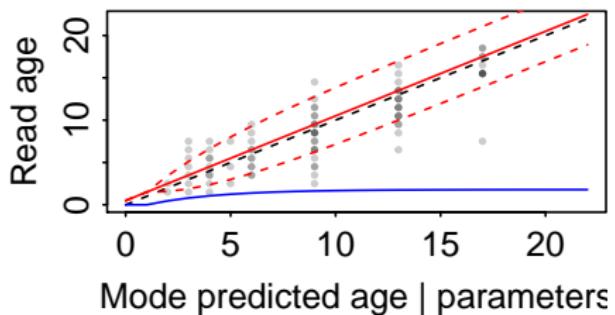
# Ageing Error



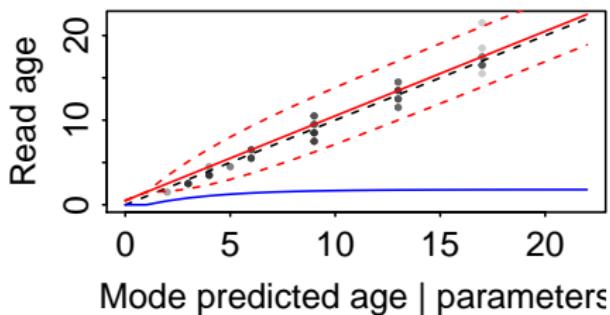
# Ageing Error

Reads(dot), Sd(blue), expected\_read(red solid line),  
and 95% CI for expected\_read(red dotted line)

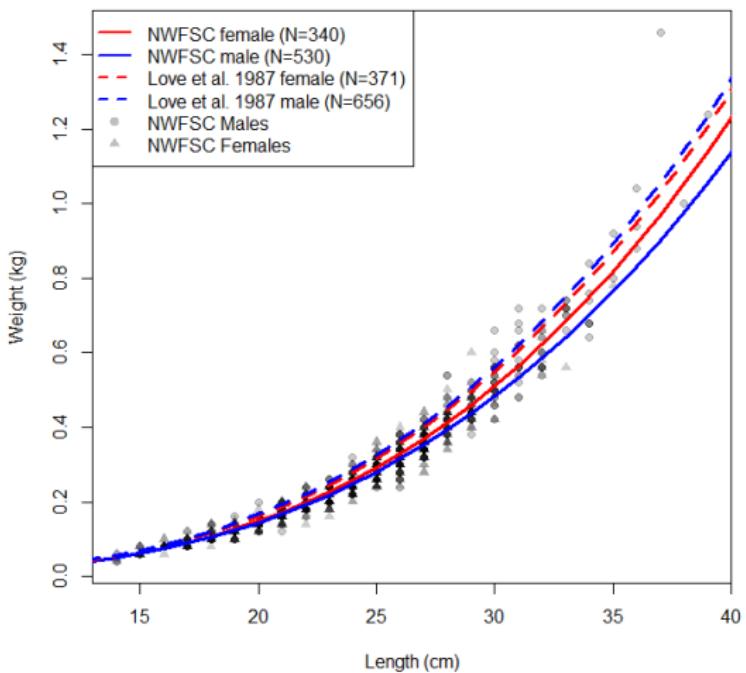
**Reader 1**



**Reader 2**



# Weight-at-Length

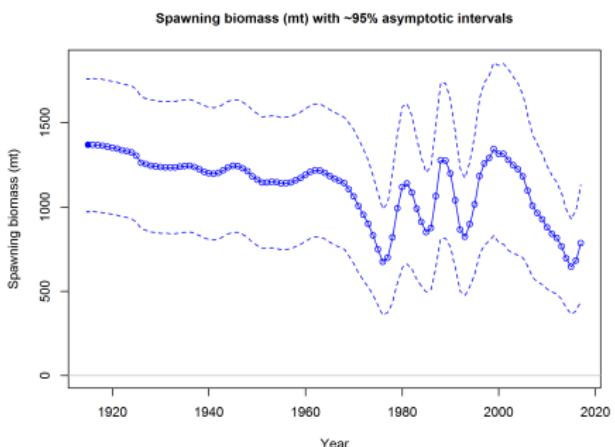


# Natural Mortality

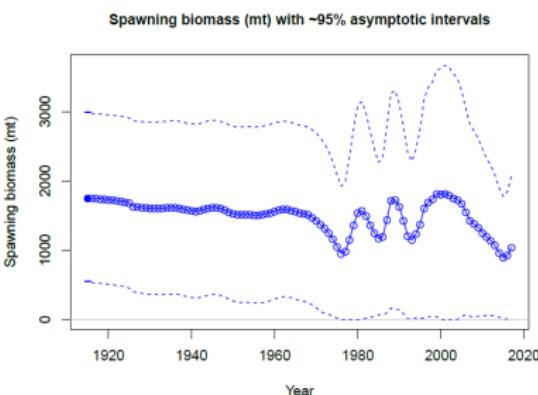
- Prior based on maximum age of 21 (maximum observed age was 27, but fish older than 21 were rare in the available ages)
- Lognormal distribution with a median of 0.25714 (Hamel/Then prior)
- Base model fixes female natural mortality ( $M = 0.25714$ )
- Male  $M$  estimated as offset from female (male  $M = 0.207733$ )
- Sensitivities explore estimating  $M$

# Natural Mortality

Base model - fixed female  $M$ , male  $M$  estimated as offset ( $\ln R_0 = 8.16$ , depl. = 0.574, female  $M = 0.25714$ , male  $M = 0.2077$ )

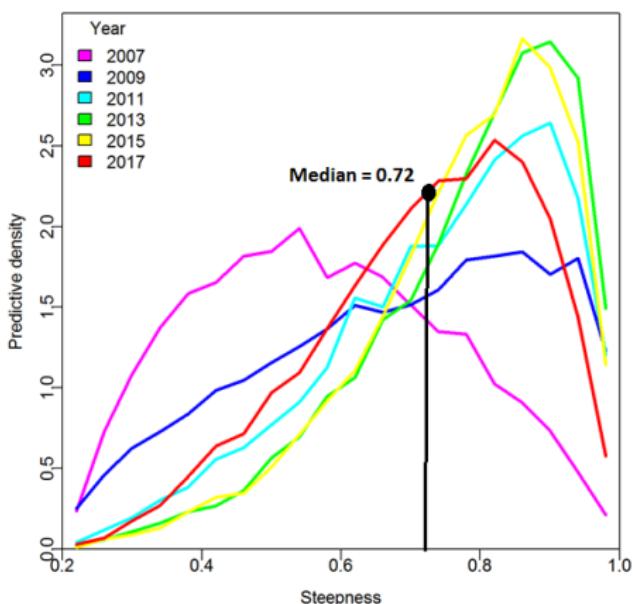


Base model with one  $M$  estimated ( $\ln R_0 = 8.54$ , depl. = 0.595,  $M = 0.266$ )



# Steepness: Density-Dependent Recruitment Compensation

- Predictive distribution for Pacific rockfish meta-analysis
- Prior median in 2017 for steepness ( $h$ ) = 0.718



# Model Specifications

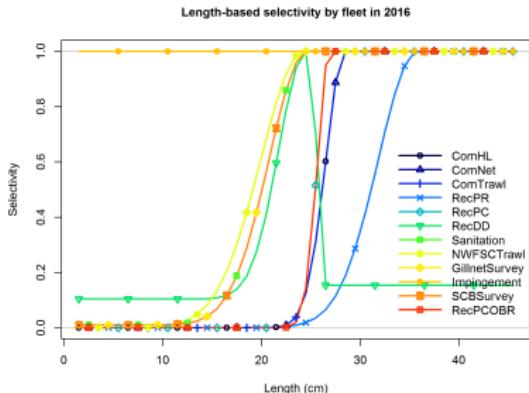
- Stock Synthesis version 3.30.05.04
- Model starts in 1916, unfished equilibrium catch prior to that
- Sex-specific growth and mortality with female  $M$  fixed at 0.2571 (prior) and male  $M$  offset is estimated at -0.2134 (male  $M = 0.2077$ )
  - $M$  fixed at 0.25 for both sexes in 2005 assessment
- Steepness fixed at 0.718 (from meta-analysis)
  - $h$  fixed at 0.7 in 2005 assessment
- Maximum age of 21
- One cm length bins
- Recruitment deviations estimated

# Selectivity

- Time blocks
  - Commercial fleet: 1916-1999 and 2000-2016 (10-in. minimum size limit as of 2000)
  - Recreational fleets: 1916-2000 (few regulations), 2001-2005 (fishery closures), 2006-2016 (consistent regulations)
- Double normal except for the impingement survey (Selectivity = 1.0 for all ages)
- Fisheries selectivity parameters estimated for commercial hook-and-line, recreational private, recreational party/charter, and recreational discard fleets

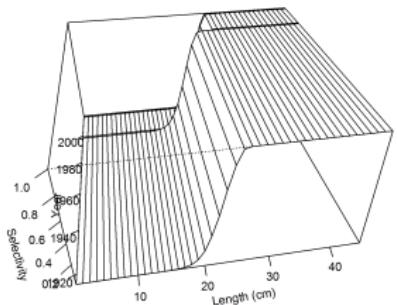
## Selectivity

- Commercial gillnet and trawl fleets mirrored to the commercial hook-and-line fleet
- Recreational CPFV onboard observer retained catch mirrored to the recreational party/charter fleet selectivity (same boats)
- Survey selectivity parameters estimated for the POTW and NWFSC trawl surveys
- The gillnet survey and Bight trawl survey mirrored to the POTW selectivity

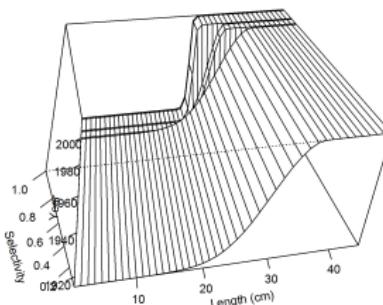


# Selectivity

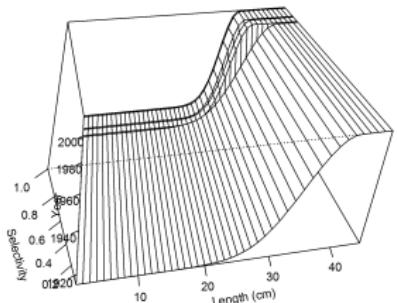
Female time-varying selectivity for ComHL



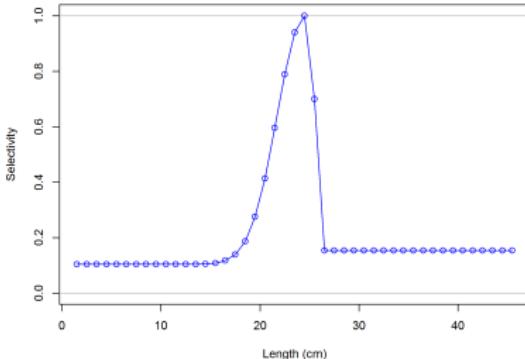
Female time-varying selectivity for RecPC



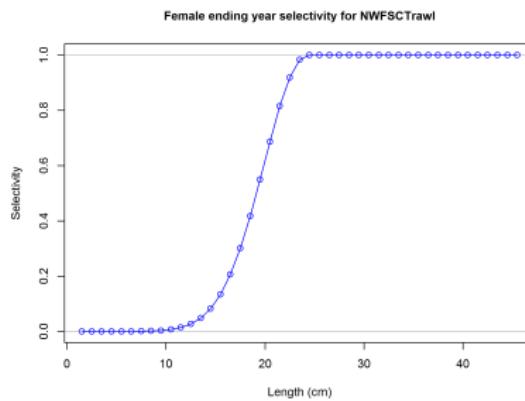
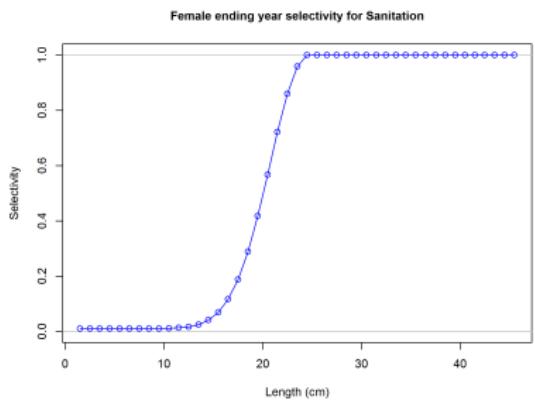
Female time-varying selectivity for RecPR



Female ending year selectivity for RecDD

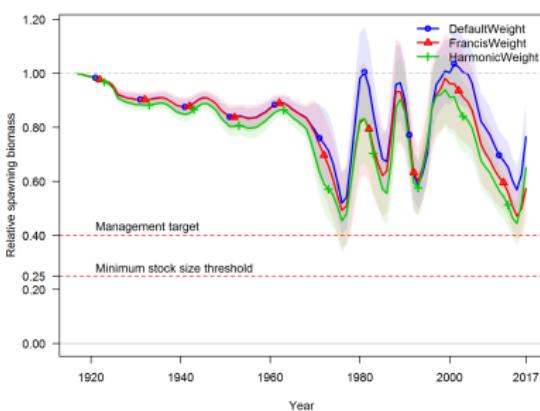
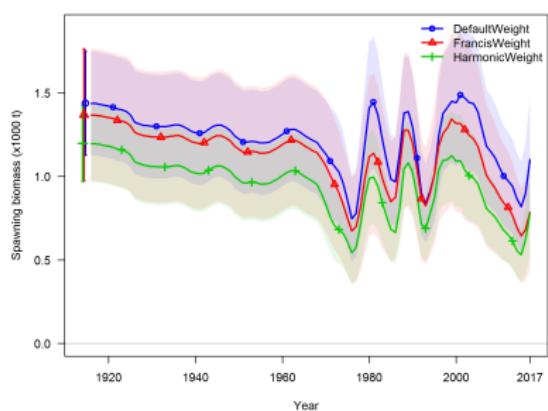


# Gear Selectivity



# Data Weighting

- Extra SD estimated for indices
- Francis weighting applied to length and age data
- Conducted sensitivities to no weighting and harmonic means



# Convergence

- Confirmed that the Hessian was positive definite
- Final gradient is  $<0.0001$
- Performed 50 trials using a 'jitter' to assess the model's ability to recover similar likelihood estimates when initialized from dispersed starting points
- The maximum difference in the likelihood from the jitter runs was 14.68 and 56% of runs were at the minimum likelihood

# Pre-STAR Base Model Output (page 1)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1_Fem_GP_1	0.257	-3	(0.01, 1)			Log_Norm (-1.3581, 0.438438)
L_at_Amin_Fem_GP_1	12.434	2	(2, 30)	OK	0.626	None
L_at_Amax_Fem_GP_1	33.312	2	(30, 50)	OK	0.720	None
VonBert_K_Fem_GP_1	0.250	2	(0.05, 0.5)	OK	0.024	None
CV_young_Fem_GP_1	0.089	3	(0.02, 0.5)	OK	0.019	None
CV_old_Fem_GP_1	0.112	3	(0.02, 0.75)	OK	0.008	None
Wtlen_1_Fem	0.000	-3	(-3, 3)			None
Wtlen_2_Fem	3.058	-3	(2, 4)			None
Mat50%_Fem	18.000	-3	(10, 30)			None
Mat_slope_Fem	-1.200	-3	(-3, 3)			None
Eggs/kg_inter_Fem	1.000	-3	(-3, 3)			None
Eggs/kg_slope_wt_Fem	0.000	-3	(-3, 3)			None
NatM_p_1_Mal_GP_1	-0.213	2	(-1, 1)	OK	0.049	Normal (0, 99)
L_at_Amin_Mal_GP_1	0.000	-2	(-3, 3)			None
L_at_Amax_Mal_GP_1	-0.159	2	(-3, 3)	OK	0.026	None
VonBert_K_Mal_GP_1	-0.295	2	(-3, 3)	OK	0.183	None
CV_young_Mal_GP_1	1.300	3	(-3, 3)	OK	0.218	None
CV_old_Mal_GP_1	-0.452	3	(-3, 3)	OK	0.158	None
Wtlen_1_Mal	0.000	-5	(0, 1)			None
Wtlen_2_Mal	2.981	-5	(2, 4)			None
CohortGrowDev	1.000	-1	(1, 1)			None
FracFemale_GP_1	0.500	-4	(0.000001, 0.999999)			None
SR_LN(R0)	8.160	1	(0, 31)	OK	0.157	None
SR_BH_stEEP	0.718	-2	(0.21, 0.99)			Full_Beta (0.718, 0.158)

# Pre-STAR Base Model Output (page 2)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SR_sigmaR	0.600	-2	(0, 2)			None
SR_regime	0.000	-4	(-5, 5)			None
SR_autocorr	0.000	-3	(0, 0.5)			None
LnQ_base_RecPR(4)	-6.775	-1	(-15, 15)			None
Q_extraSD_RecPR(4)	0.013	4	(0.0001, 1)	OK	0.020	None
LnQ_base_RecPC(5)	-11.223	-1	(-15, 15)			None
Q_extraSD_RecPC(5)	0.267	4	(0.0001, 1)	OK	0.047	None
LnQ_base_RecDD(6)	-10.894	-1	(-15, 15)			None
Q_extraSD_RecDD(6)	0.078	4	(0.0001, 1)	OK	0.044	None
LnQ_base_Sanitation(7)	-10.544	-1	(-15, 15)			None
Q_extraSD_Sanitation(7)	0.225	4	(0.0001, 1)	OK	0.047	None
LnQ_base_NWFSCTrawl(8)	-1.023	-1	(-15, 15)			None
Q_extraSD_NWFSC Trawl(8)	0.250	4	(0.0001, 1)	OK	0.145	None
LnQ_base_GillnetSurvey(9)	-12.050	-1	(-15, 15)			None
Q_extraSD_GillnetSurvey(9)	0.122	4	(0.0001, 1)	OK	0.070	None
LnQ_base_SCBSurvey(11)	-11.052	-1	(-15, 15)			None
Q_extraSD_SCBSurvey(11)	0.166	4	(0.0001, 1)	OK	0.142	None
LnQ_base_RecPCOBR(12)	-10.171	-1	(-15, 15)			None
Q_extraSD_RecPCOBR(12)	0.140	4	(0.0001, 1)	OK	0.046	None
SizeSel_P1_ComHL(1)	25.963	5	(13, 44)	OK	2.868	None
SizeSel_P2_ComHL(1)	15.000	-3	(-10, 16)			None
SizeSel_P3_ComHL(1)	2.761	5	(-1, 10)	OK	0.954	None
SizeSel_P4_ComHL(1)	15.000	-3	(-1, 16)			None
SizeSel_P5_ComHL(1)	-15.902	5	(-25, -1)	OK	121.578	None
SizeSel_P6_ComHL(1)	10.000	-3	(-5, 11)			None
SizeSel_P1_ComNet(2)	1.000	-2	(1, 45)			None

# Pre-STAR Base Model Output (page 3)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SizeSel_P2_ComNet(2)	45.000	-3	(1, 45)			None
SizeSel_P1_CompTrawl(3)	1.000	-2	(1, 45)			None
SizeSel_P2_CompTrawl(3)	45.000	-3	(1, 45)			None
SizeSel_P1_RecPR(4)	41.212	5	(13, 44)	OK	2.054	None
SizeSel_P2_RecPR(4)	15.000	-3	(-10, 16)			None
SizeSel_P3_RecPR(4)	4.493	5	(-1, 10)	OK	0.163	None
SizeSel_P4_RecPR(4)	15.000	-3	(-1, 16)			None
SizeSel_P5_RecPR(4)	-8.340	5	(-25, -1)	OK	0.784	None
SizeSel_P6_RecPR(4)	10.000	-3	(-5, 11)			None
SizeSel_P1_RecPC(5)	36.624	5	(13, 44)	OK	1.358	None
SizeSel_P2_RecPC(5)	15.000	-3	(-10, 16)			None
SizeSel_P3_RecPC(5)	4.473	5	(-1, 10)	OK	0.158	None
SizeSel_P4_RecPC(5)	15.000	-3	(-1, 16)			None
SizeSel_P5_RecPC(5)	-8.344	5	(-25, -1)	OK	1.872	None
SizeSel_P6_RecPC(5)	10.000	-3	(-5, 11)			None
SizeSel_P1_RecDD(6)	24.530	5	(13, 44)	OK	0.074	None
SizeSel_P2_RecDD(6)	-11.238	4	(-15, 16)	OK	57.708	None
SizeSel_P3_RecDD(6)	2.727	4	(-1, 10)	OK	0.518	None
SizeSel_P4_RecDD(6)	-9.302	4	(-20, 5)	OK	65.524	None
SizeSel_P5_RecDD(6)	-2.156	5	(-25, 3)	OK	0.472	None
SizeSel_P6_RecDD(6)	-1.709	4	(-5, 11)	OK	0.457	None
SizeSel_P1_Sanitation(7)	24.627	4	(13, 44)	OK	0.580	None
SizeSel_P2_Sanitation(7)	15.000	-3	(-10, 16)			None
SizeSel_P3_Sanitation(7)	3.388	4	(-1, 10)	OK	0.140	None
SizeSel_P4_Sanitation(7)	15.000	-3	(-1, 16)			None

# Pre-STAR Base Model Output (page 4)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SizeSel_P4_Sanitation(7)	15.000	-3	(-1, 16)			None
SizeSel_P5_Sanitation(7)	-4.618	4	(-25, 5)	OK	0.633	None
SizeSel_P6_Sanitation(7)	10.000	-3	(-5, 11)			None
SizeSel_P1_NWFSCTrawl(8)	24.306	4	(13, 44)	OK	2.258	None
SizeSel_P2_NWFSCTrawl(8)	15.000	-3	(-10, 16)			None
SizeSel_P3_NWFSCTrawl(8)	3.652	4	(-1, 10)	OK	0.558	None
SizeSel_P4_NWFSCTrawl(8)	15.000	-3	(-1, 16)			None
SizeSel_P5_NWFSCTrawl(8)	-12.844	4	(-25, 5)	OK	166.385	None
SizeSel_P6_NWFSCTrawl(8)	10.000	-3	(-5, 11)			None
SizeSel_P1_GillnetSurvey(9)	1.000	-2	(1, 45)			None
SizeSel_P2_GillnetSurvey(9)	45.000	-3	(1, 45)			None
SizeSel_P1_SCBSurvey(11)	1.000	-2	(1, 45)			None
SizeSel_P2_SCBSurvey(11)	45.000	-3	(1, 45)			None
SizeSel_P1_RecPCOB(12)	1.000	-2	(1, 45)			None
SizeSel_P2_RecPCOB(12)	45.000	-3	(1, 45)			None
SizeSel_P1_ComHL(1)_BLK1repl_1999	28.442	6	(13, 44)	OK	0.489	None
SizeSel_P3_ComHL(1)_BLK1repl_1999	2.007	6	(-1, 10)	OK	0.251	None
SizeSel_P1_RecPR(4)_BLK2repl_2000	36.584	6	(13, 44)	OK	1.031	None
SizeSel_P1_RecPR(4)_BLK2repl_2006	35.815	6	(13, 44)	OK	0.652	None
SizeSel_P3_RecPR(4)_BLK2repl_2000	3.602	6	(-1, 10)	OK	0.165	None
SizeSel_P3_RecPR(4)_BLK2repl_2006	3.463	6	(-1, 10)	OK	0.110	None
SizeSel_P1_RecPC(5)_BLK2repl_2000	31.799	6	(13, 44)	OK	1.370	None
SizeSel_P1_RecPC(5)_BLK2repl_2006	26.886	6	(13, 44)	OK	0.464	None
SizeSel_P3_RecPC(5)_BLK2repl_2000	3.041	6	(-1, 10)	OK	0.417	None
SizeSel_P3_RecPC(5)_BLK2repl_2006	1.066	6	(-1, 10)	OK	0.412	None

# Pre-STAR Base Model Output

Year	Spawning biomass (mt)	~ 95% confidence interval	Estimated deple- tion	~ 95% confidence interval
2008	963.57	(555.81-1371.32)	0.70	(0.572-0.837)
2009	927.07	(539.76-1314.38)	0.68	(0.554-0.802)
2010	878.16	(513.26-1243.07)	0.64	(0.526-0.758)
2011	841.15	(494.98-1187.31)	0.61	(0.508-0.722)
2012	814.87	(483.41-1146.34)	0.60	(0.495-0.696)
2013	765.85	(451.39-1080.3)	0.56	(0.465-0.655)
2014	693.82	(401.18-986.46)	0.51	(0.417-0.598)
2015	644.49	(362.67-926.31)	0.47	(0.382-0.561)
2016	681.67	(382.78-980.56)	0.50	(0.399-0.597)
2017	785.33	(439.85-1130.8)	0.57	(0.455-0.694)

# Pre-STAR Base Model Output

Year	OFL	ABC	ACL	ACT	Total Catch
2007	219		175		139.583
2008	219		175		103.887
2009	175		175		113.318
2010	155		155		105.968
2011	141	135	135		105.215
2012	132	126	126		120.008
2013	126	120	120		115.142
2014	122	117	117		123.822
2015	119	114	114		83.8908
2016	117	111	111		74.1613
2017	289	264	150	110	-
2018	278	254	150	110	-

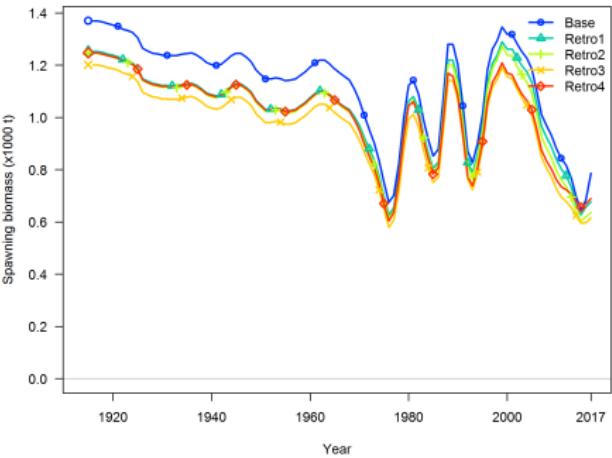
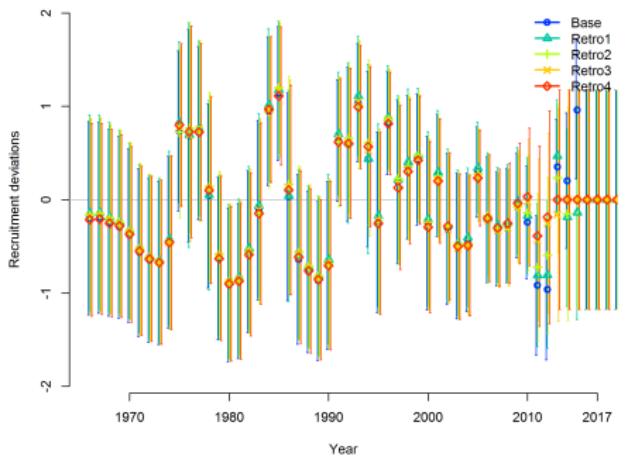
# Pre-STAR Base Model Output

Switch to browser for r4SS output

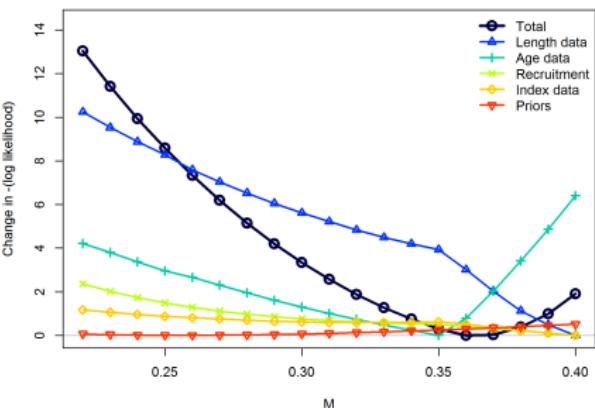
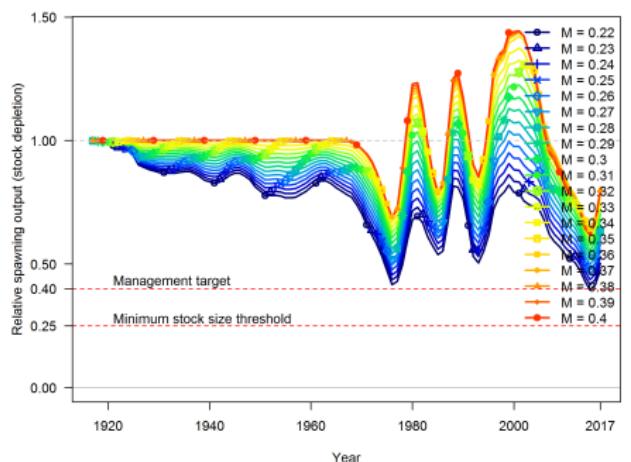


# Retrospective Analysis

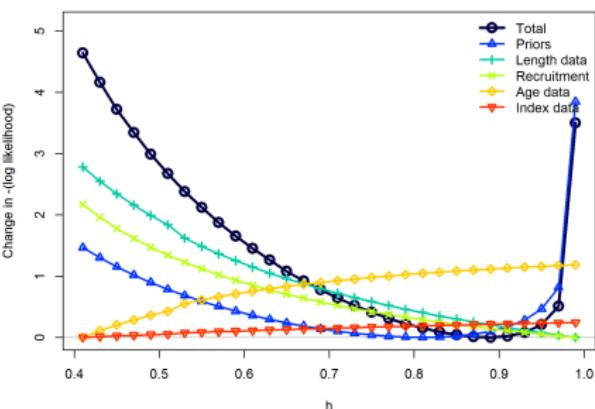
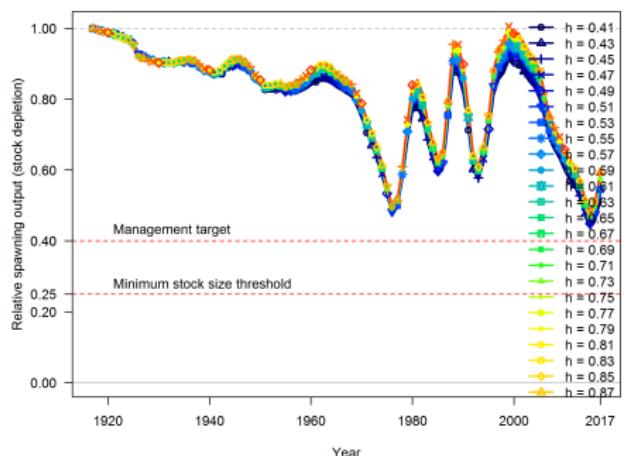
Retro1 = Remove one year; Retro2 = Remove last two years; etc.



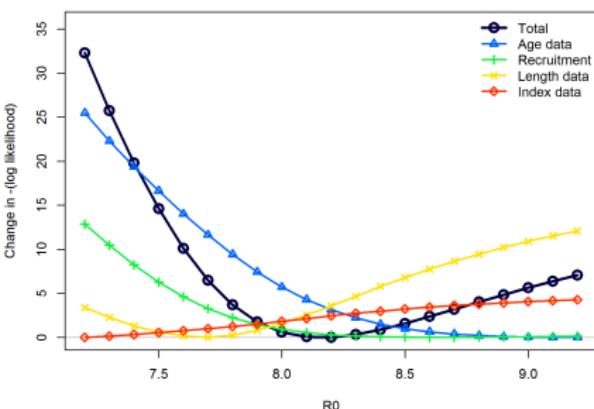
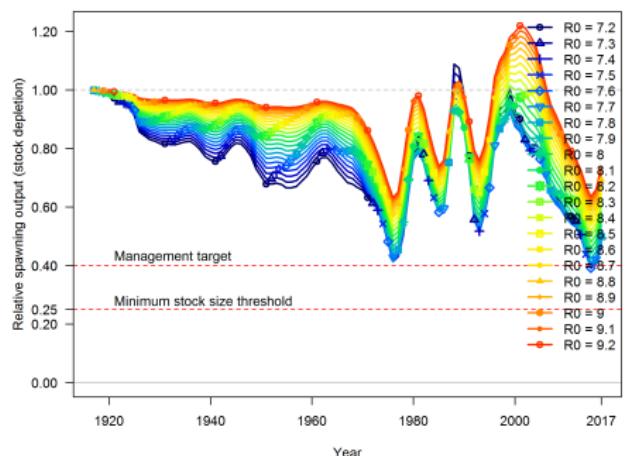
# Likelihood Profiles - Natural Mortality



# Likelihood Profiles - Steepness



# Likelihood Profiles - $\ln R_0$



# Sensitivities

## Sensitivities to Likelihood Components and Model Specification

Remove fleets, only one index, or length composition only

Sensitivity relative to the base model

Boxes are the 95% CI from the base model

### Metrics

$SB_0$  Population scale

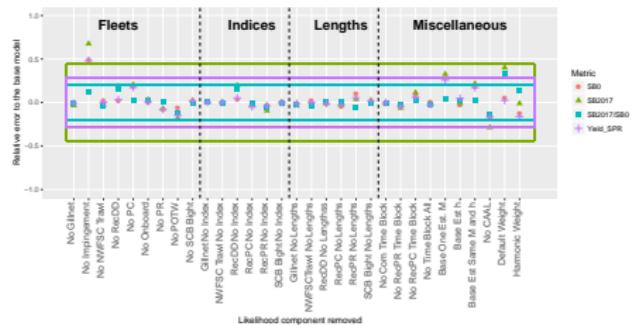
$SB_{2017}$  Population scale

$SB_{2017}/SB_0$

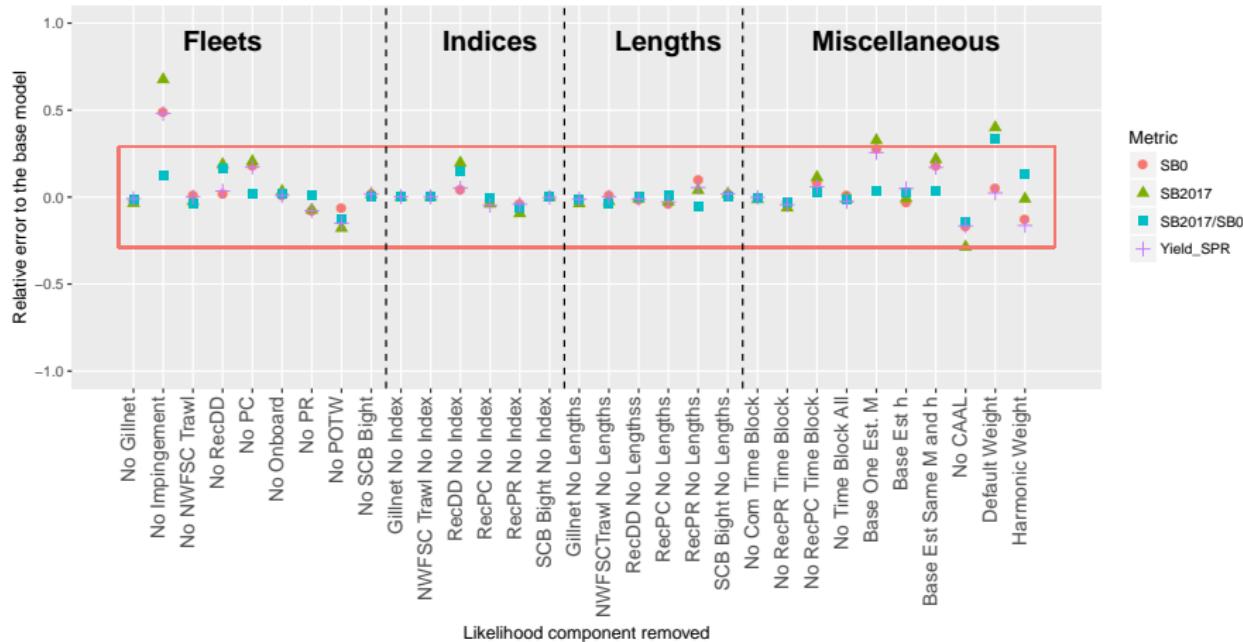
Depletion/Population status

$MSY_{SPR50\%}$

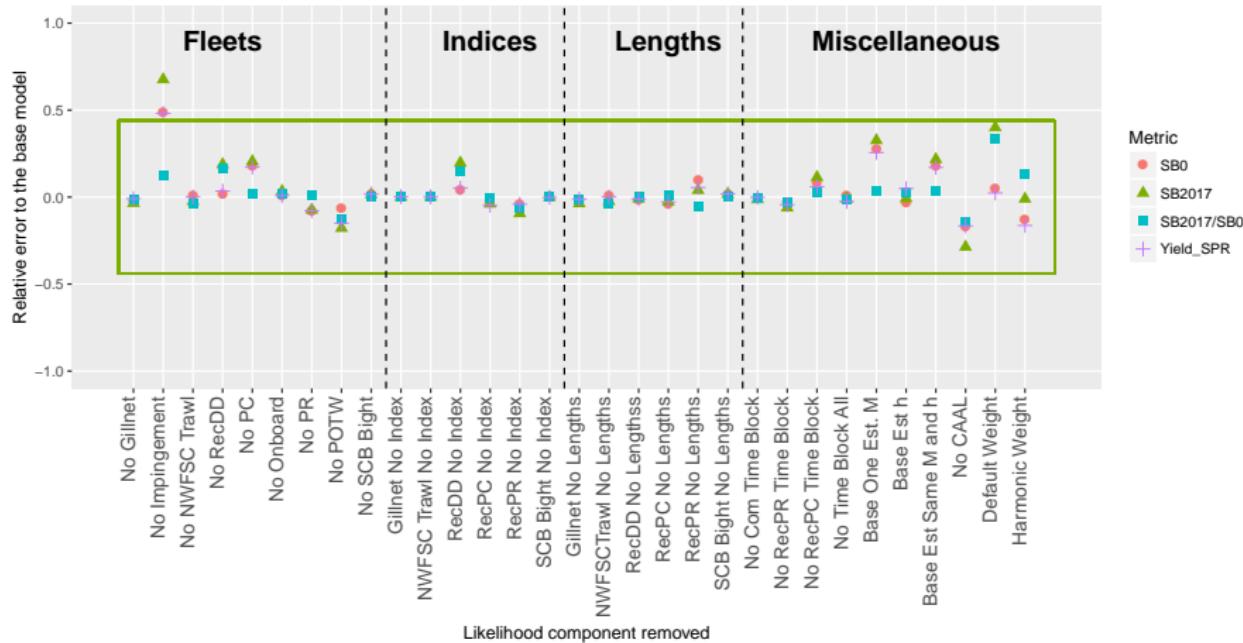
Yield/Productivity/scale



# Sensitivities - $SB_0$



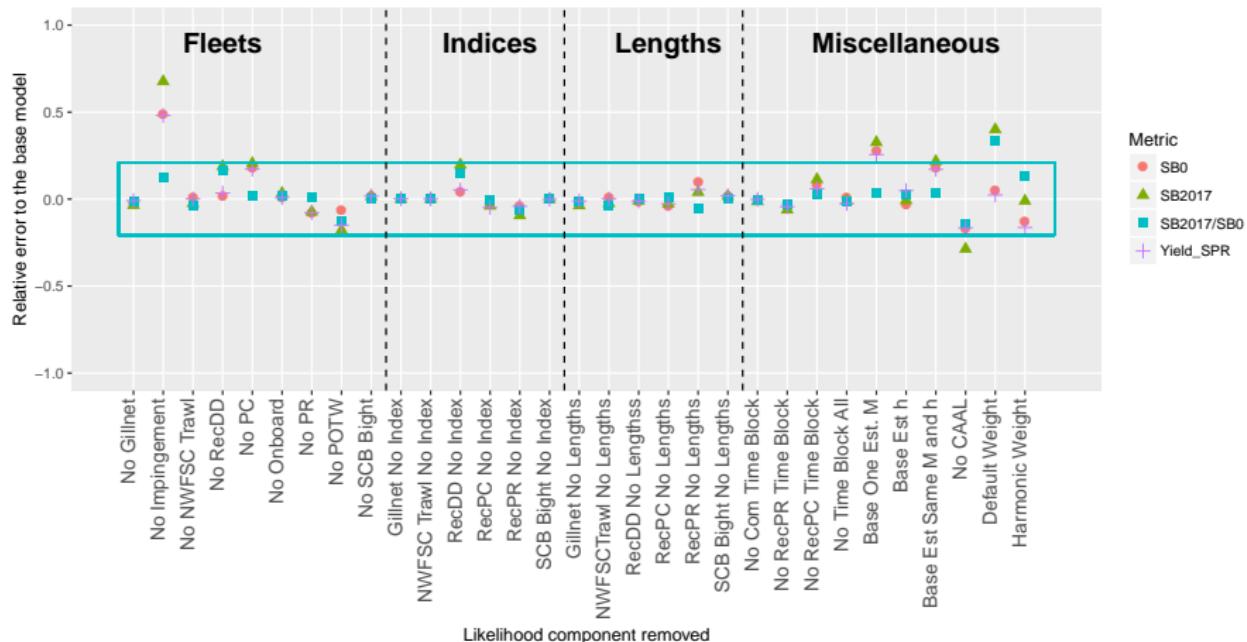
# Sensitivities - SB<sub>2017</sub>



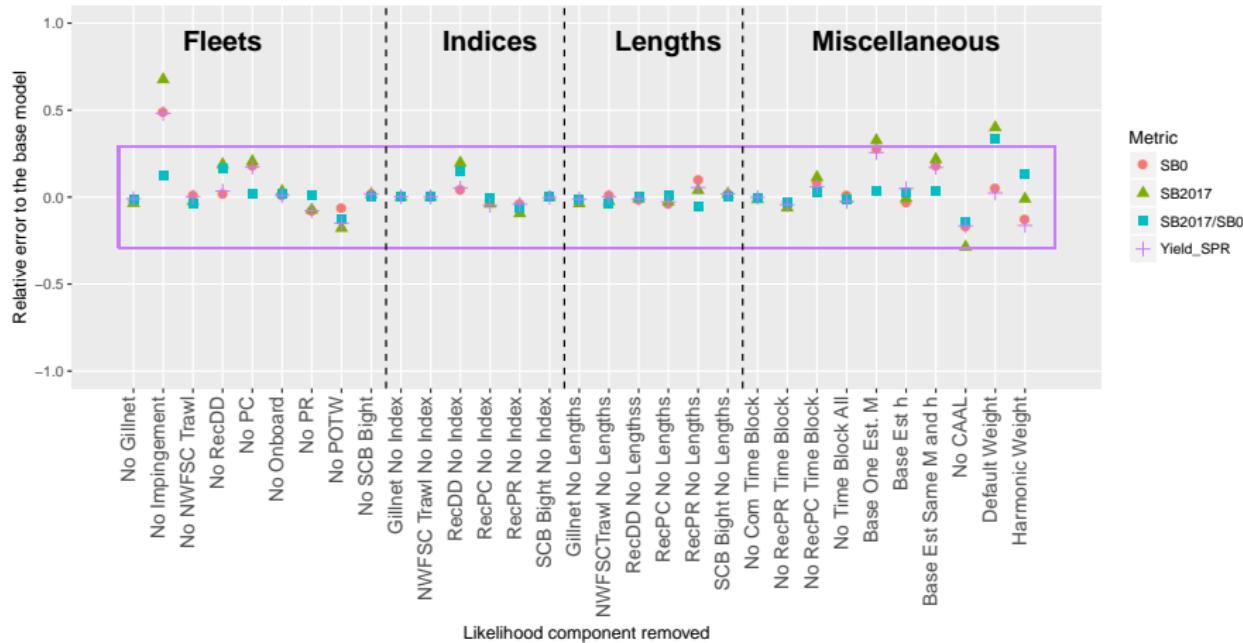
**Metric**

- SB0
- SB2017
- SB2017/SB0
- Yield\_SPR

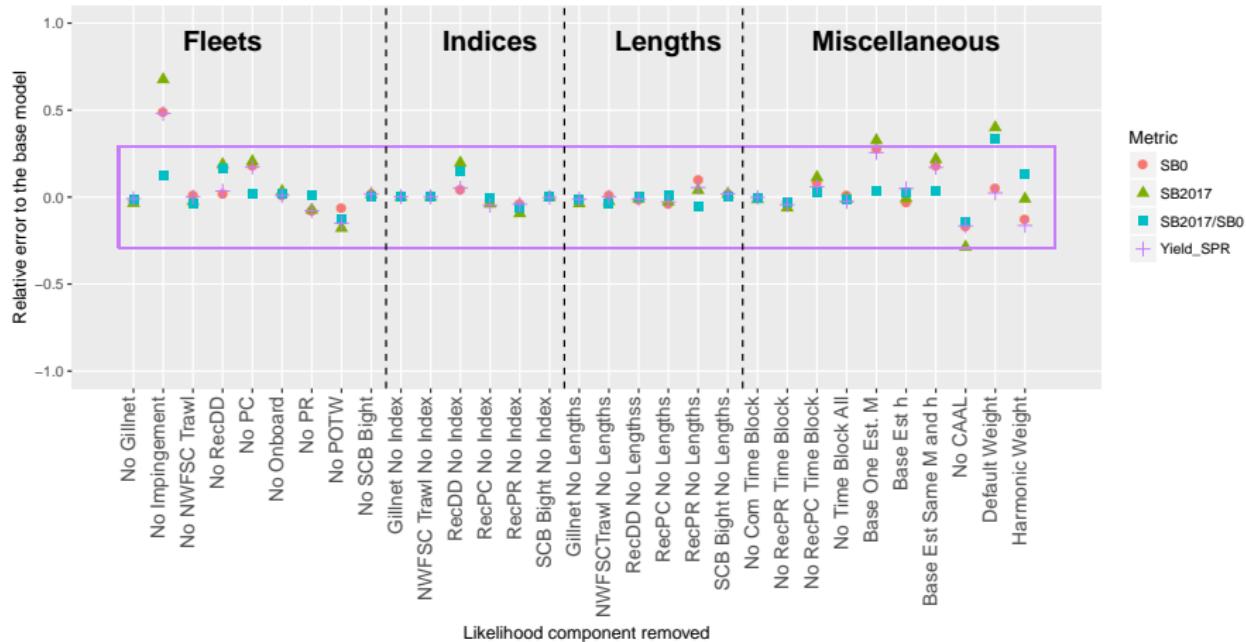
# Sensitivities - Depletion



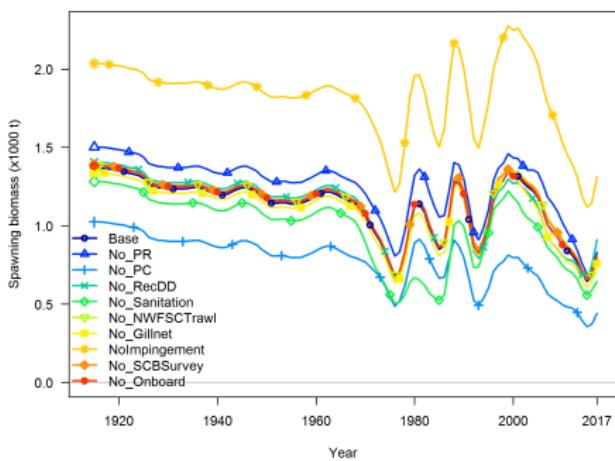
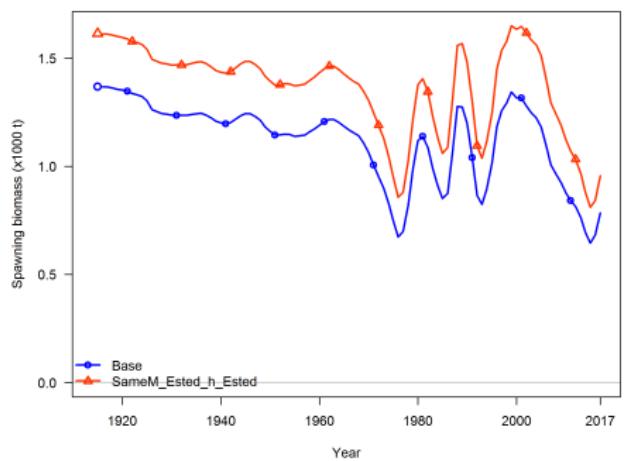
# Sensitivities - Yield at $SPR_{50\%}$



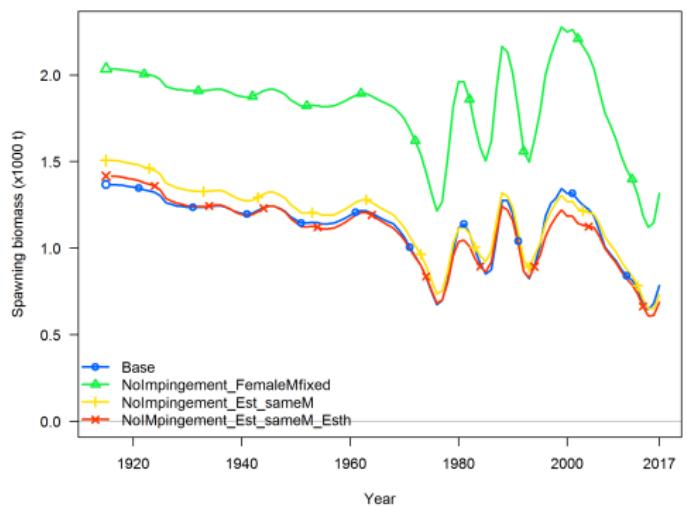
# Sensitivities - All



# Sensitivities

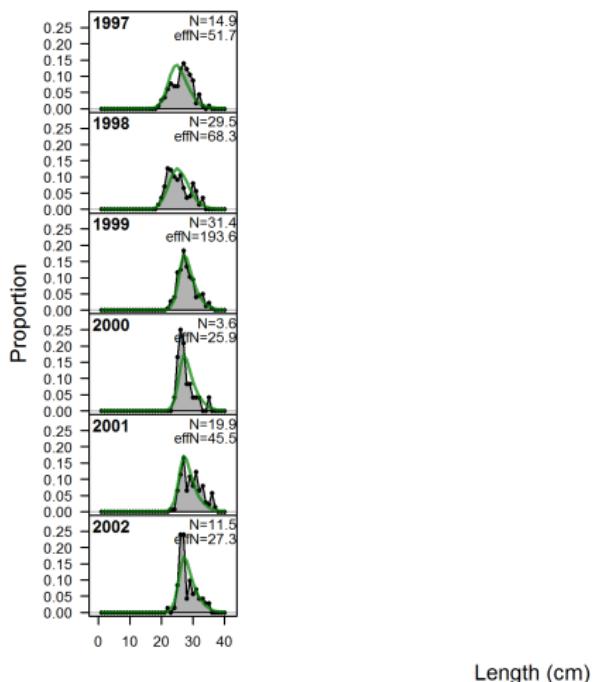


# Sensitivities

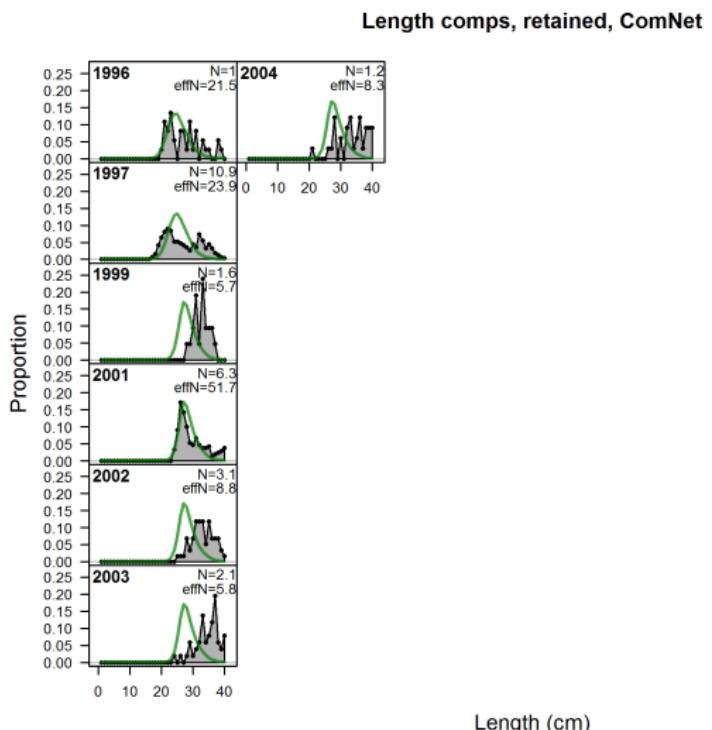


# Length composition fits

Length comps, retained, ComHL

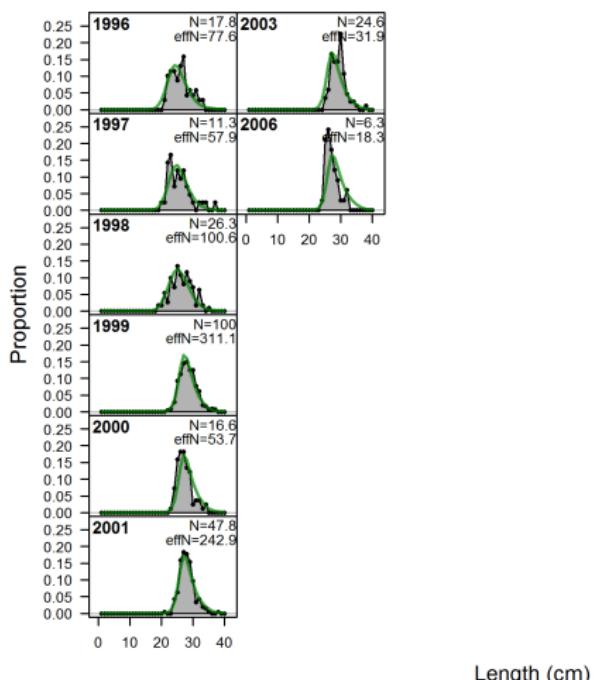


# Length composition fits



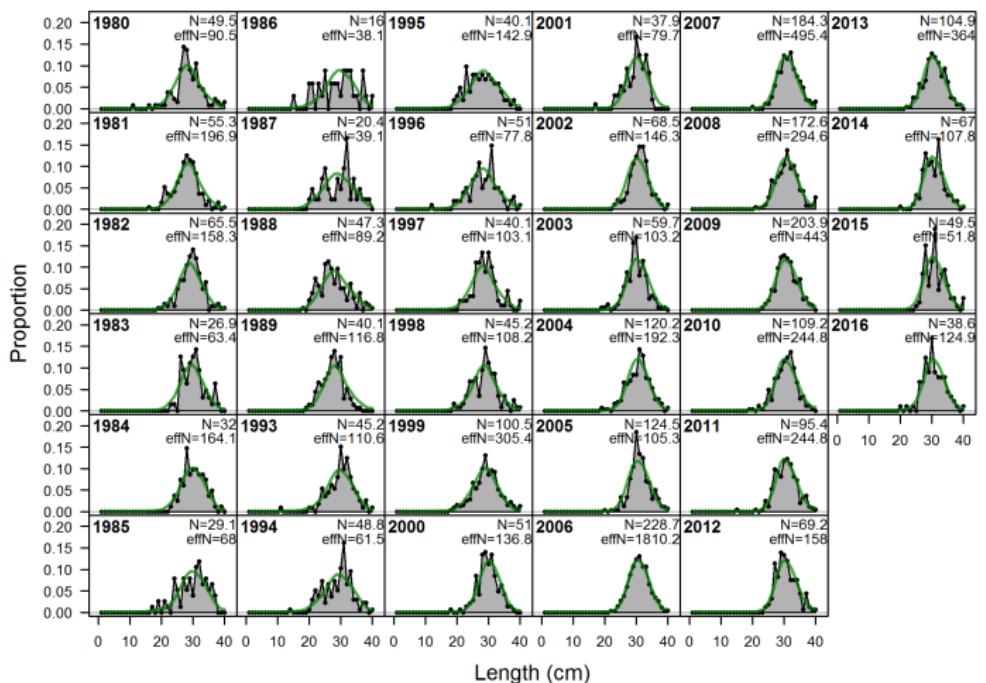
# Length composition fits

Length comps, retained, ComTrawl



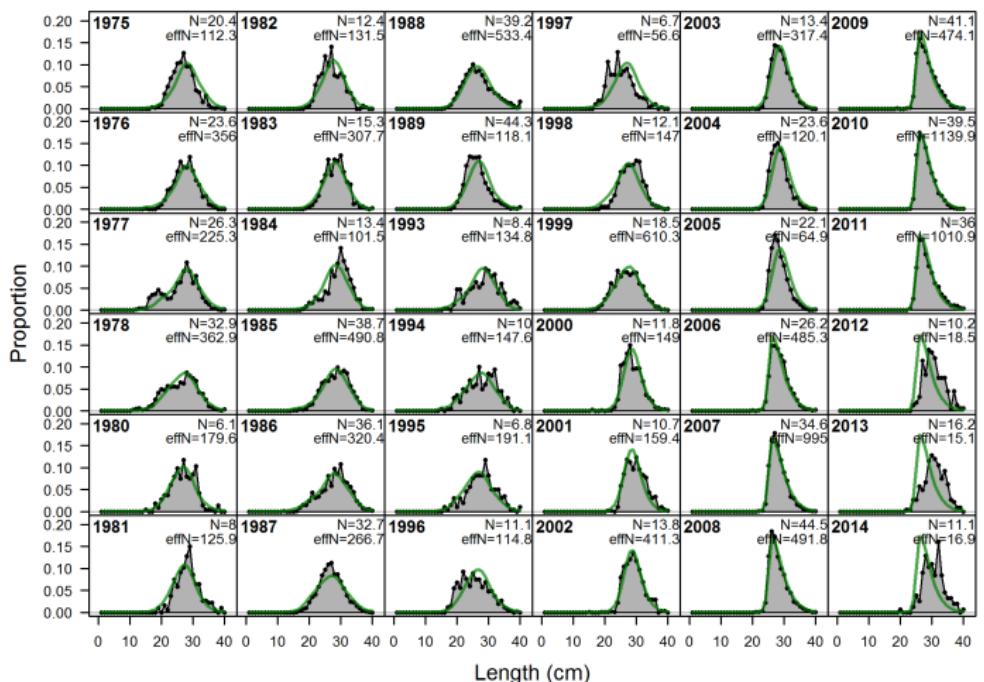
# Length composition fits

Length comps, retained, RecPR



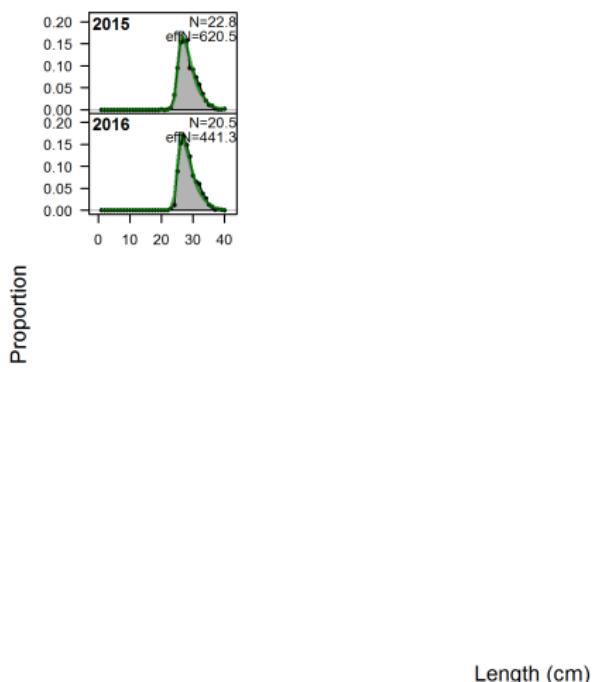
# Length composition fits

Length comps, retained, RecPC



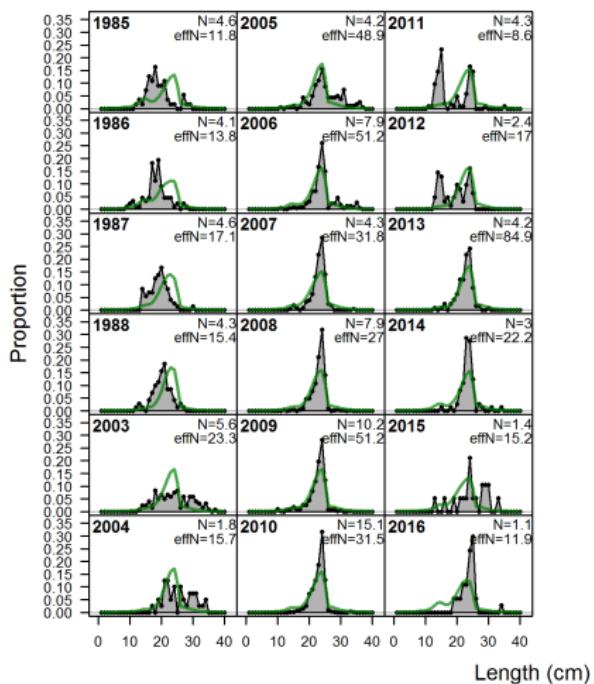
# Length composition fits

Length comps, retained, RecPC



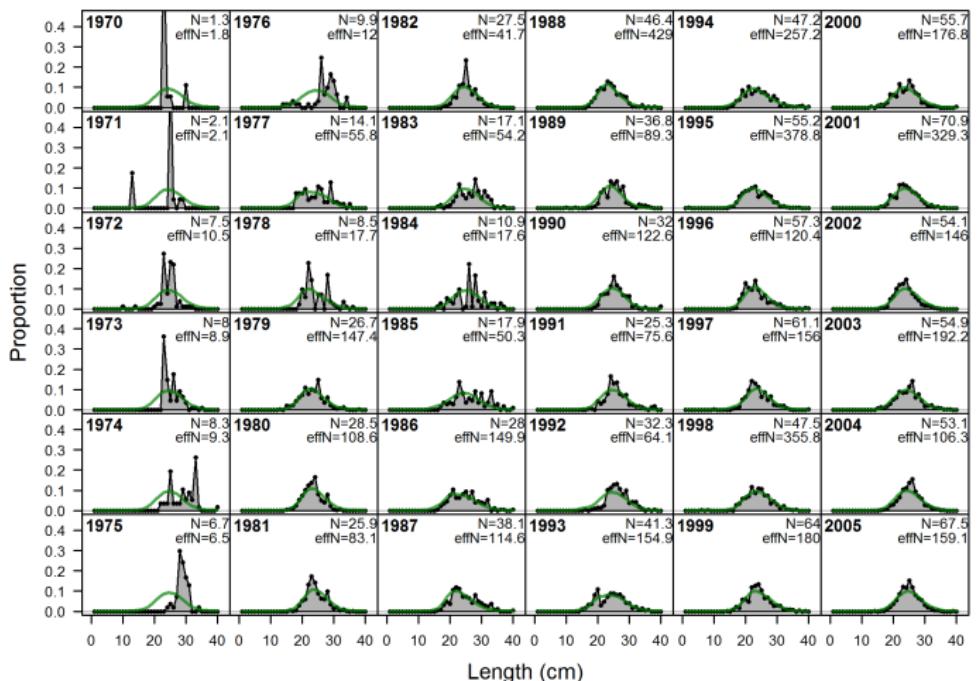
# Length composition fits

Length comps, retained, RecDD



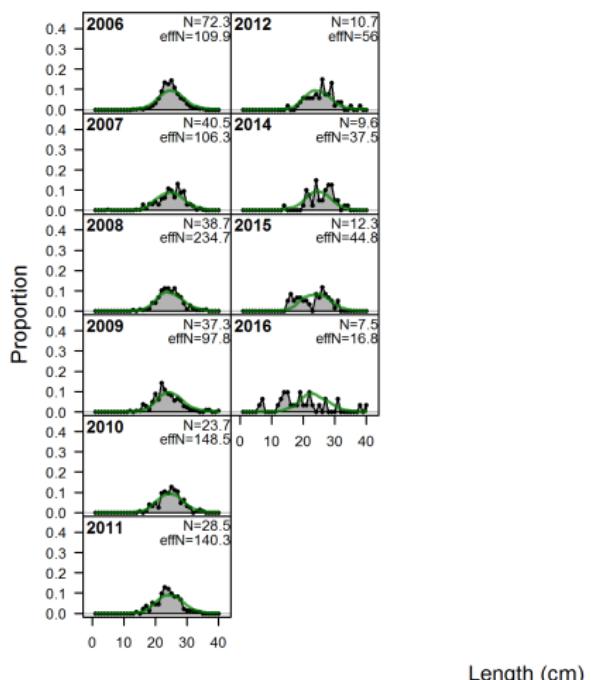
# Length composition fits

Length comps, retained, Sanitation



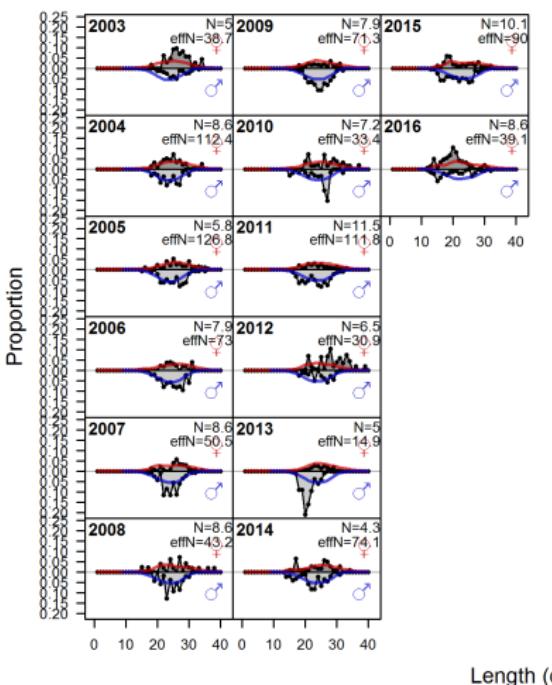
# Length composition fits

Length comps, retained, Sanitation



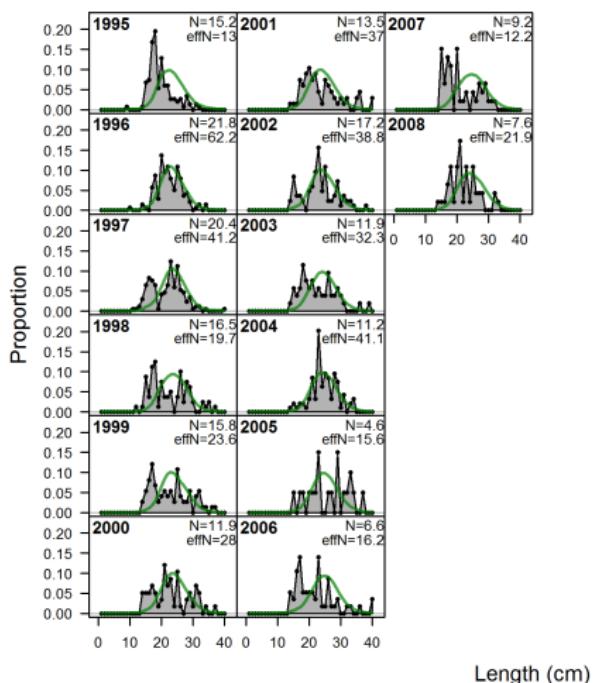
# Length composition fits

Length comps, whole catch, NWFSC Trawl



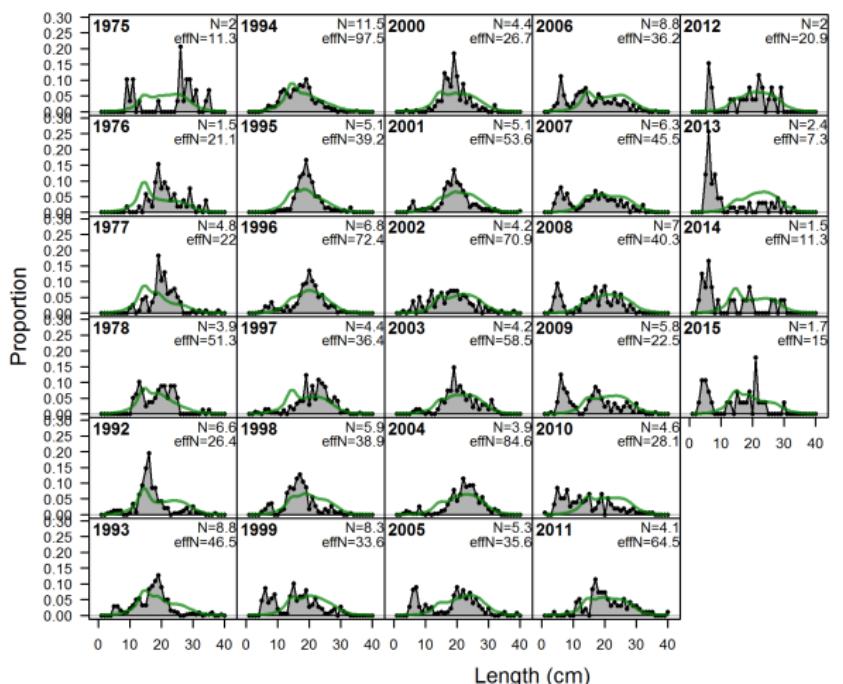
# Length composition fits

Length comps, retained, GillnetSurvey



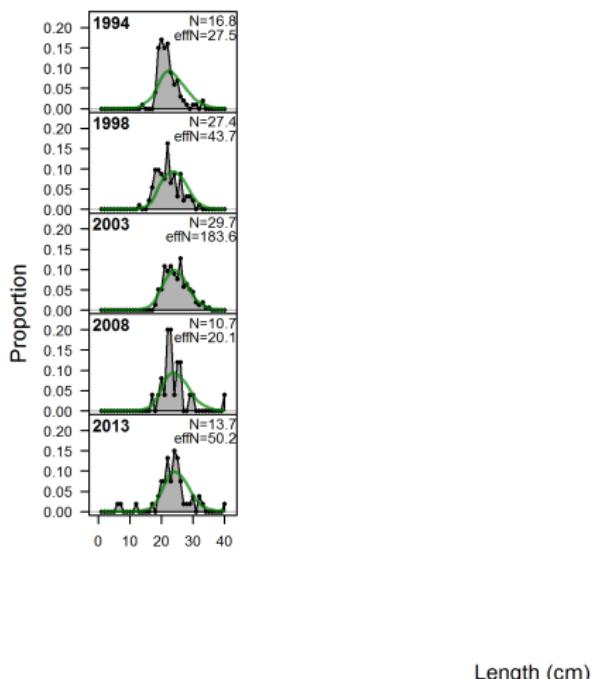
# Length composition fits

Length comps, retained, Impingement

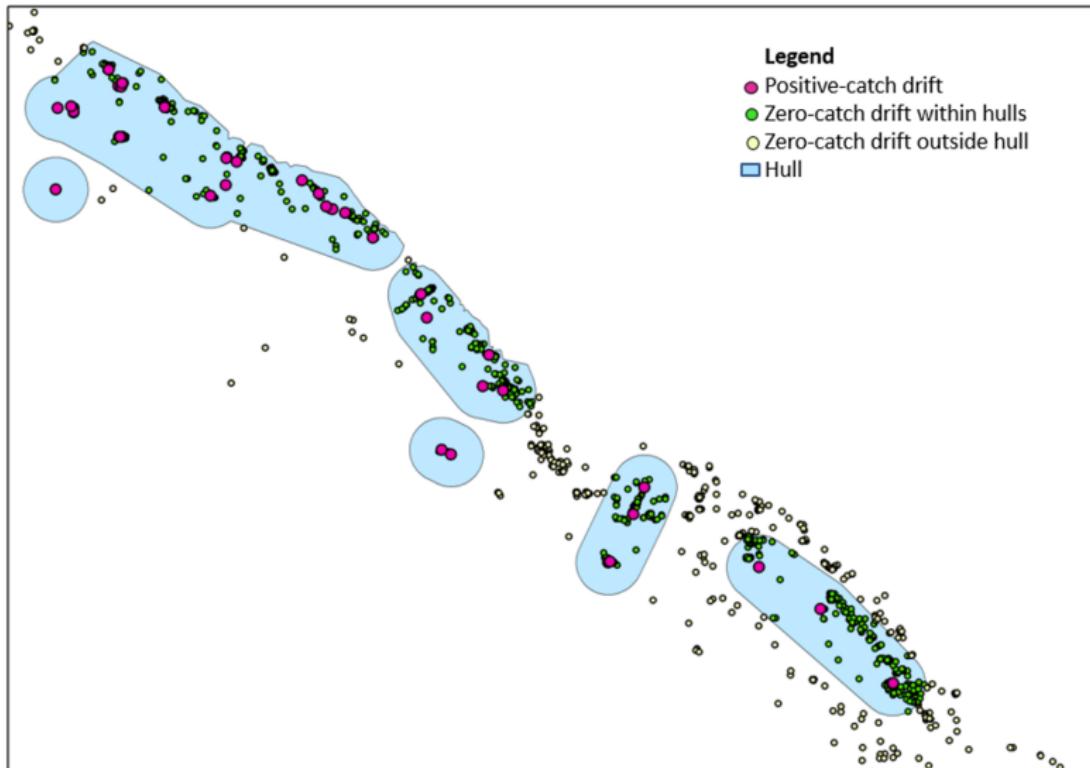


# Length composition fits

Length comps, retained, SCBSurvey



# Hull method (Onboard observer index)



# VAST diagnostics

