Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

ISC Billfish Working Group

Overview

- **Overview of the 2018 Benchmark Stock Assessment**

- **2018 Assessment Data and Model**
  - **Swordfish Life History Information**
  - **Fishery Definitions and Selectivity Modeling**
  - **Updated Catch, Standardized CPUE, and Size Composition Data**
  - **Likelihood Components and Data Weighting**
  - **Base Case Model Diagnostics**

- **2018 Assessment Results**
  - **Comparison with 2014 Assessment**
  - **Stock Status**
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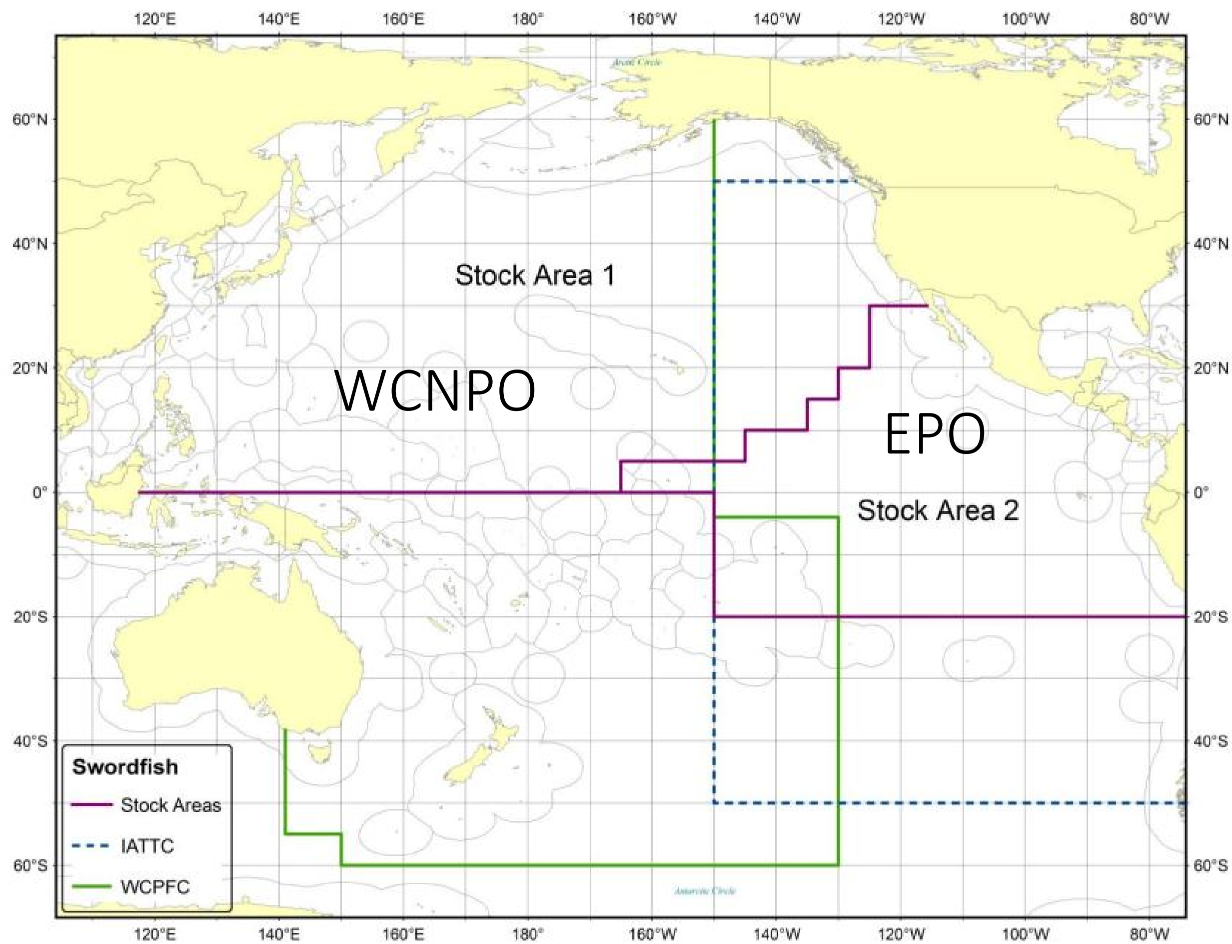
North Pacific Swordfish Stock Areas

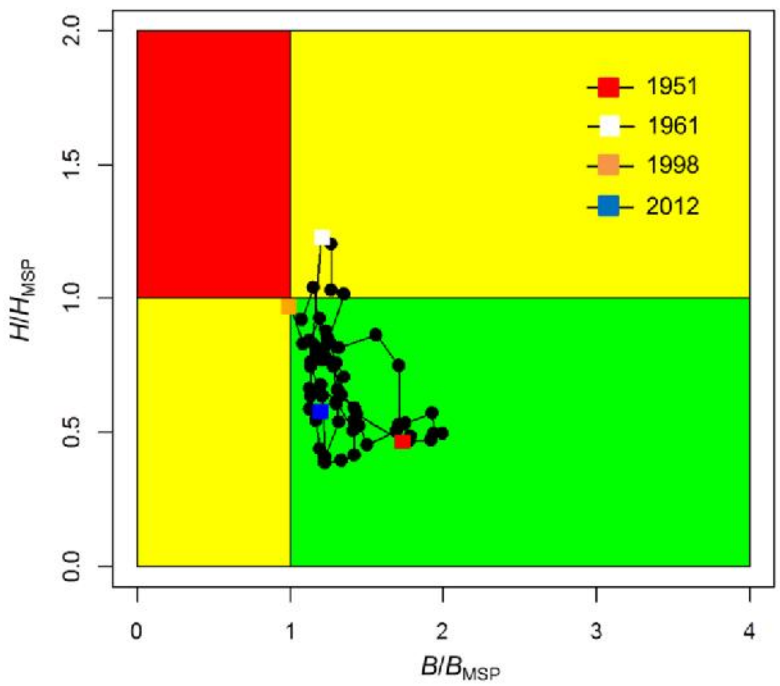


WCNPO Swordfish Assessment:
Chang et al. (2014) ISC/14/BILLWG-1/02

EPO Swordfish Assessment:
Yau et al. (2014) ISC/14/BILLWG-1/01

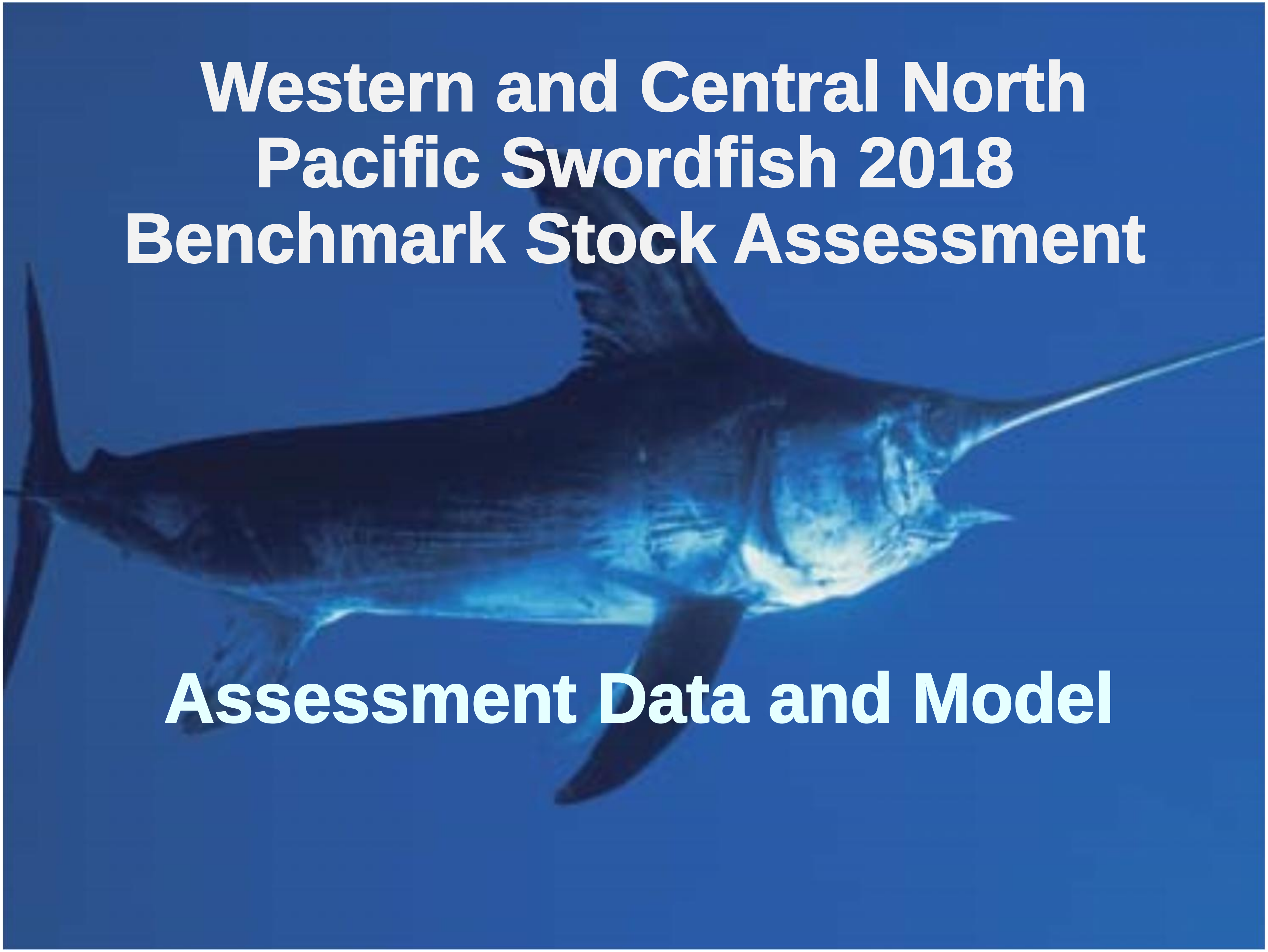
Overview of the 2014 Stock Assessment

- 2014 Stock Assessment Summary
  - Bayesian surplus production model (ISC 2014)
  - B_{2012} = 72,500 mt (19 % above B_{MSY})
  - H_{2012} = 0.58 (40% below H_{MSY})
  - **WCNPO swordfish was not experiencing overfishing and was not overfished relative to MSY-based reference points**



Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

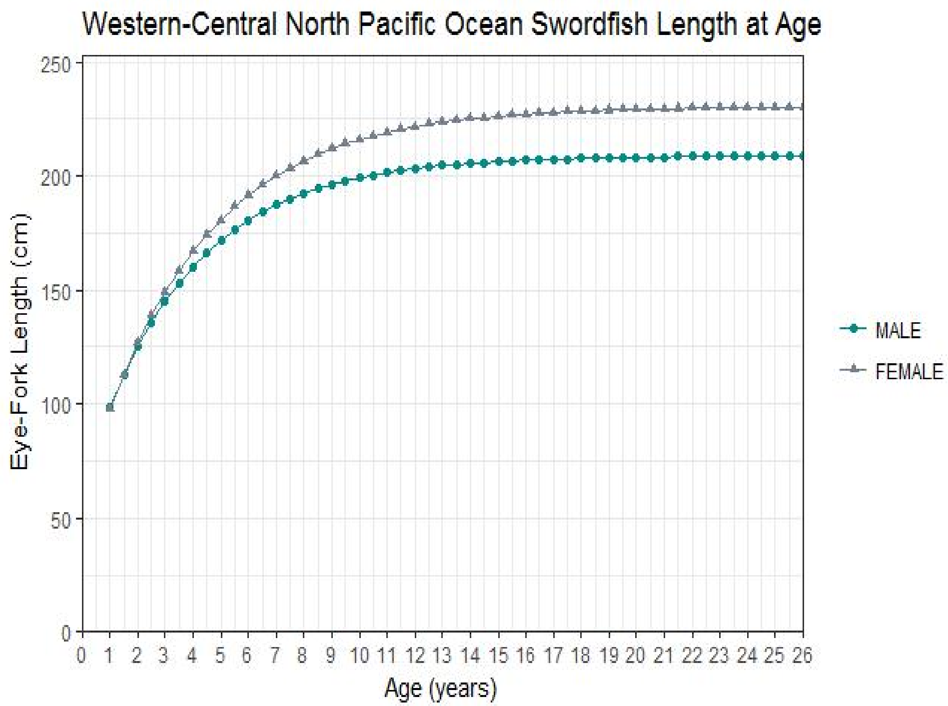
Assessment Data and Model

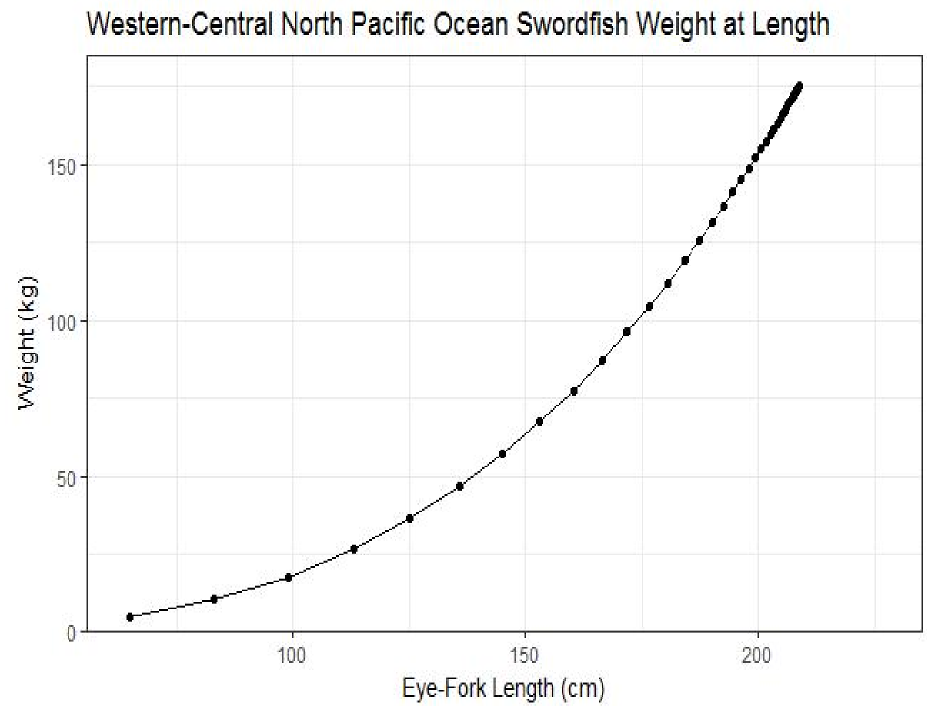


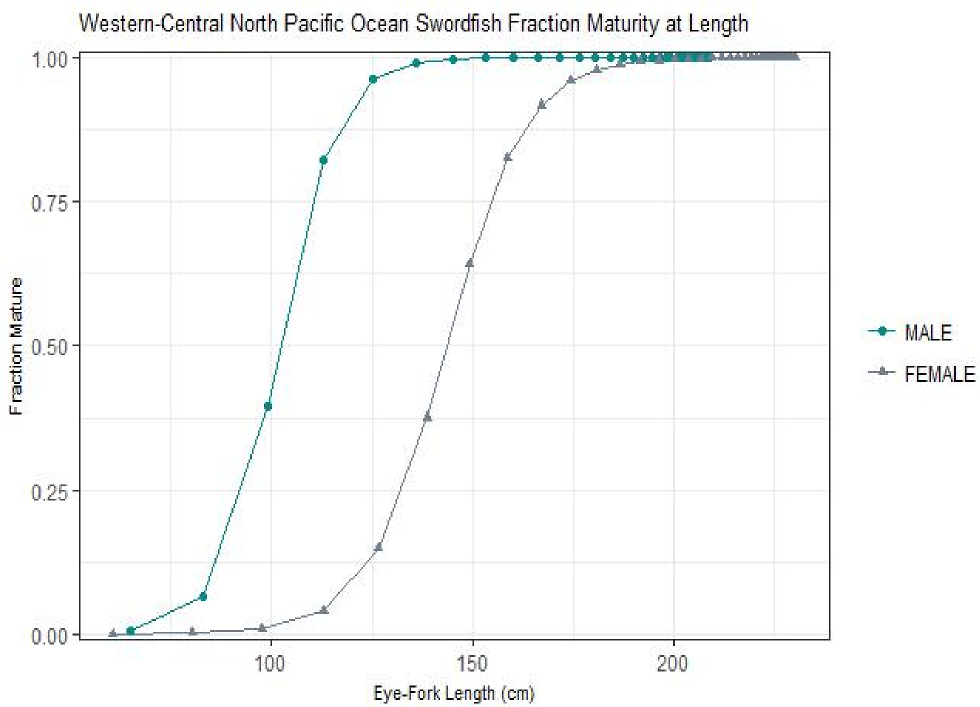
WCNPO Swordfish
Life History Information

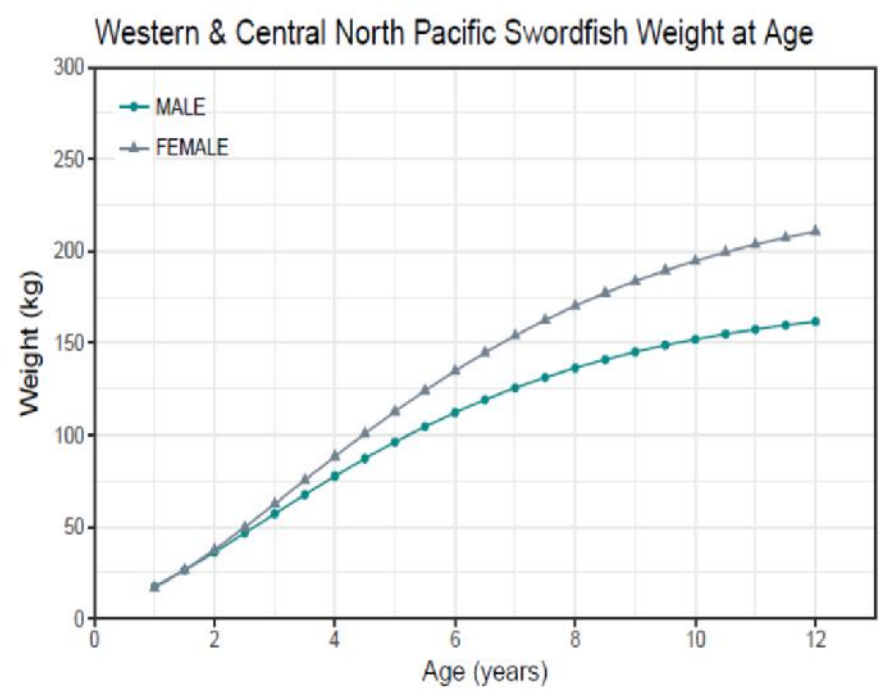
Life History and Fishery Parameters

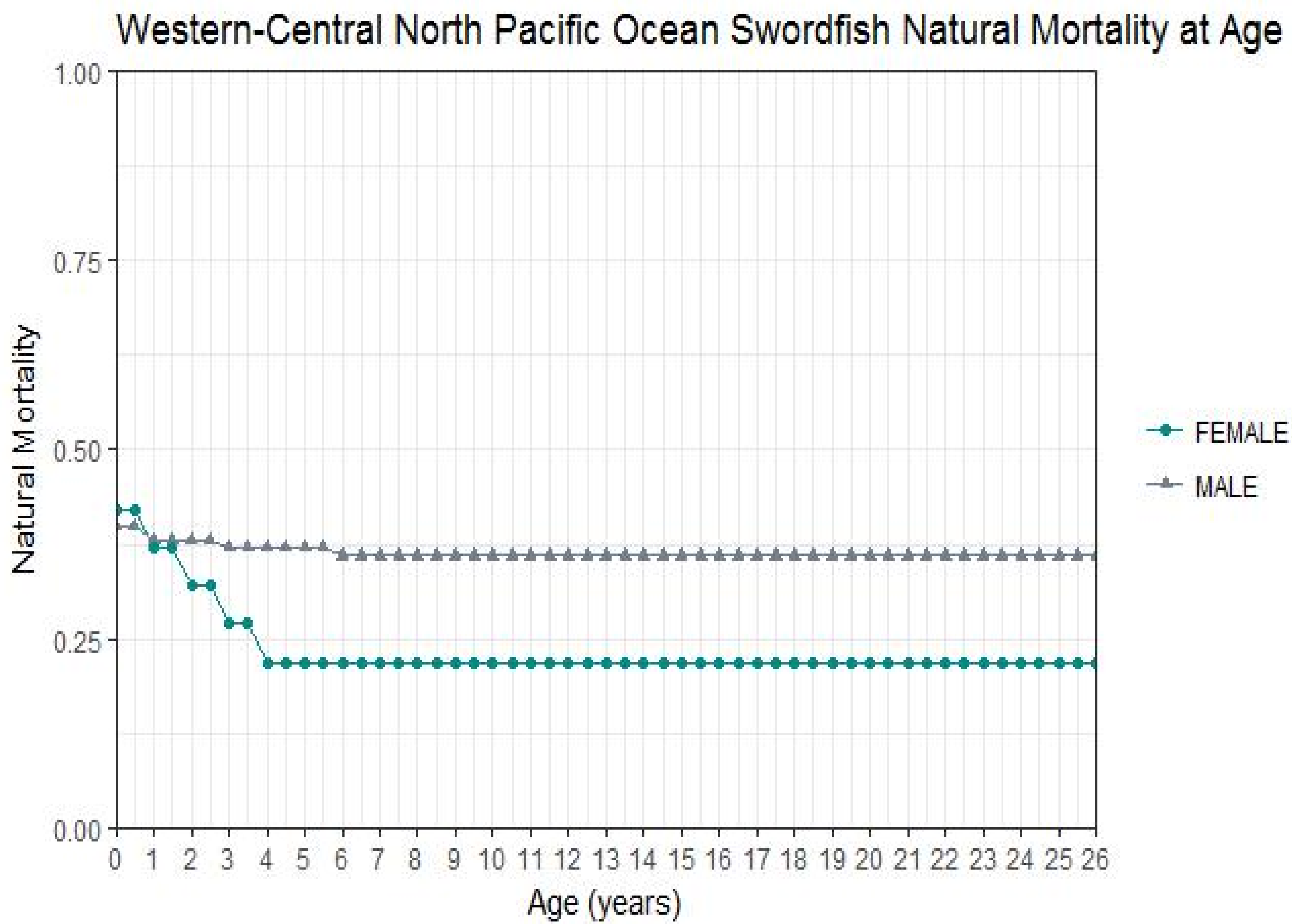
Parameter (units)	**Value**	**Estimated?**
Natural mortality (M, age-specific^{-yr})	Female: M_0 = 0.42, M_1 = 0.37, M_2 = 0.32, M_3 = 0.27, M_{4+} = 0.22 Male: M_0 = 0.40, M_{1-2} = 0.38, M_{3-5} = 0.37, M_{4+} = 0.36	Fixed
Length_at_min_age (EFL cm)	Female: L(A_{min}) = 97.7 Male: L(A_{min}) = 99.0	Fixed
Length_at_max_age (EFL cm)	Female: L(A_{max}) = 226.3 Male: L(A_{max}) = 206.4	Fixed
Von Bertalanffy_K	Female: *k* = 0.246 Male: *k* = 0.271	Fixed
$W=aL^b$ (kg)	Both genders: *a* = 1.299 ×10-5 *b* = 3.0738	Fixed
Size at 50-percent maturity (EFL cm) and maturity ogive slope parameter	Female: L_{50} = 143.6, β = -0.103 Male: L_{50} = 102.0, β = -0.141	Fixed
Stock-recruitment steepness (*h*)	*h*= 0.9	Fixed
Unfished log-scale recruitment (Ln(*R0*))	-	Estimated
Standard deviation of recruitment (*σR*)	*σR* = 0.6	Fixed
Initial age structure	-	Estimated
Recruitment deviations	-	Estimated
Selectivity	-	Estimated
Catchability		Estimated

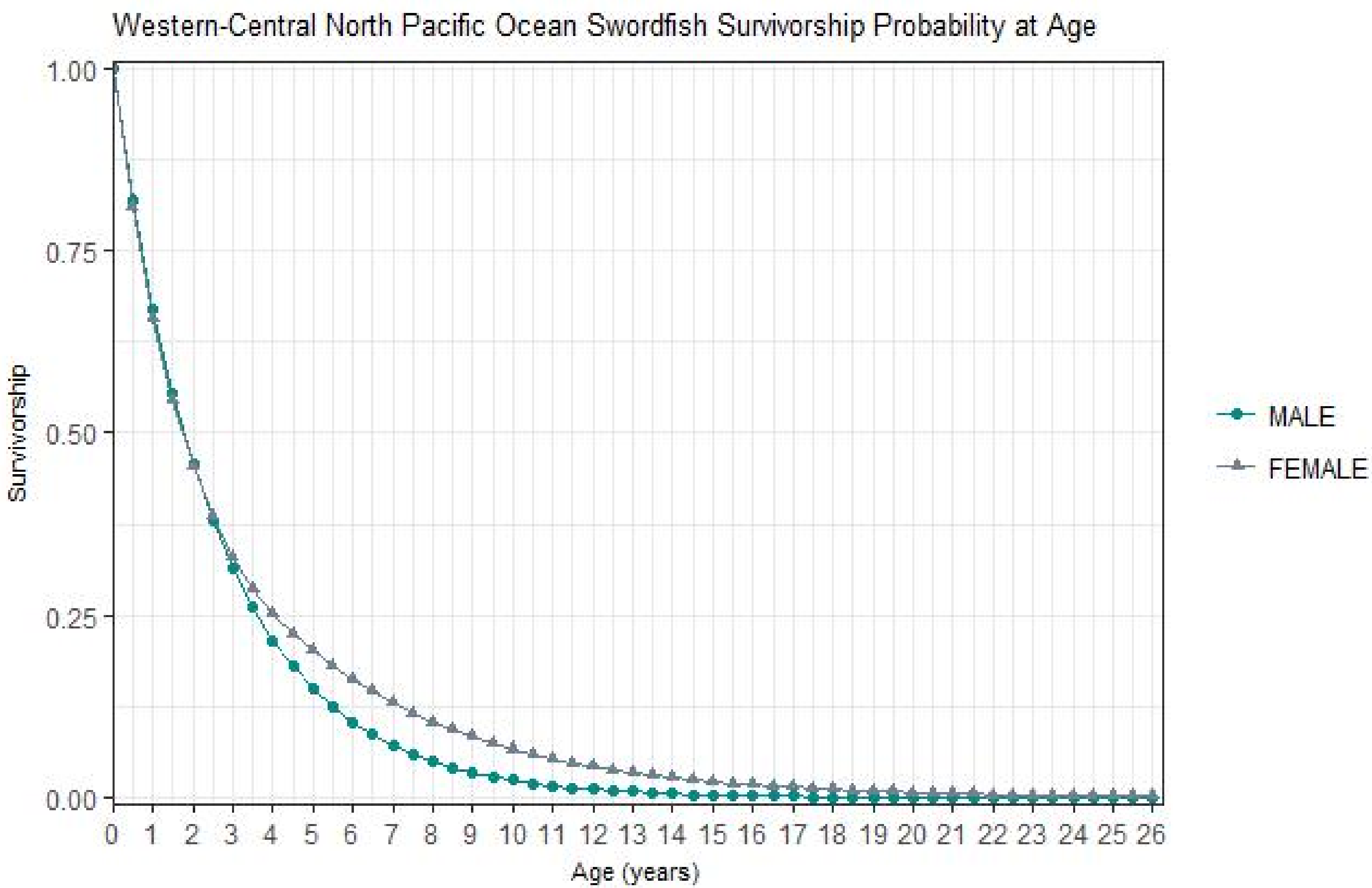

Western-Central North Pacific Ocean Swordfish Length at Age
Eye-Fork Length (cm)
Age (years)
MALE
FEMALE


Western-Central North Pacific Ocean Swordfish Weight at Length
Weight (kg)
Eye-Fork Length (cm)

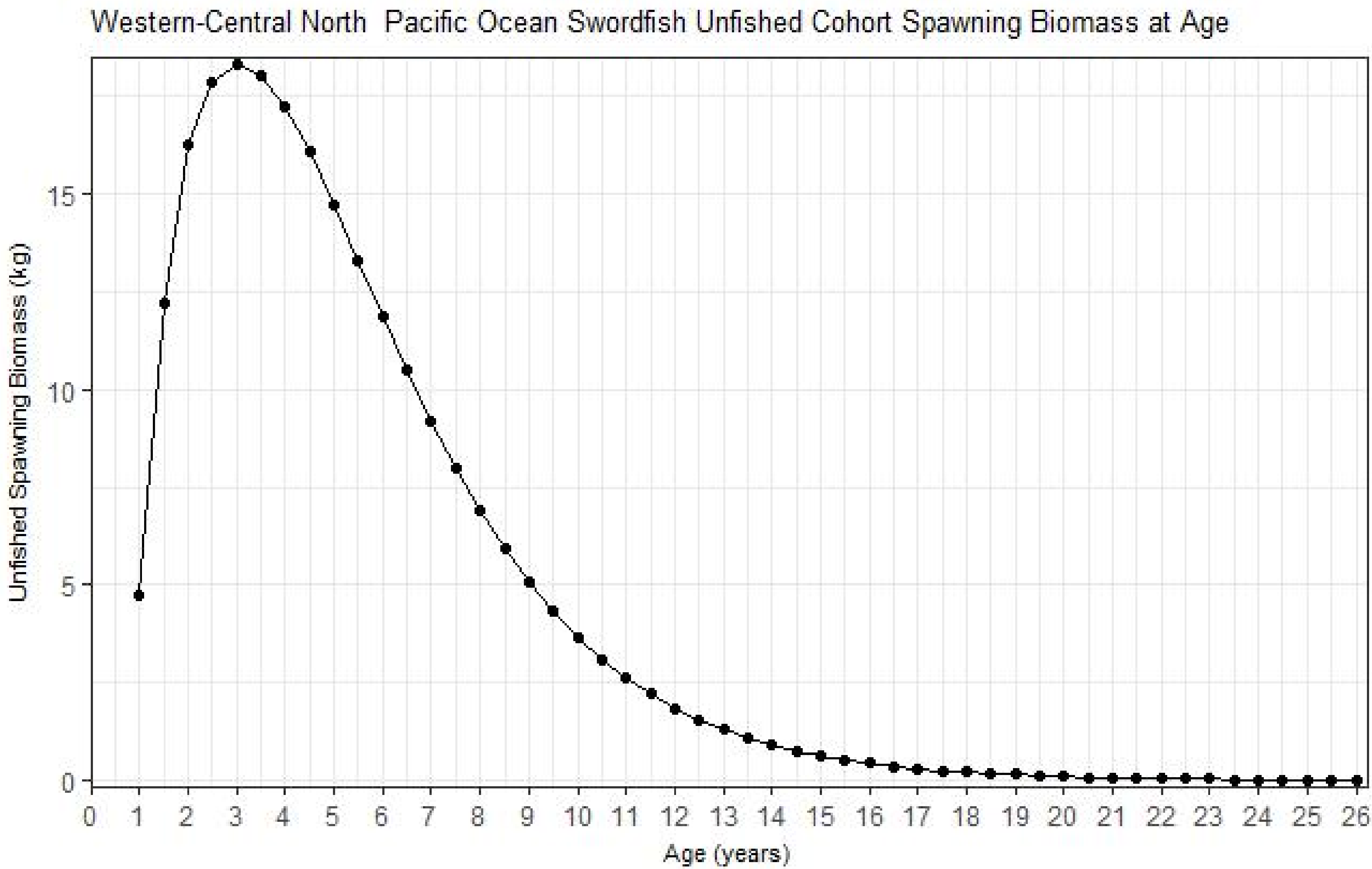

Western-Central North Pacific Ocean Swordfish Fraction Maturity at Length
Fraction Mature
Eye-Fork Length (cm)
MALE
FEMALE


Western & Central North Pacific Swordfish Weight at Age
MALE
FEMALE
Weight (kg)
Age (years)


Western-Central North Pacific Ocean Swordfish Natural Mortality at Age
1.00
0.75
0.50
0.25
0.00
Natural Mortality
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
Age (years)
FEMALE
MALE


Western-Central North Pacific Ocean Swordfish Survivorship Probability at Age
Survivorship
1.00
0.75
0.50
0.25
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Age (years)
MALE
FEMALE

( ) = exp (− ( ))


Western-Central North Pacific Ocean Swordfish Unfished Cohort Spawning Biomass at Age
Unfished Spawning Biomass (kg)
0
5
10
15
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Age (years)

. . ( ) = . ( ) × × . (( ))

Steepness

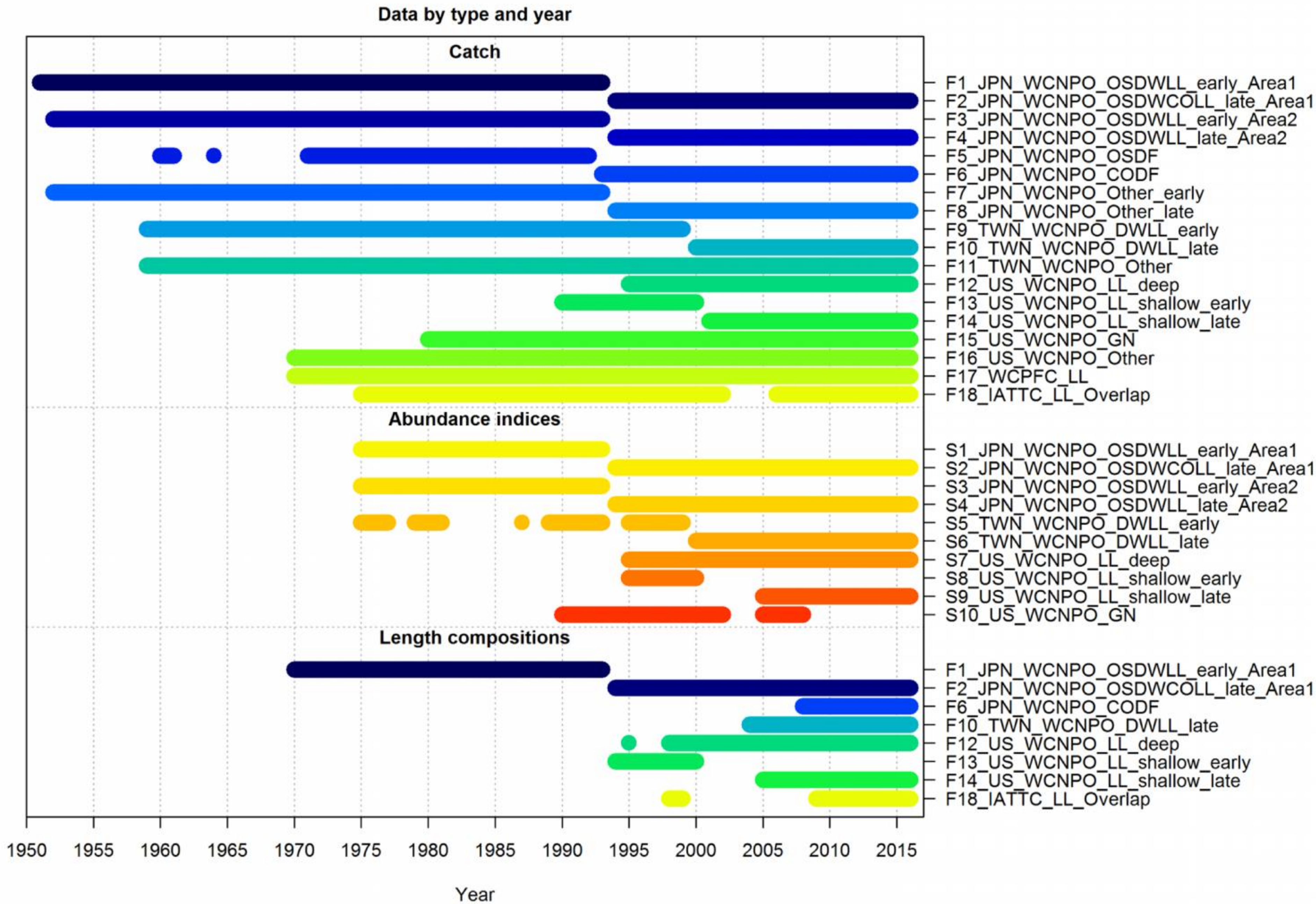
- Stock-Recruitment Resilience
- For **WCNPO Swordfish**, a steepness of h=0.90 based on Myers et al. (1999) and Sharma and Arocha (2017)

$$= \quad (\quad) = \frac{4h}{(1-h) + \quad (5h-1)}$$

Definition of WCNPO Swordfish Fisheries

WCNPO Swordfish Fleets

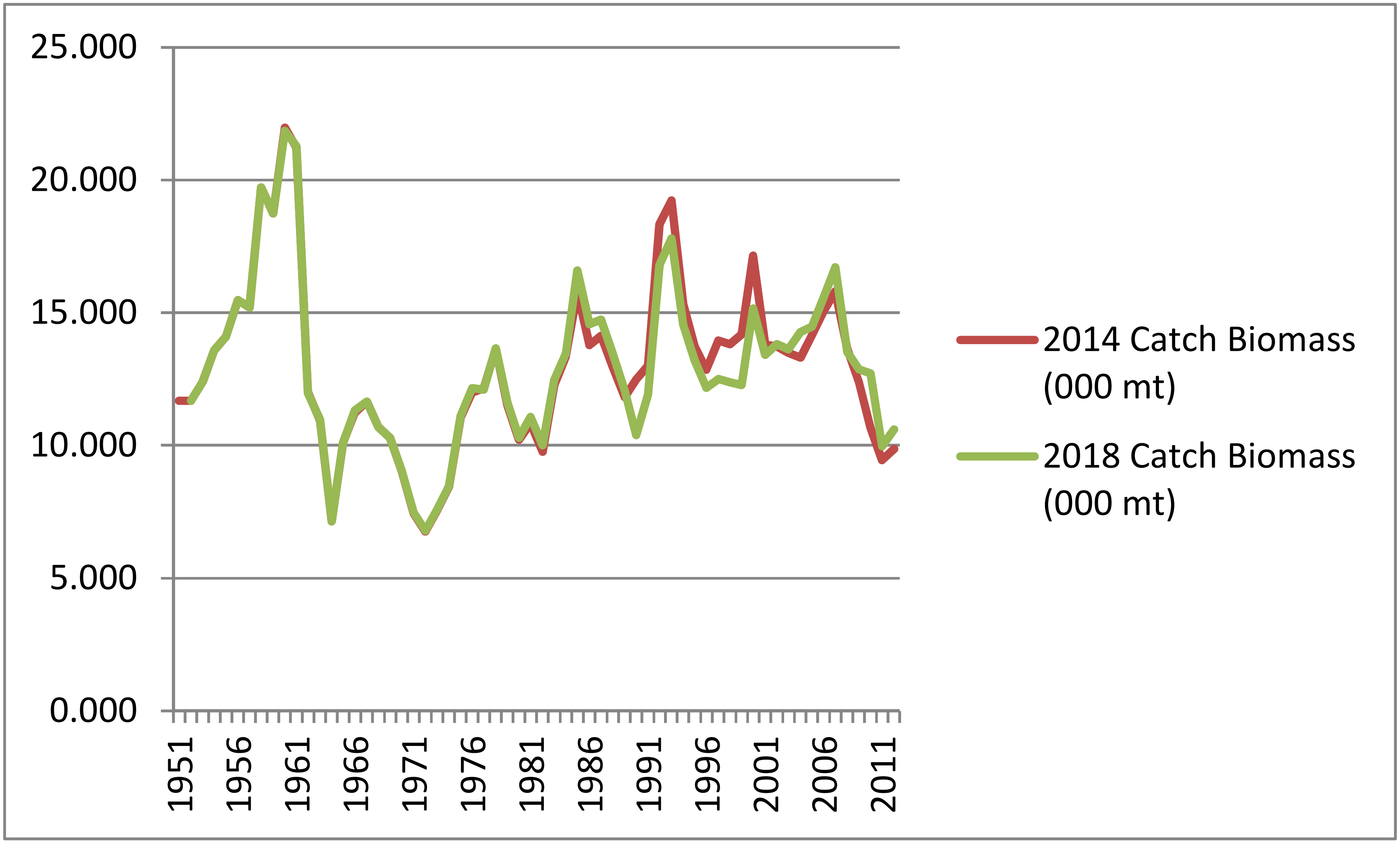
Size Data	CPUE	Fleet Name	Time Series	Source
F1 – N	S1 – Y	JPN_WCNPO_OSDWLL_early_Area 1	1975-1993	Kanaiwa and Ijima 2018
F2-Y	S2 – Y	JPN_WCNPO_OSDWLL_late_Area1	1994-2016	Kanaiwa and Ijima 2018
F3	S3 – Y	JPN_WCNPO_OSDWLL_early_Area 2	1975-1993	Kanaiwa and Ijima 2018
F4	S4 – Y	JPN_WCNPO_OSDWLL_late_Area2	1994-2016	Kanaiwa and Ijima 2018
F5	-	JPN_WCNPO_OSDF	1960-1992	Hirotaka Ijima, pers. comm.
F6 – N	-	JPN_WCNPO_CODF	1993-2014	Hirotaka Ijima, pers. comm.
F7	-	JPN_WCNPO_Other_Early	1952-1993	Hirotaka Ijima, pers. comm.
F8	-	JPN_WCNPO_Other_Late	1994-2016	Hirotaka Ijima, pers. comm.
F9	S5 – N	TWN_WCNPO_DWLL _early	1975-1999	Chang et al. 2018
F10-Y	S6 – Y	TWN_WCNPO_DWLL _late	2000-2016	Chang et al. 2018
F11	-	TWN_WCNPO_Other	1959-2016	Yi-Jay Chang, pers. comm
F12 – N	S7 – Y	US_WCNPO_LL_deep	1995-2016	Sculley et al. 2018
F13 – N	S8 – Y	US_WCNPO_LL_shallow_early	1995-2000	Sculley et al. 2018
F14-Y	S9 – Y	US_WCNPO_LL_shallow_late	2005-2016	Sculley et al. 2018
F15	S10 – N	US_WCNPO_GN	1985-2006	Courtney et al. 2009
F16	-	US_WCNPO_Other	1970-2016	Ito et al. 2018
F17	-	WCPFC_LL	1970-2016	Darryl Tagami, pers. comm.
F18-Y	-	IATTC_LL_Overlap	1975-2016	Shane Griffiths, pers. comm.


Data by type and year
Catch
Abundance indices
Length compositions
F1_JPN_WCNPO_OSDWLL_early_Area1
F2_JPN_WCNPO_OSDWCOLL_late_Area1
F3_JPN_WCNPO_OSDWLL_early_Area2
F4_JPN_WCNPO_OSDWLL_late_Area2
F5_JPN_WCNPO_OSDF
F6_JPN_WCNPO_CODF
F7_JPN_WCNPO_Other_early
F8_JPN_WCNPO_Other_late
F9_TWN_WCNPO_DWLL_early
F10_TWN_WCNPO_DWLL_late
F11_TWN_WCNPO_Other
F12_US_WCNPO_LL_deep
F13_US_WCNPO_LL_shallow_early
F14_US_WCNPO_LL_shallow_late
F15_US_WCNPO_GN
F16_US_WCNPO_Other
F17_WCPFC_LL
F18_IATTC_LL_Overlap
S1_JPN_WCNPO_OSDWLL_early_Area1
S2_JPN_WCNPO_OSDWCOLL_late_Area1
S3_JPN_WCNPO_OSDWLL_early_Area2
S4_JPN_WCNPO_OSDWLL_late_Area2
S5_TWN_WCNPO_DWLL_early
S6_TWN_WCNPO_DWLL_late
S7_US_WCNPO_LL_deep
S8_US_WCNPO_LL_shallow_early
S9_US_WCNPO_LL_shallow_late
S10_US_WCNPO_GN
F1_JPN_WCNPO_OSDWLL_early_Area1
F2_JPN_WCNPO_OSDWCOLL_late_Area1
F6_JPN_WCNPO_CODF
F10_TWN_WCNPO_DWLL_late
F12_US_WCNPO_LL_deep
F13_US_WCNPO_LL_shallow_early
F14_US_WCNPO_LL_shallow_late
F18_IATTC_LL_Overlap
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

WCNPO Swordfish Catch Data

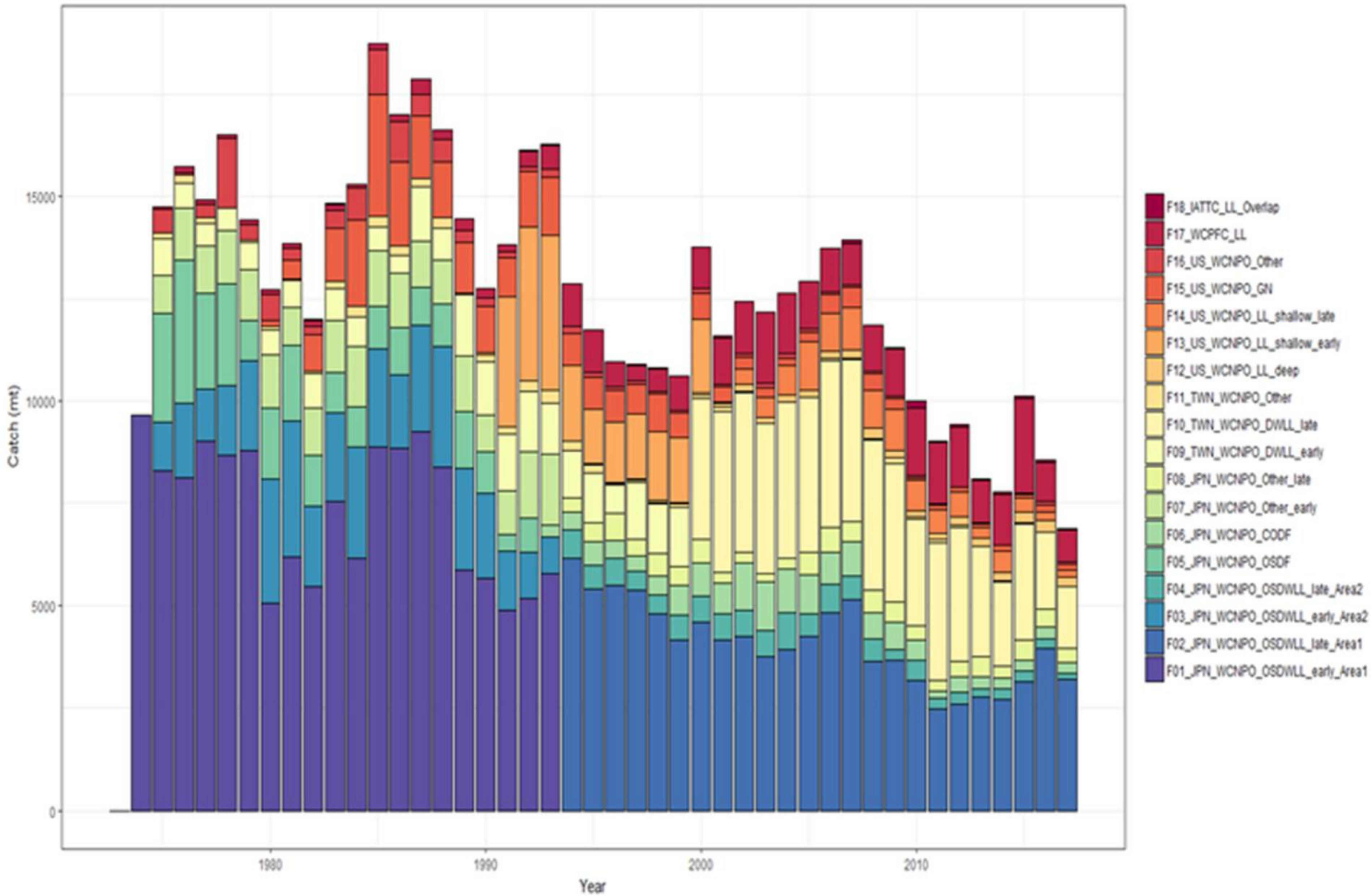
- Catches are assumed to be well reported
- Catch data for 1975 to 2016 were gathered from all available fleets and sources
- There were some differences between the catch data used in the 2014 assessment and the 2018 benchmark

Differences in Annual Catches (mt) Between 2018 and 2014 Stock Assessments

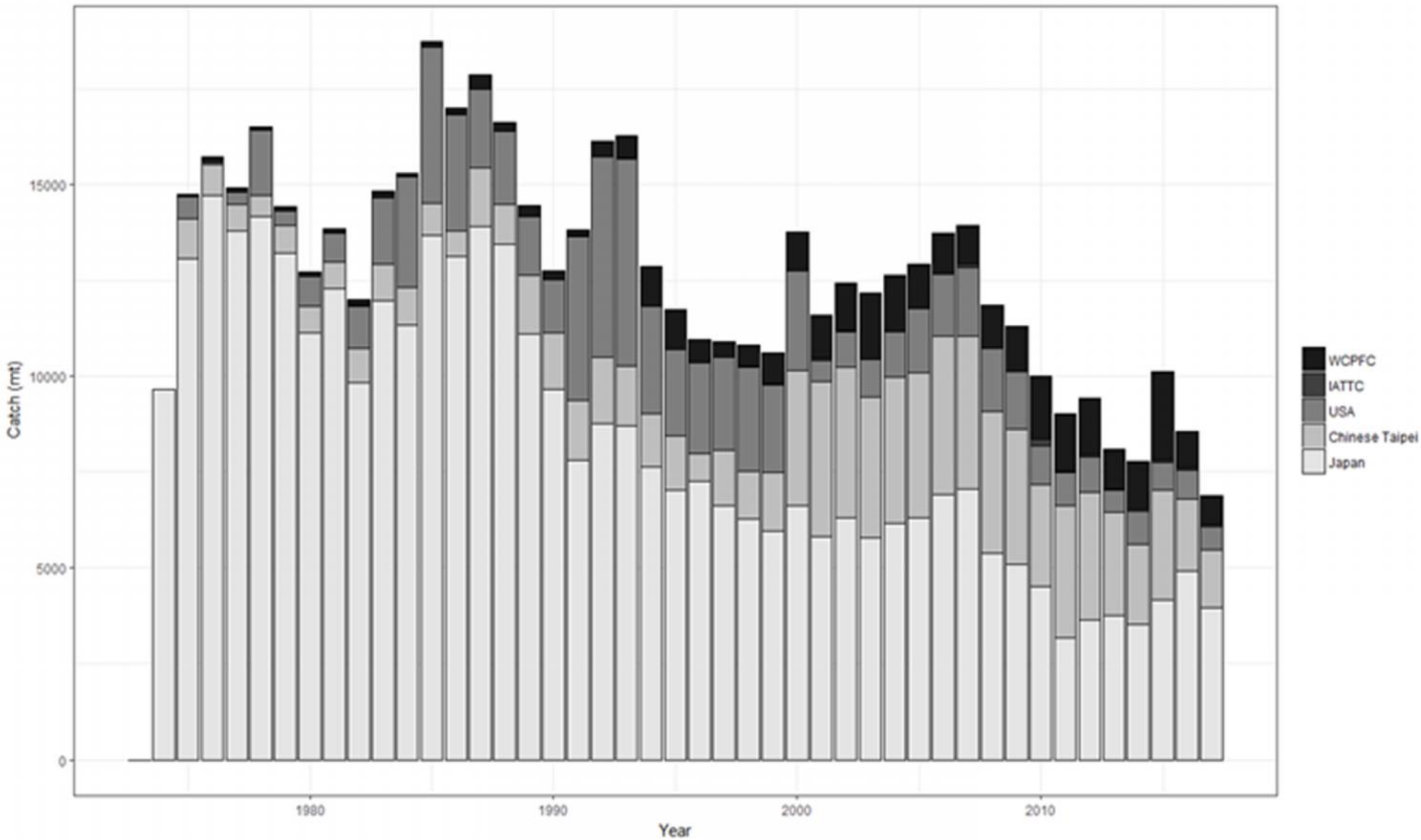


Very similar catch patterns over time with a 0% average catch difference

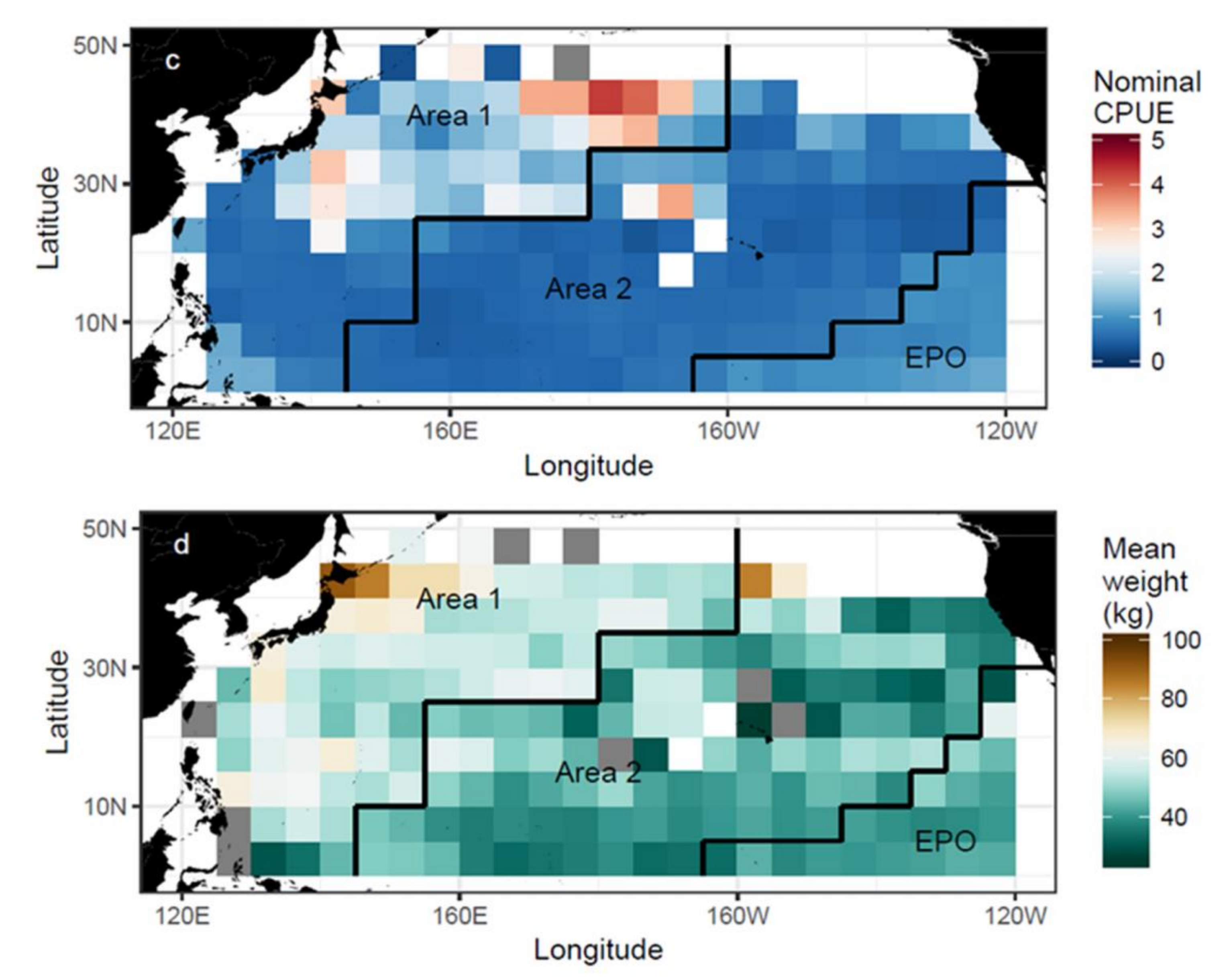
Finalized WCNPO Swordfish Catch Data by Fleet



WCNPO Swordfish Catch by ISC Country and Tuna RFMO

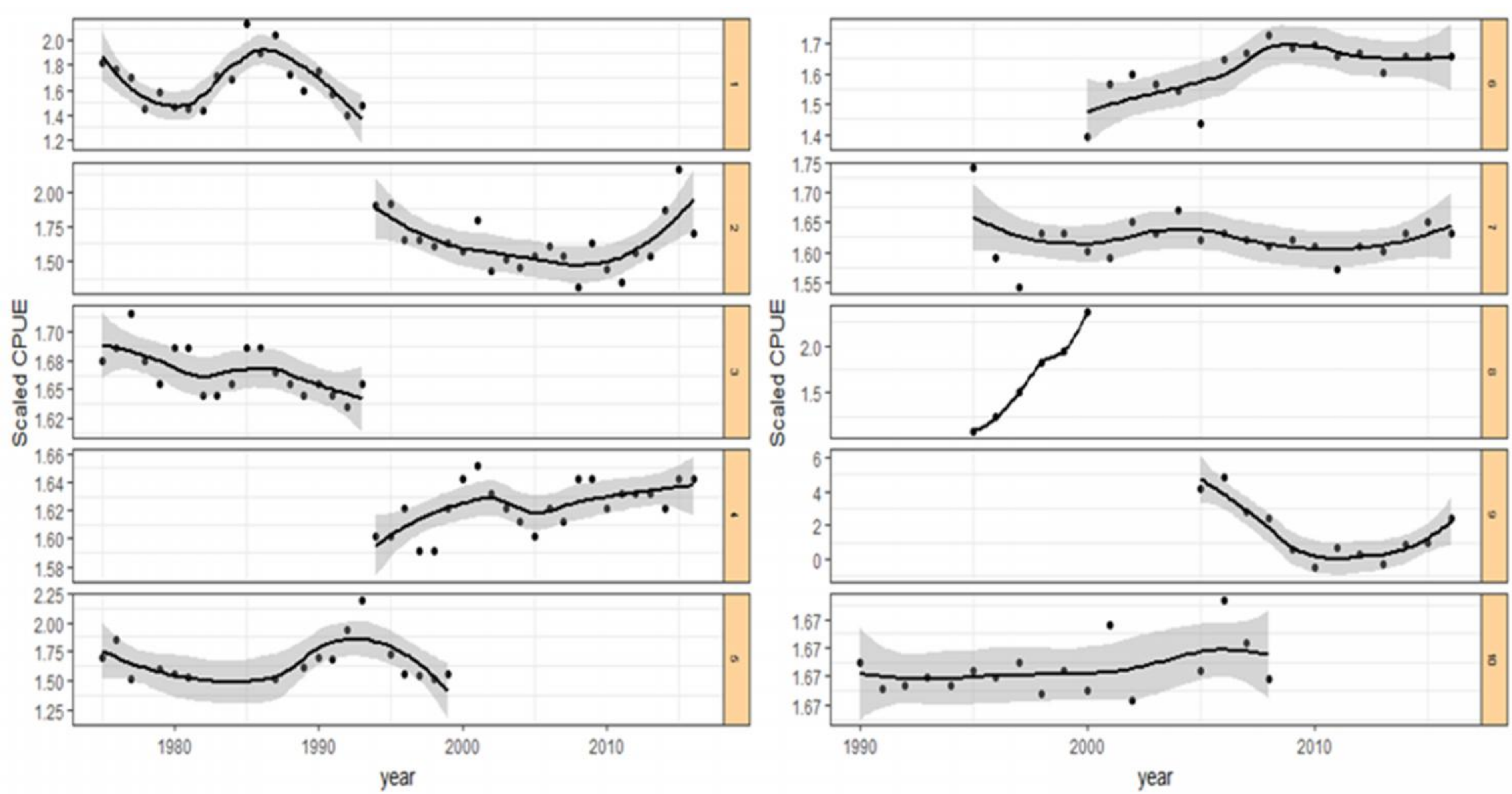


Area Stratification for Japanese Longline Fleets in WCNPO



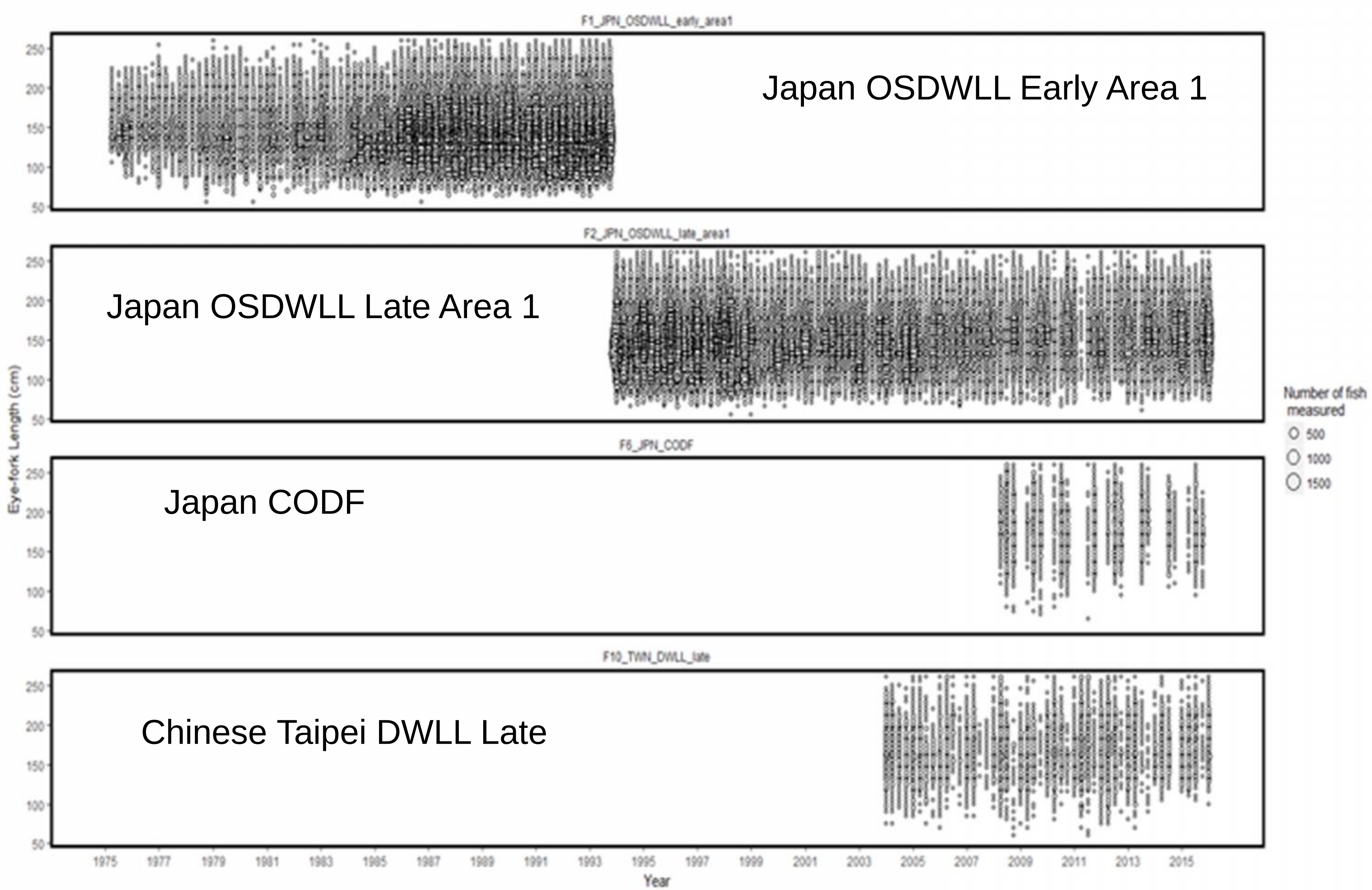
Relative Abundance Indices Based on Standardized Catch-Per-Unit Effort

Standardized CPUE by Fleet

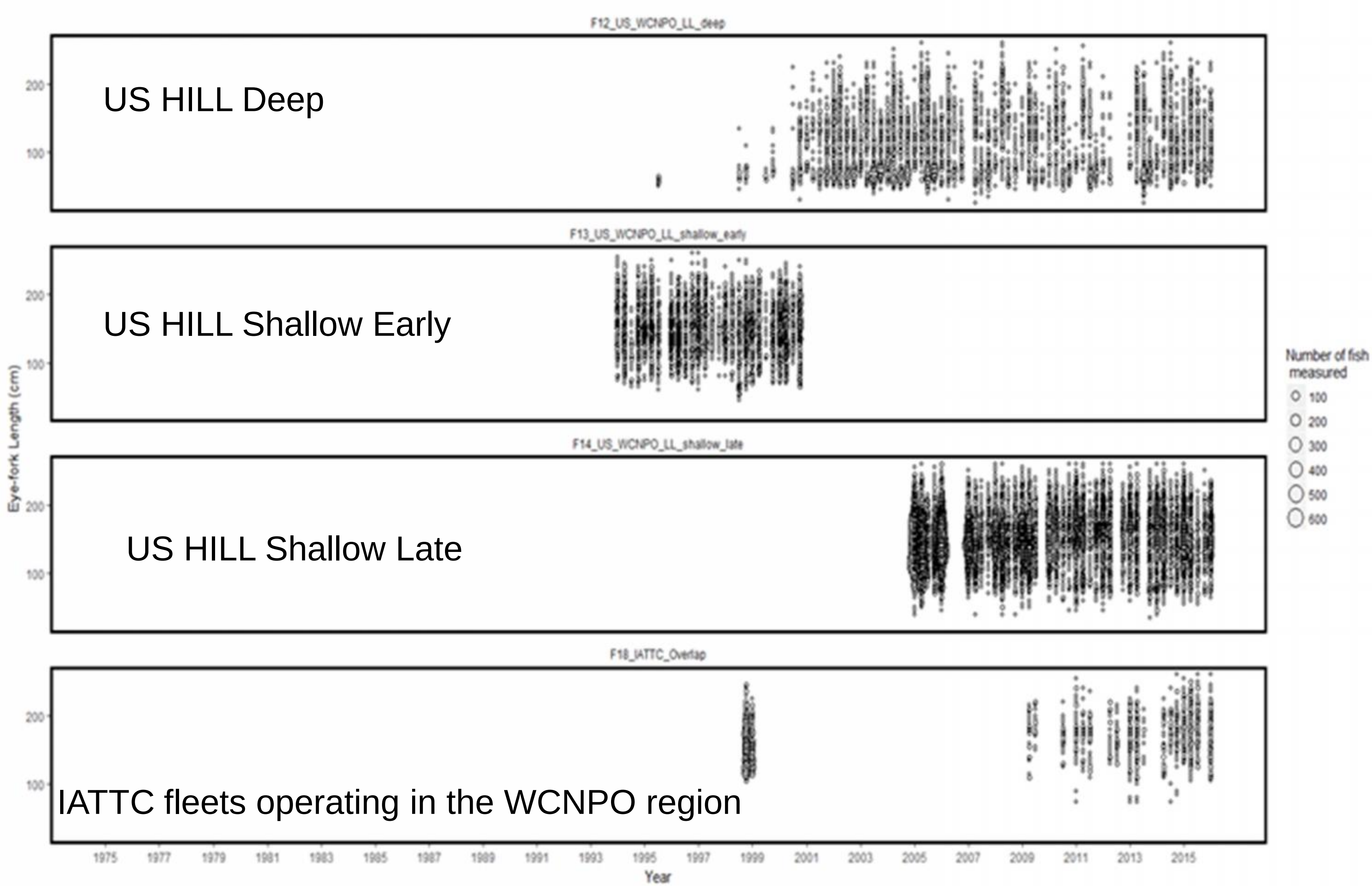


Size Composition Data

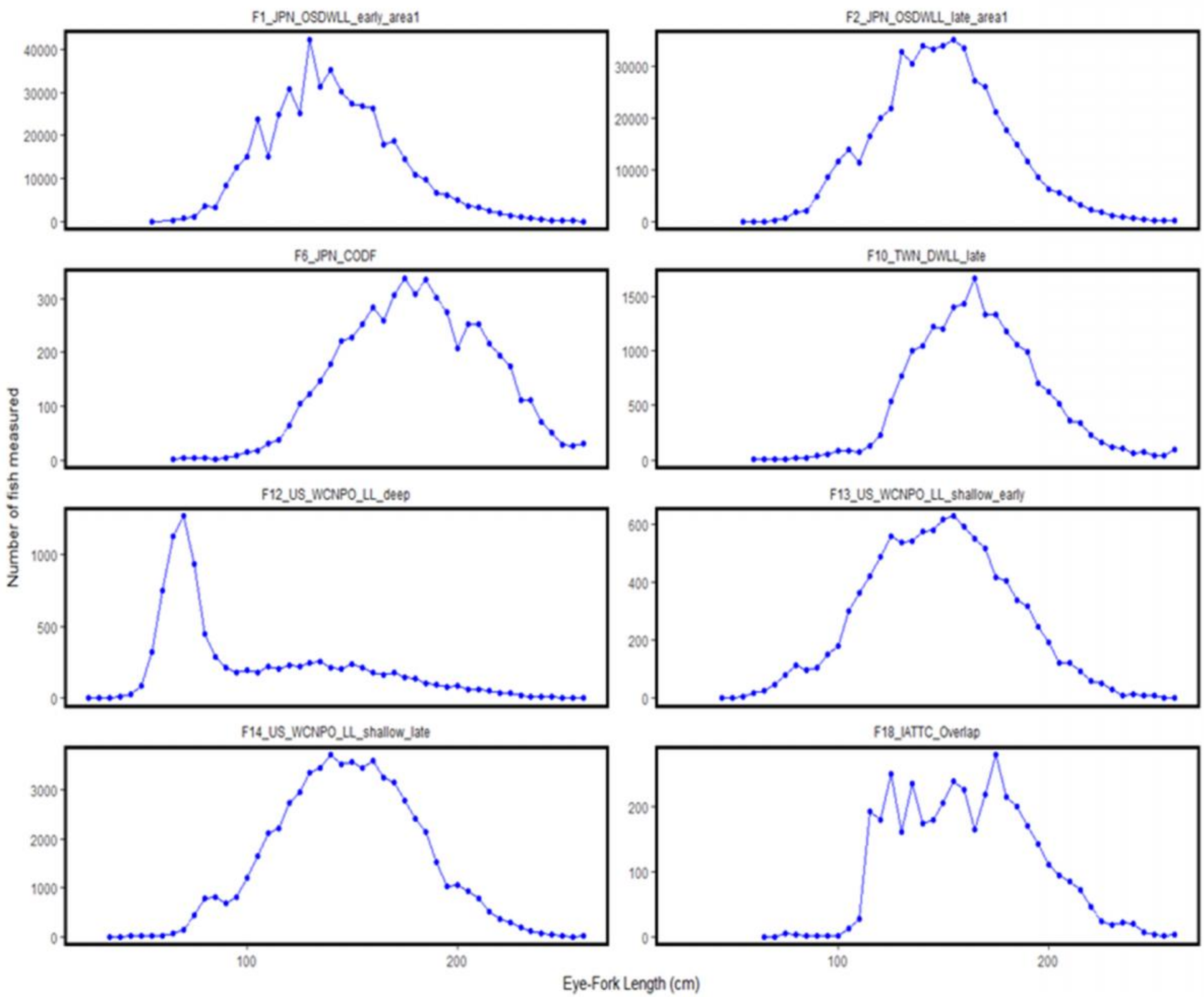
Size Composition Data by Fleet



Size Composition Data By Fleet



Aggregated Size Composition Data By Fleet



Assessment Modeling Approach

- ✓ 2018 benchmark assessment used the Stock Synthesis 3.30 assessment model in a maximum likelihood estimation framework with some parameter constraints for fishery selectivity parameters

- ✓ A large number of candidate model configurations (on the order of ~ 1000 models) were explored and evaluated with various model diagnostics

- ✓ The 2018 base case assessment model was the best fitting model of the ensemble of candidate models

Assessment Modeling Approach

- ✓ Stock projections were conducted for 2017-2026 using a two-gender implementation of the SSFuture software developed by Dr. Ichinokawa and others and modified by Dr. Ijima for for WCNPO swordfish
- ✓ Uncertainty in the initial stock numbers at age by gender was estimated using parametric bootstrapping of the fitted base case assessment model
- ✓ Uncertainty in future recruitment was incorporated by randomly sampling from the fitted stock-recruitment model as estimated in the base case assessment model.

Swordfish Fishery-Specific Selectivity Assumptions

Fleet	Selectivity Function
F1	Mirror F2
F2	Double-normal
F3	Mirror F14
F4	Mirror F14
F5	Mirror F10
F6	Mirror F18
F7	Mirror F2
F8	Mirror F2
F9	Mirror F10
F10	Asymptotic lognormal
F11	Mirror F2
F12	Mirror F14
F13	Mirror F14
F14	Double-normal
F15	Mirror F10
F16	Mirror F10
F17	Mirror F10
F18	Asymptotic lognormal
S1	Mirror F2
S2	Mirror F2
S3	Mirror F14
S4	Mirror F14
S5	Mirror F10
S6	Mirror F10
S7	Mirror F14
S8	Mirror F14
S9	Mirror F14
S10	Mirror F10

F2 is Japanese Offshore Distant Water Longline in Area 1 for 1994-2016

F10 is Taiwanese Distant Water Longline for 2000-2016

F14 is USA Shallow-Set Longline for 2005-2016

F18 is IATTC Longline in RFMO Overlap Area for 1975-2016

Mirror fleet = fisheries with similar fishery selectivity patterns

Data Observation Models

Abundance Indices

- ✓ Lognormal observation errors for abundance indices
- ✓ log(SE) = sqrt(log(1+CV^2)) for the individual CPUE standardizations
- ✓ Values of log(SE) < 0.25 were rescaled to set log(SE) = 0.25

Size Composition Data

- ✓ Multinomial observation errors for size composition data
- ✓ Input effective sample size (effN) was rescaled to a mean effN of 25
- ✓ Size compositions with fewer than 15 individuals measured were removed

Estimation of Recruitment Deviations From Stock-Recruitment Curve

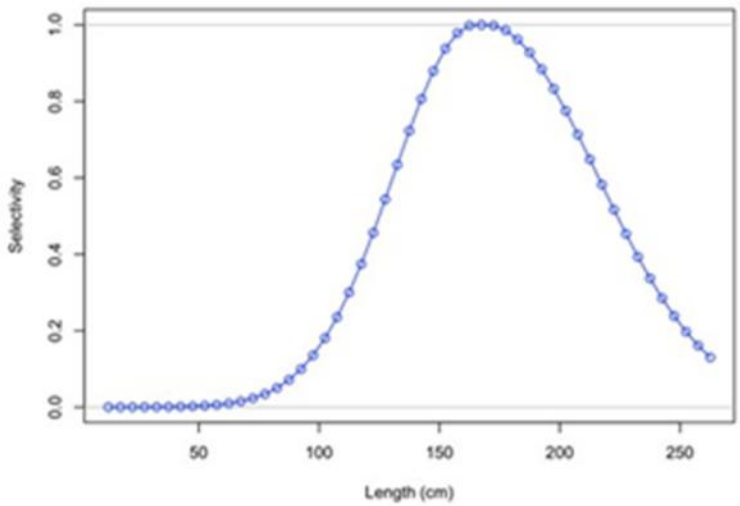
- Recruitment was estimated during 1975-2016 (with bias adjustment) and used the expected recruitment value from the estimated stock-recruitment curve for 2016

- Recruitment variability (σ_R, the standard deviation of log-recruitment) was fixed at $\sigma_R = 0.6$

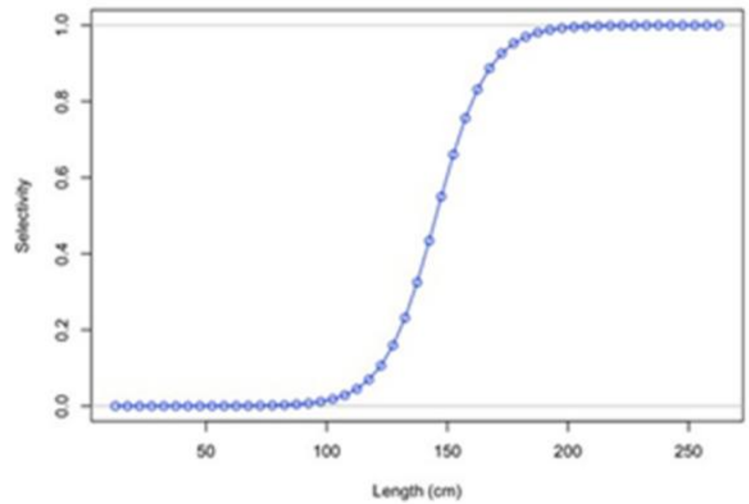
Model Diagnostics and Goodness of Fit

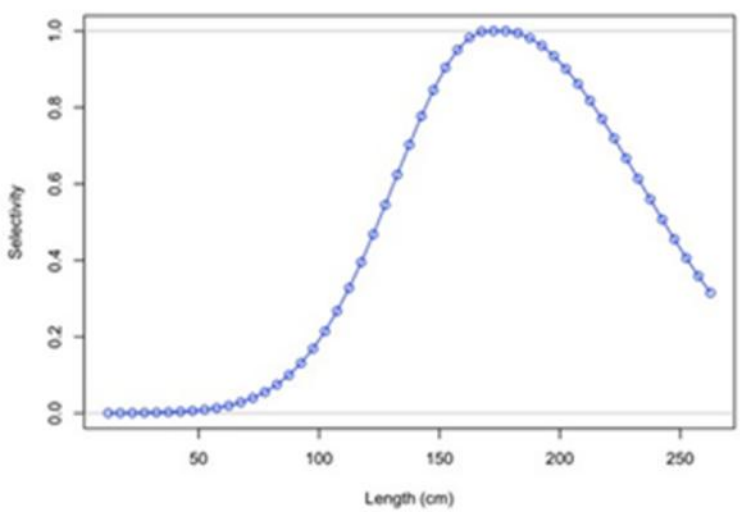
Fishery Selectivities by Fleet

Japanese Offshore Distant Water Longline in Area 1 for 1994-2016

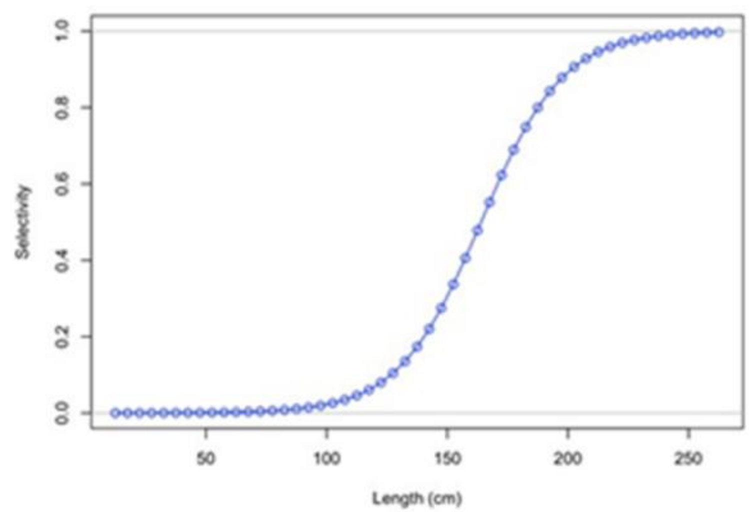


Taiwanese Distant Water Longline for 2000-2016





USA Shallow-Set Longline for 2005-2016

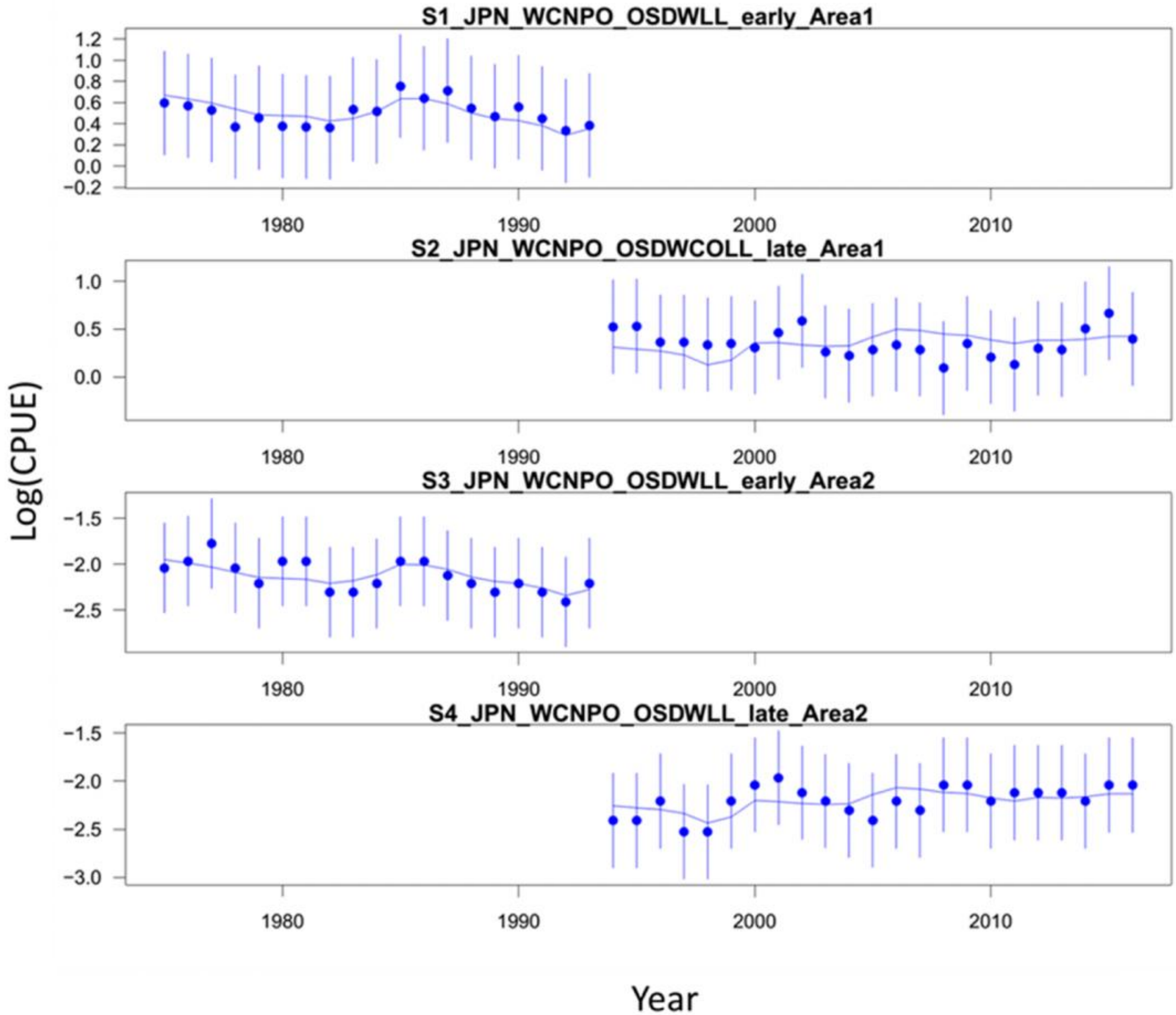


IATTC Longline in RFMO Overlap Area for 1975-2016

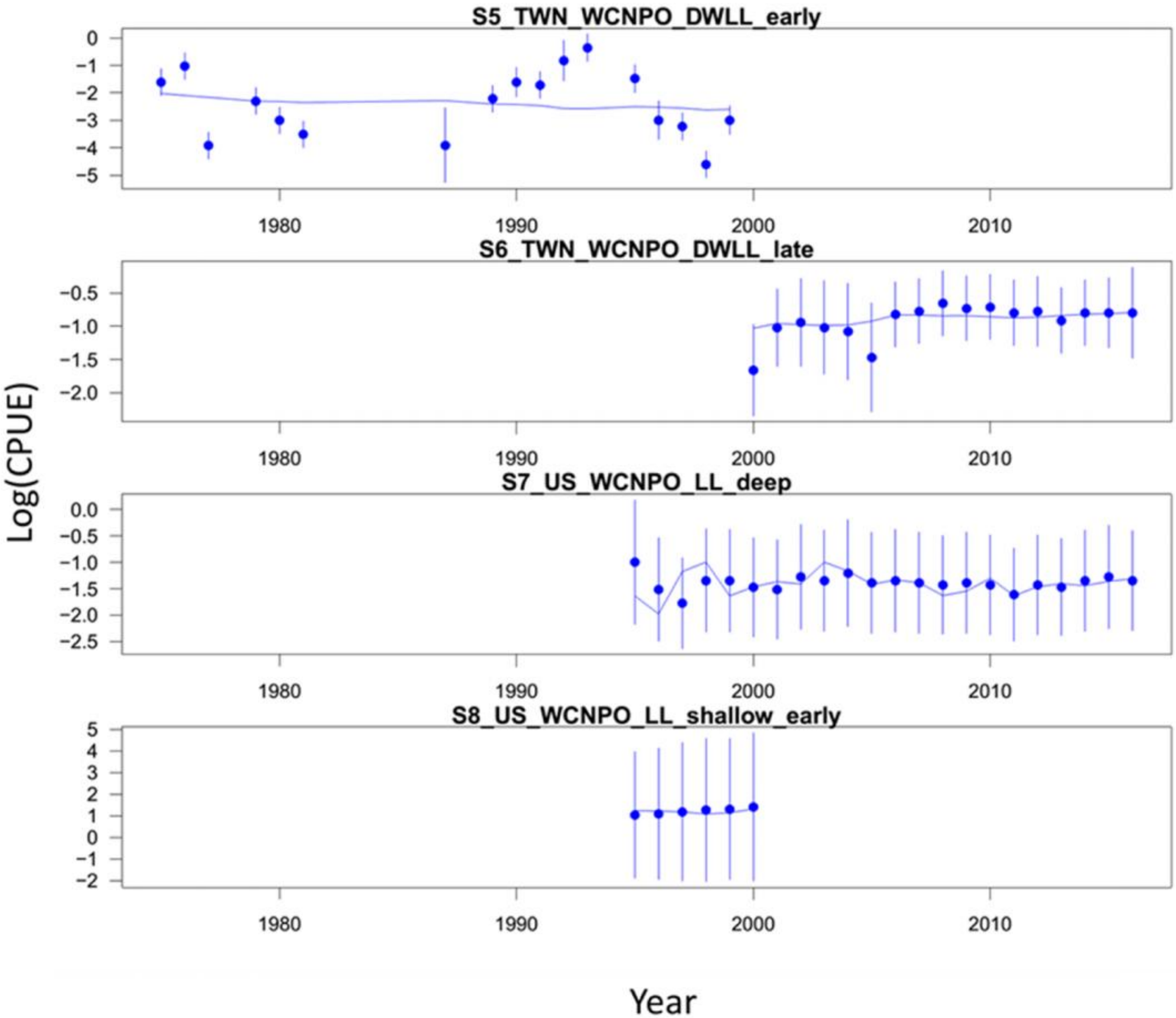
Fits to Standardized CPUE by Fleet

Fleet	***N***	**Input log(SE)**	**RMSE**	**SDNR**	χ^2
S1_JPN_WCNPO_OSDWLL_early_Area1	19	0.250	0.083	0.340	1.266
S2_JPN_WCNPO_OSDWCOLL_late_Area1	23	0.250	0.173	0.706	1.242
S3_JPN_WCNPO_OSDWLL_early_Area2	19	0.250	0.109	0.447	1.266
S4_JPN_WCNPO_OSDWLL_late_Area2	23	0.250	0.134	0.547	1.242
S5_TWN_WCNPO_DWLL_early	17	0.294	1.185	4.416	1.282
S6_TWN_WCNPO_DWLL_late	17	0.296	0.218	0.616	1.282
S7_US_WCNPO_LL_deep	22	0.492	0.258	0.535	1.247
S8_US_WCNPO_LL_shallow_early	6	1.630	0.145	0.144	1.488
S9_US_WCNPO_LL_shallow_late	12	0.371	0.143	0.405	1.337
S10_US_WCNPO_GN	17	0.817	0.586	0.735	1.282

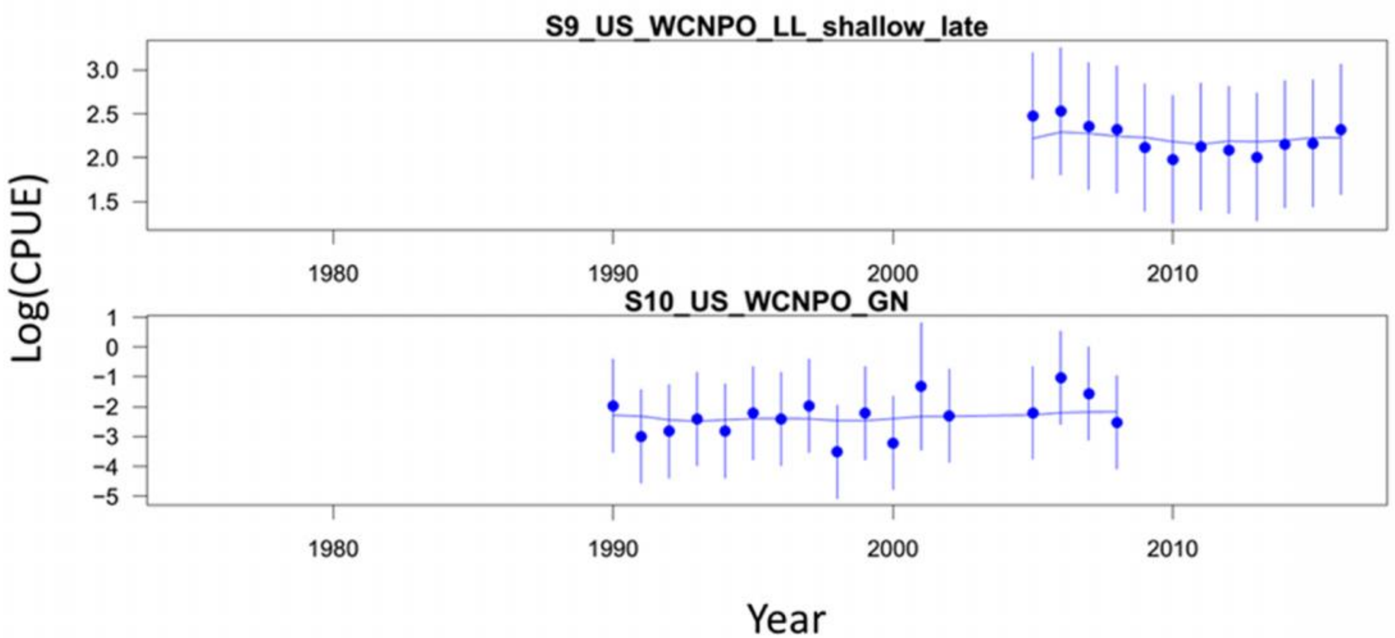
Fits to Standardized CPUE by Fleet



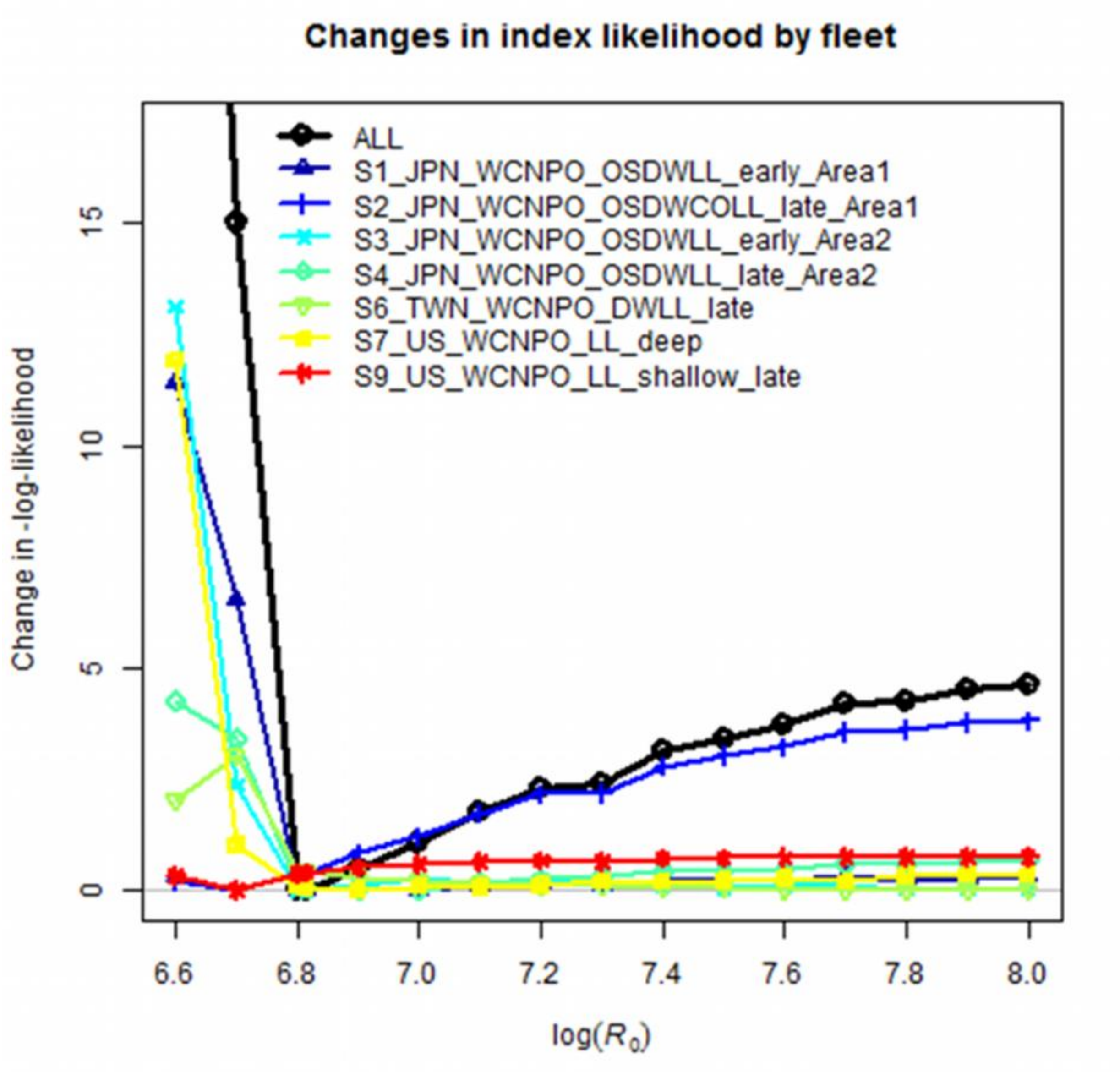
Fits to Standardized CPUE by Fleet



Fits to Standardized CPUE by Fleet

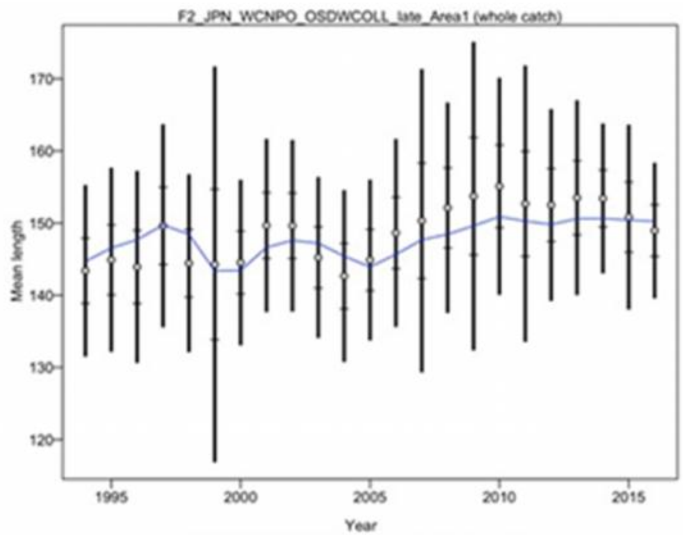


Results of Likelihood Profiles by CPUE Index for Unfished Recruitment R_0

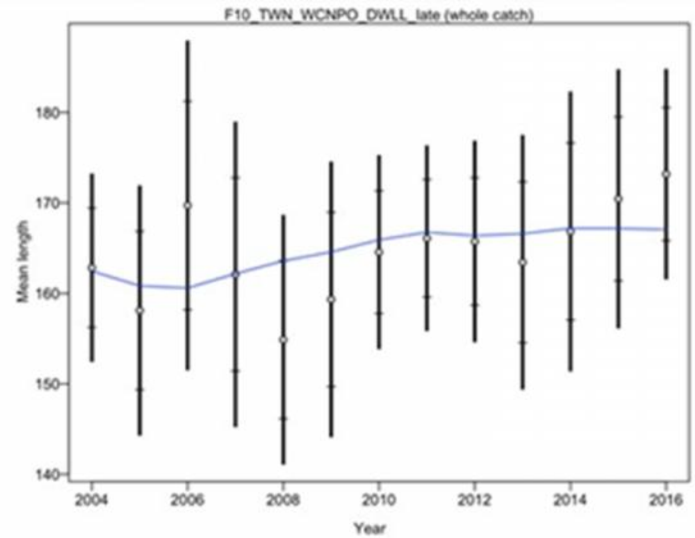


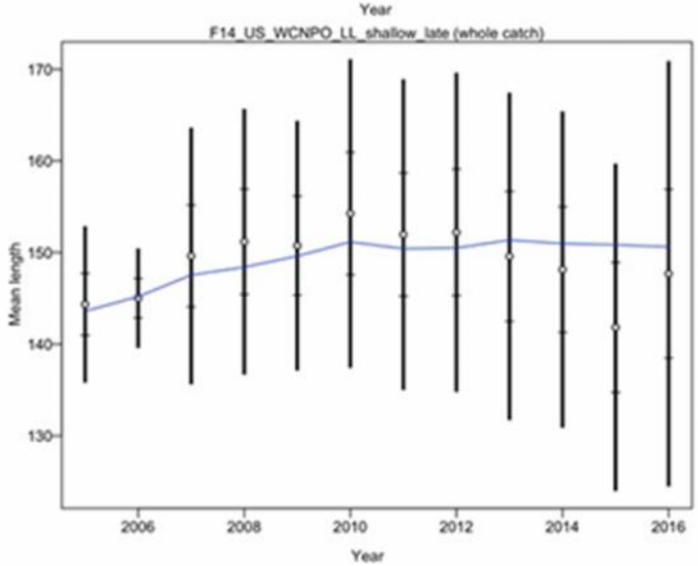
Fits to Size Composition Data by Fleet

Japanese Offshore Distant Water Longline in Area 1 for 1994-2016

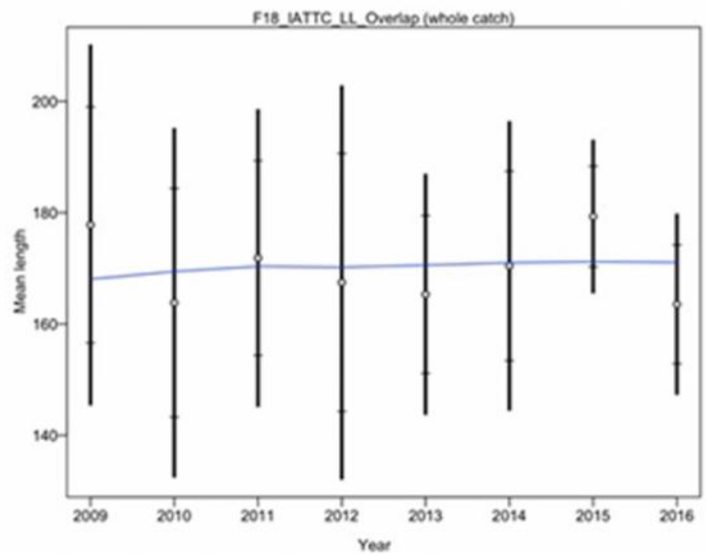


Taiwanese Distant Water Longline for 2000-2016





USA Shallow-Set Longline for 2005-2016

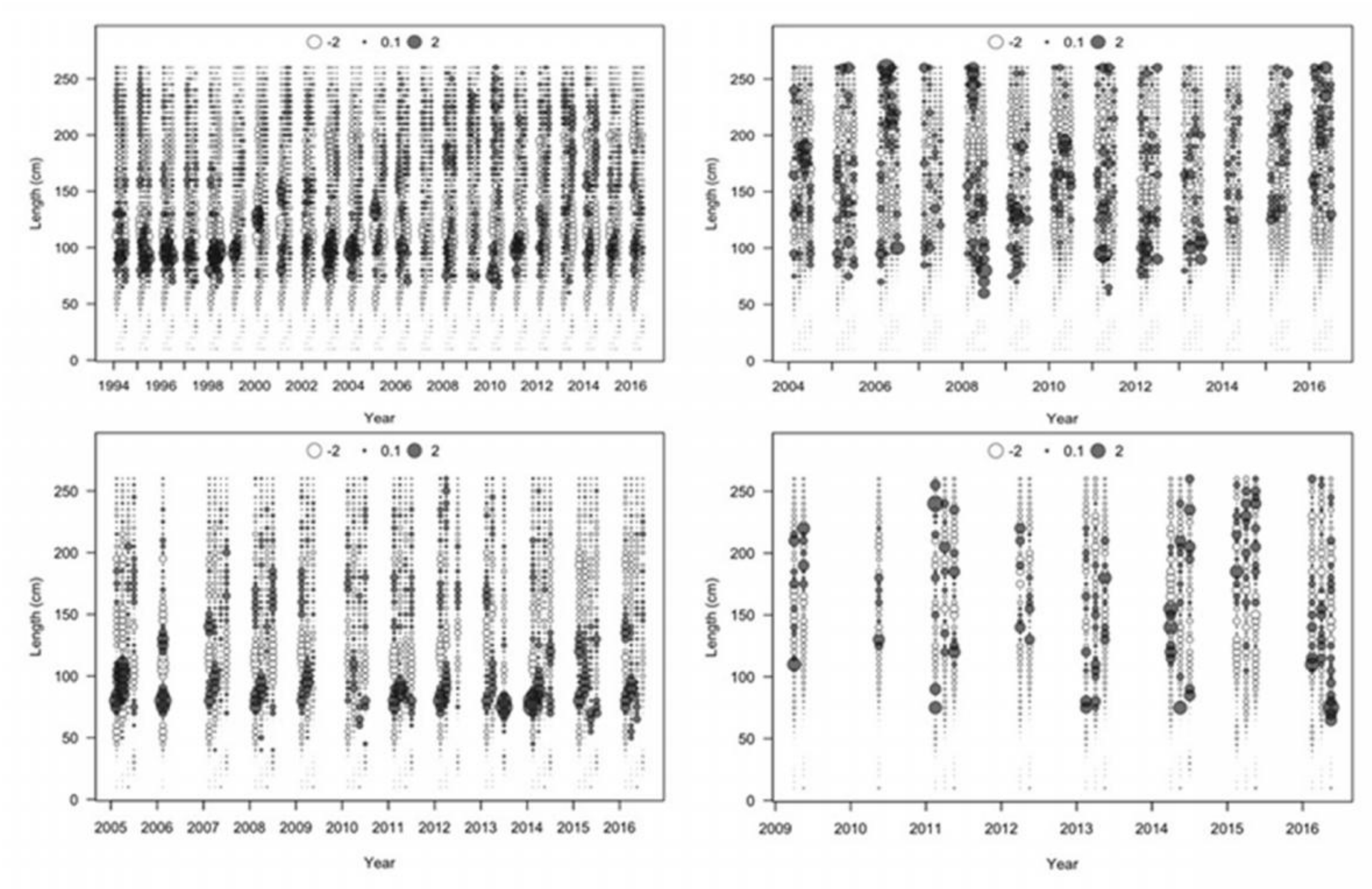


IATTC Longline in RFMO Overlap Area for 2009-2016

Fits to Size Composition Data by Fleet

Japanese Offshore Distant Water Longline in Area 1 for 1994-2016

Taiwanese Distant Water Longline for 2000-2016



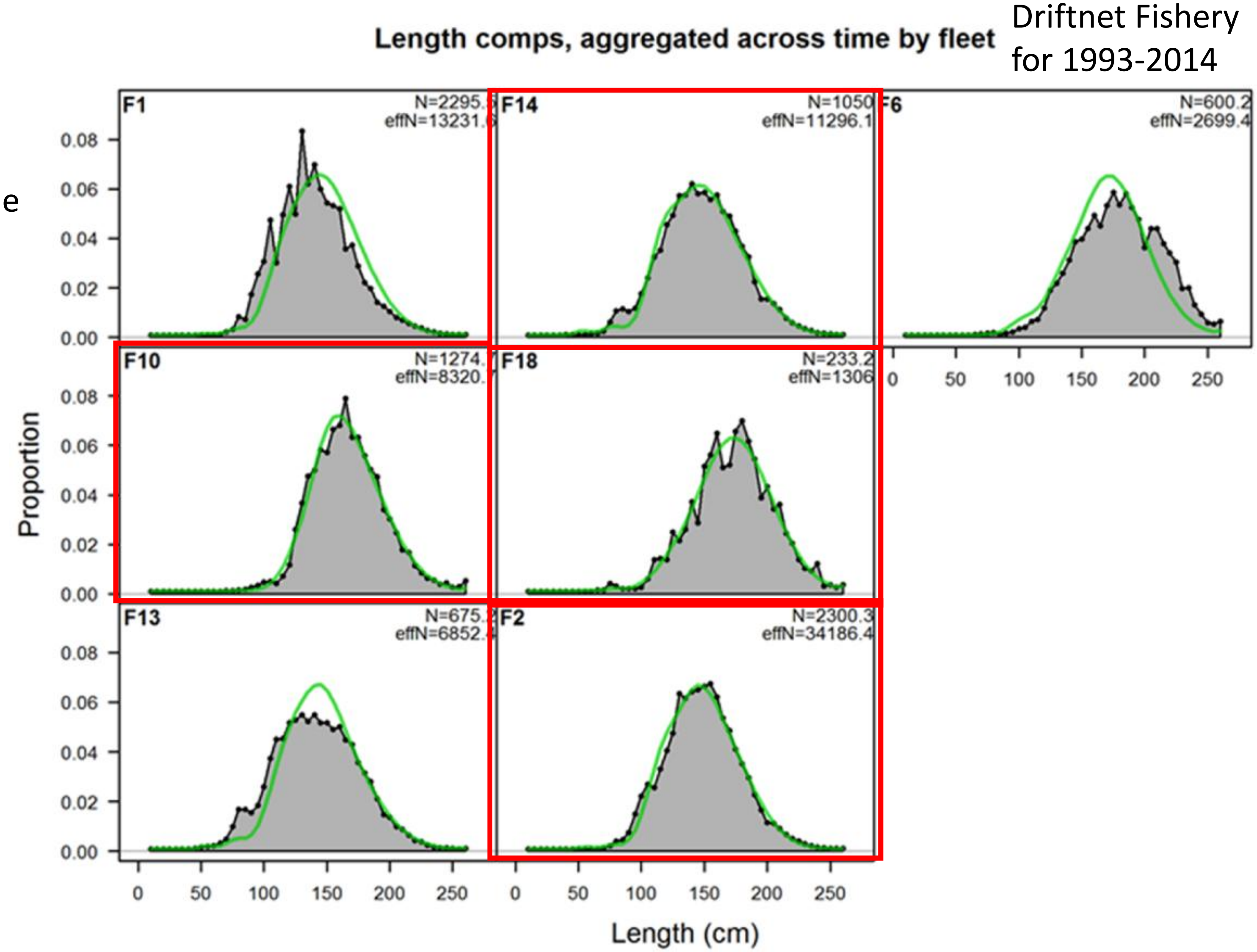
USA Shallow-Set Longline
for 2005-2016

IATTC Longline in RFMO
Overlap Area for 2009-2016

Fits to Size Composition Data by Fleet

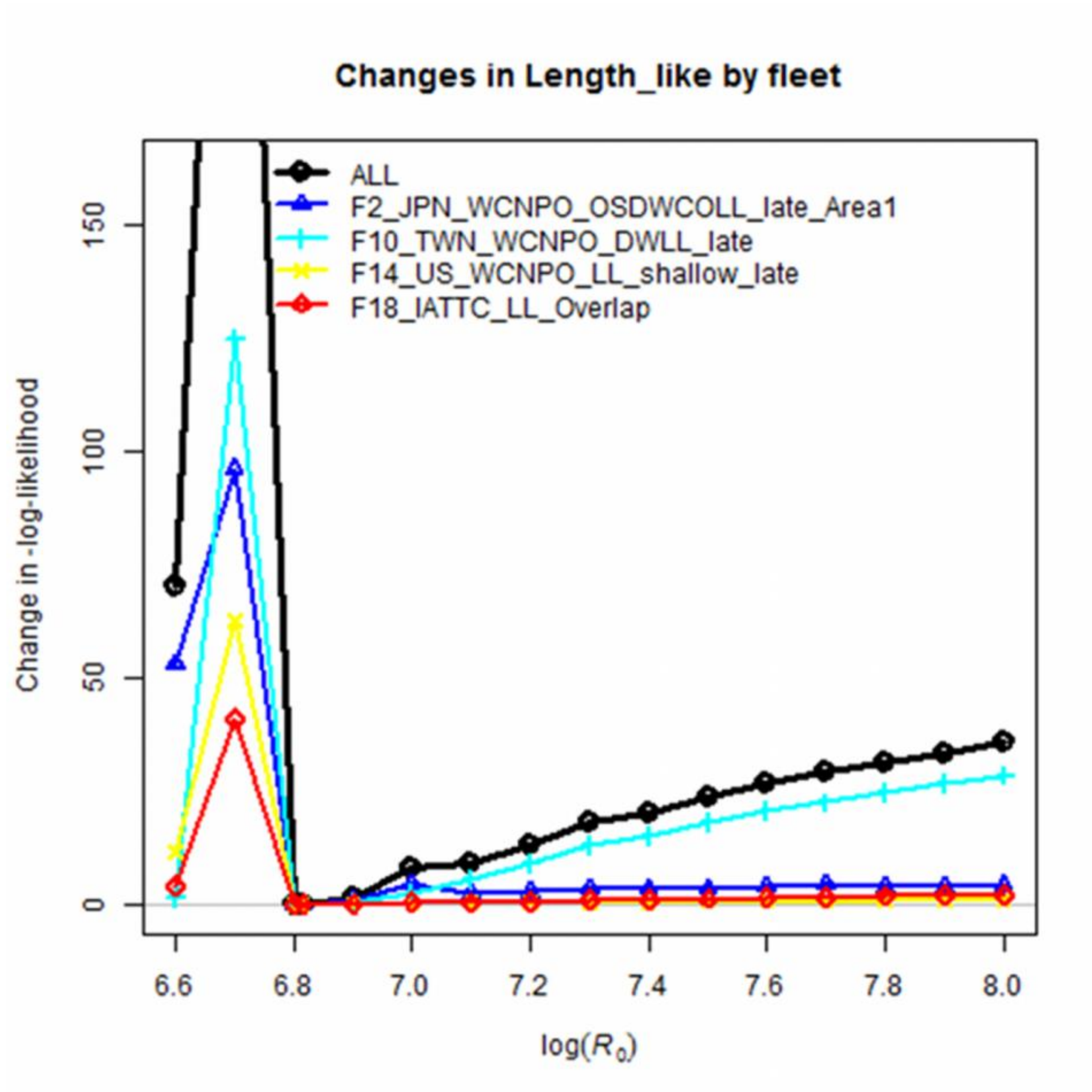
Japanese Coastal Driftnet Fishery for 1993-2014

Japanese Offshore Distant Water Longline in Area 1 for 1975-1993



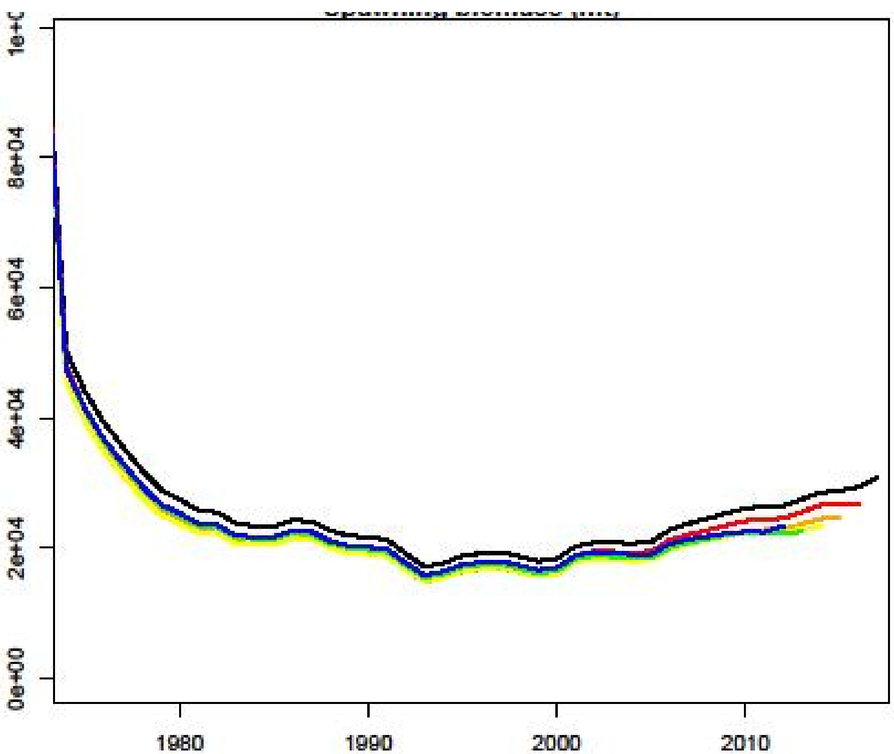
USA Shallow-Set Longline for 1995-2000

Results of Likelihood Profiles by Size Composition for Unfished Recruitment R_0

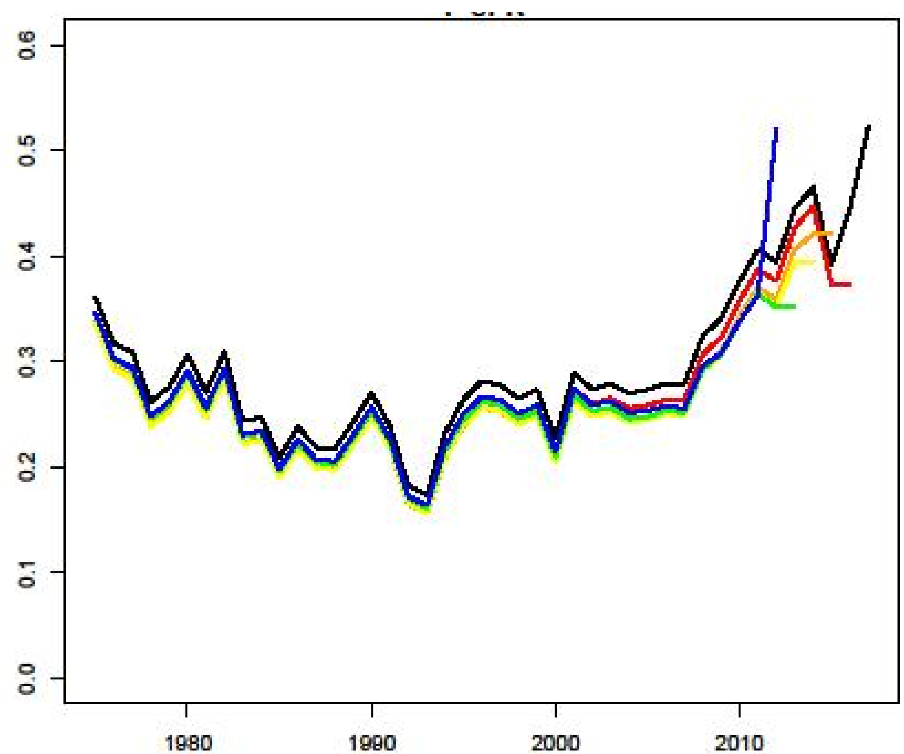


WCNPO Swordfish Retrospective Analyses

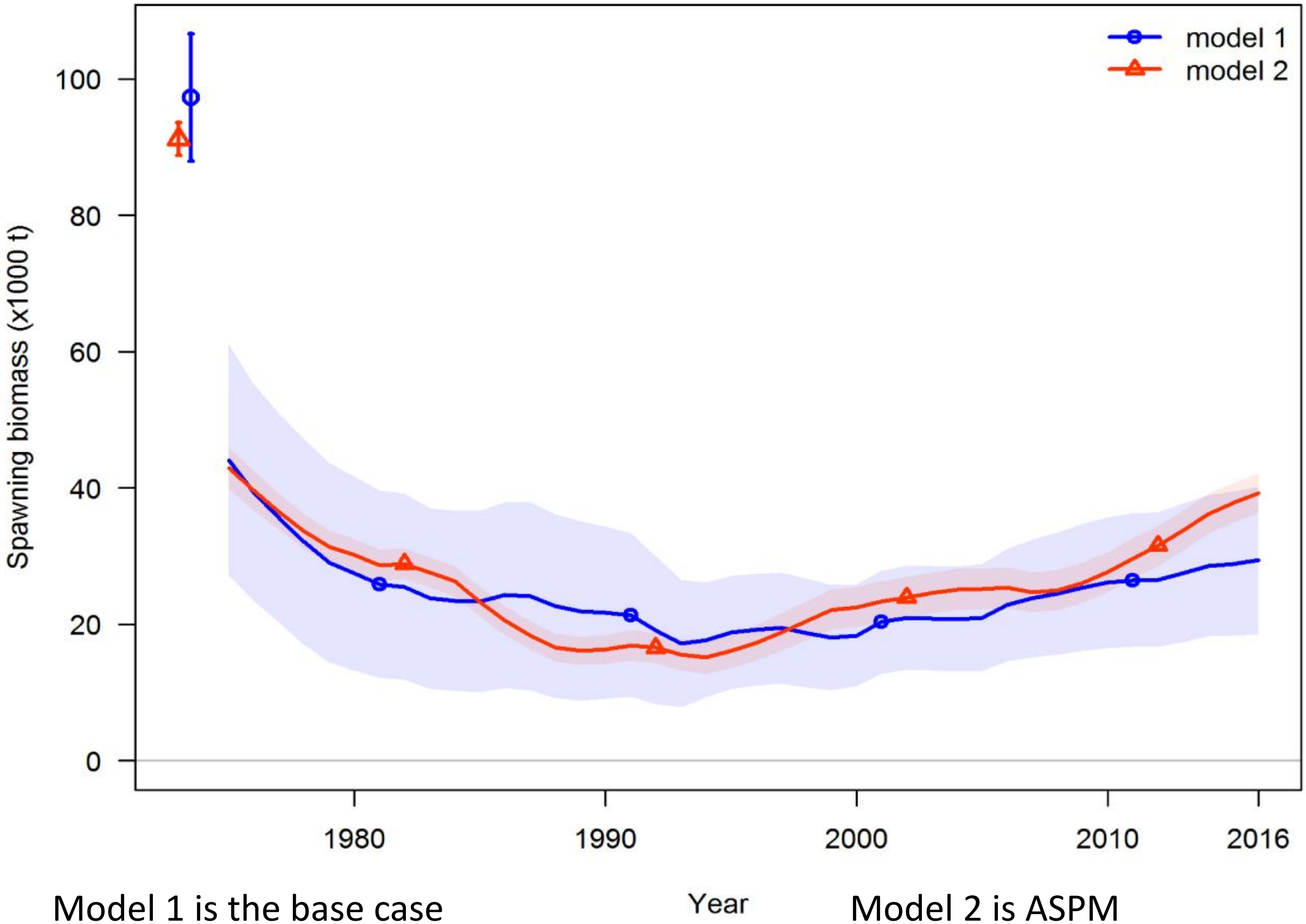
Spawning Biomass (mt)



SPR



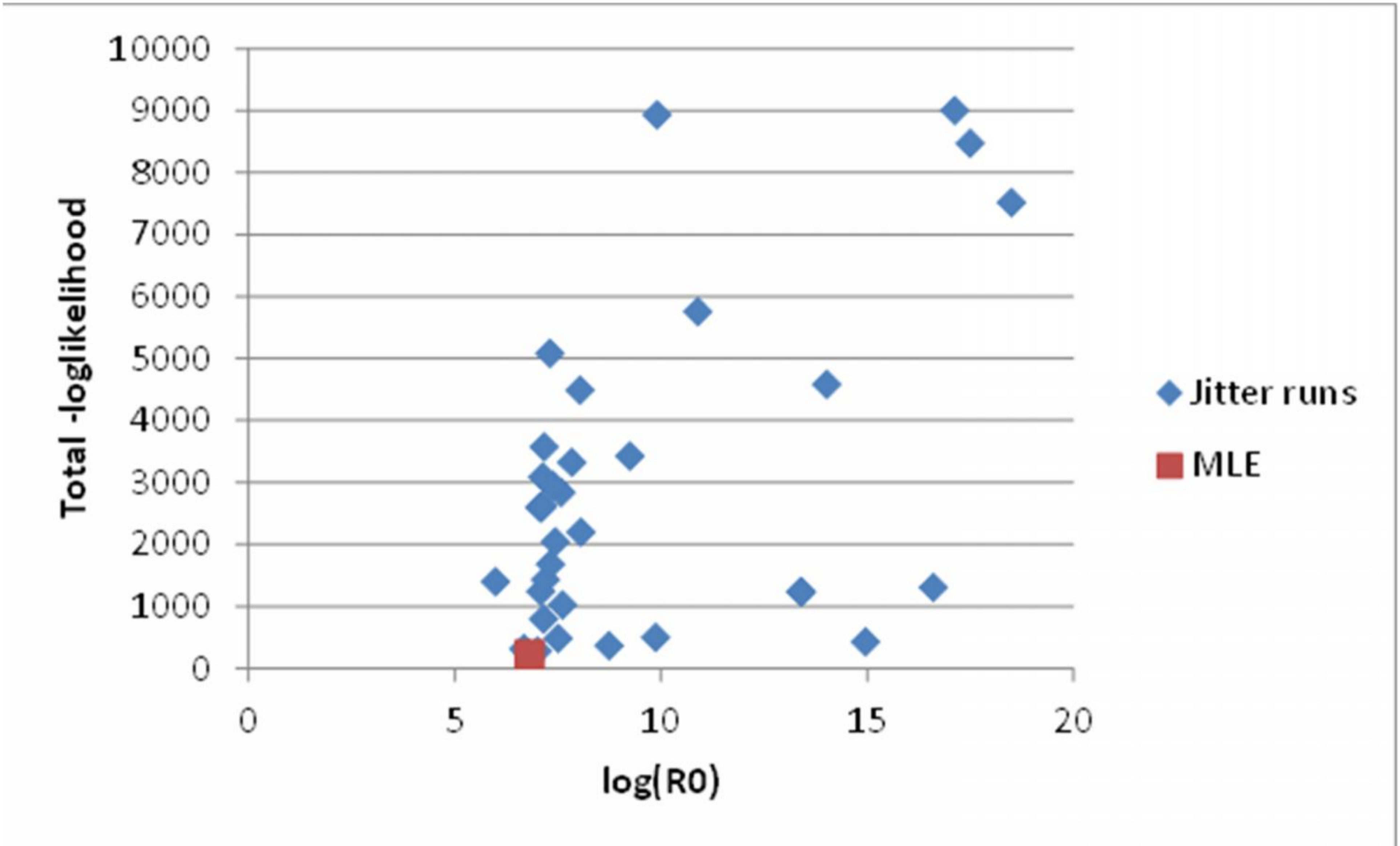
WCNPO Swordfish Age-Structured Production Model Diagnostic



Model 1 is the base case

Model 2 is ASPM

WCNPO Swordfish Randomized Initial Parameter Value Analyses



Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

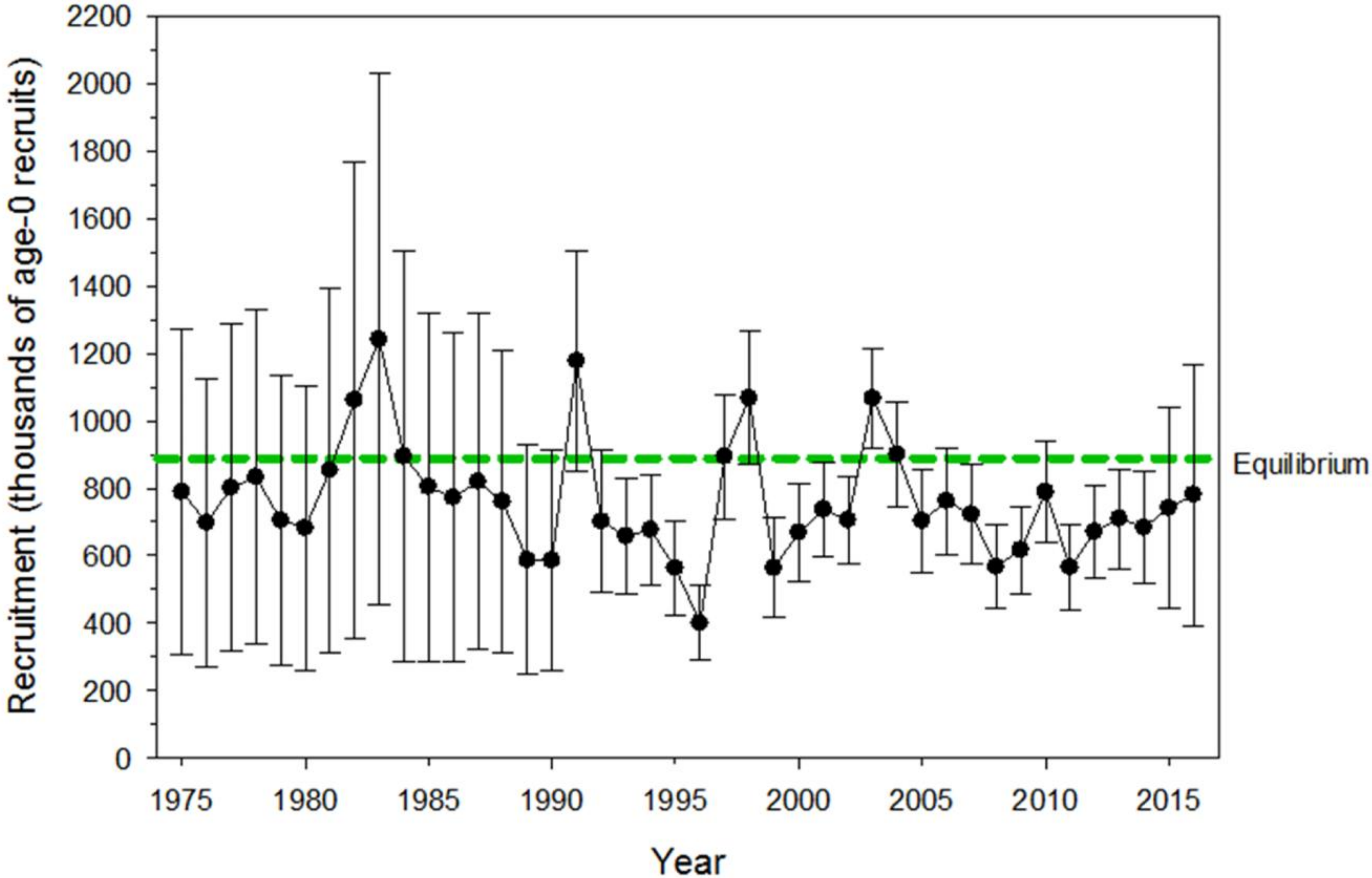
Stock Status and Conservation Information

WCNPO Swordfish Reference Points

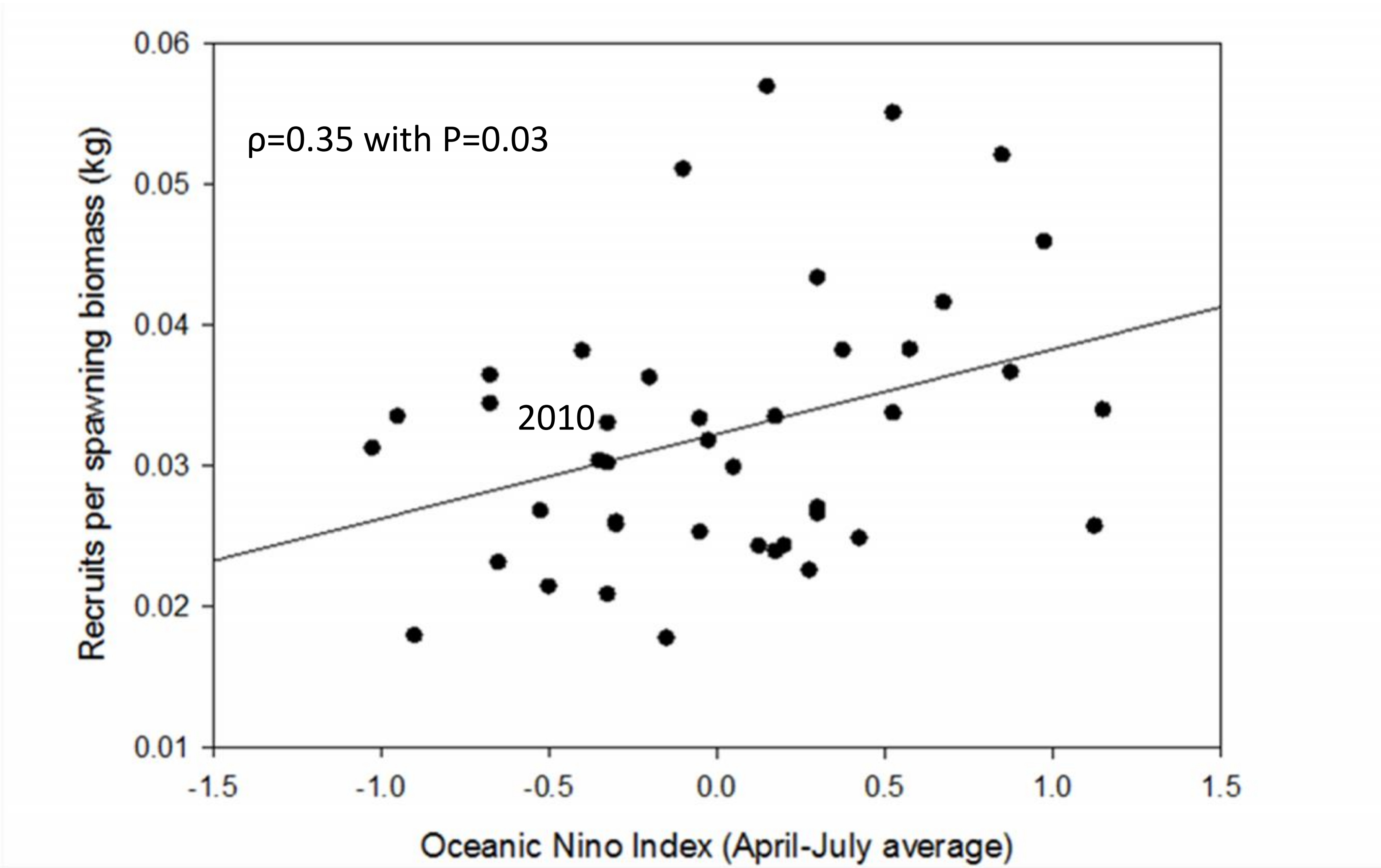
Reference Point	Estimate
F_{MSY}	0.17
$F_{0.2*SSB(F=0)}$	0.16
$F_{2013-2015}$	0.08
SSB_{MSY}	15,702 mt
SSB_{2016}	29,403 mt
MSY	14,941 mt
$C_{2012-2016}$	10,160 mt
SPR_{MSY}	18%
SPR_{2016}	45%

F is Average F ages 1-10

WCNPO Swordfish Recruitment

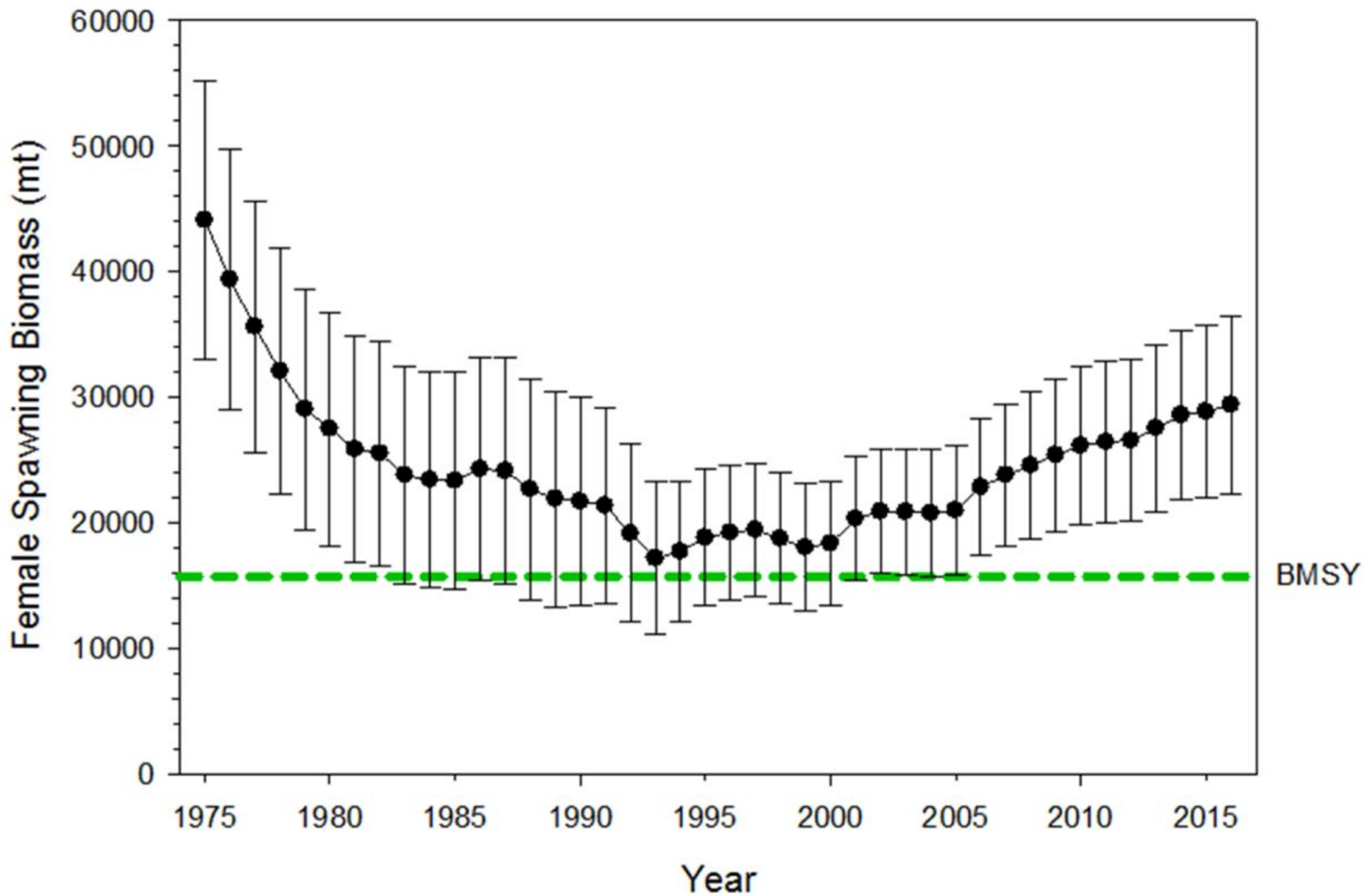


WCNPO Swordfish El Nino Forcing on Recruitment Success



R2010=789000 recruits, highest since 2004

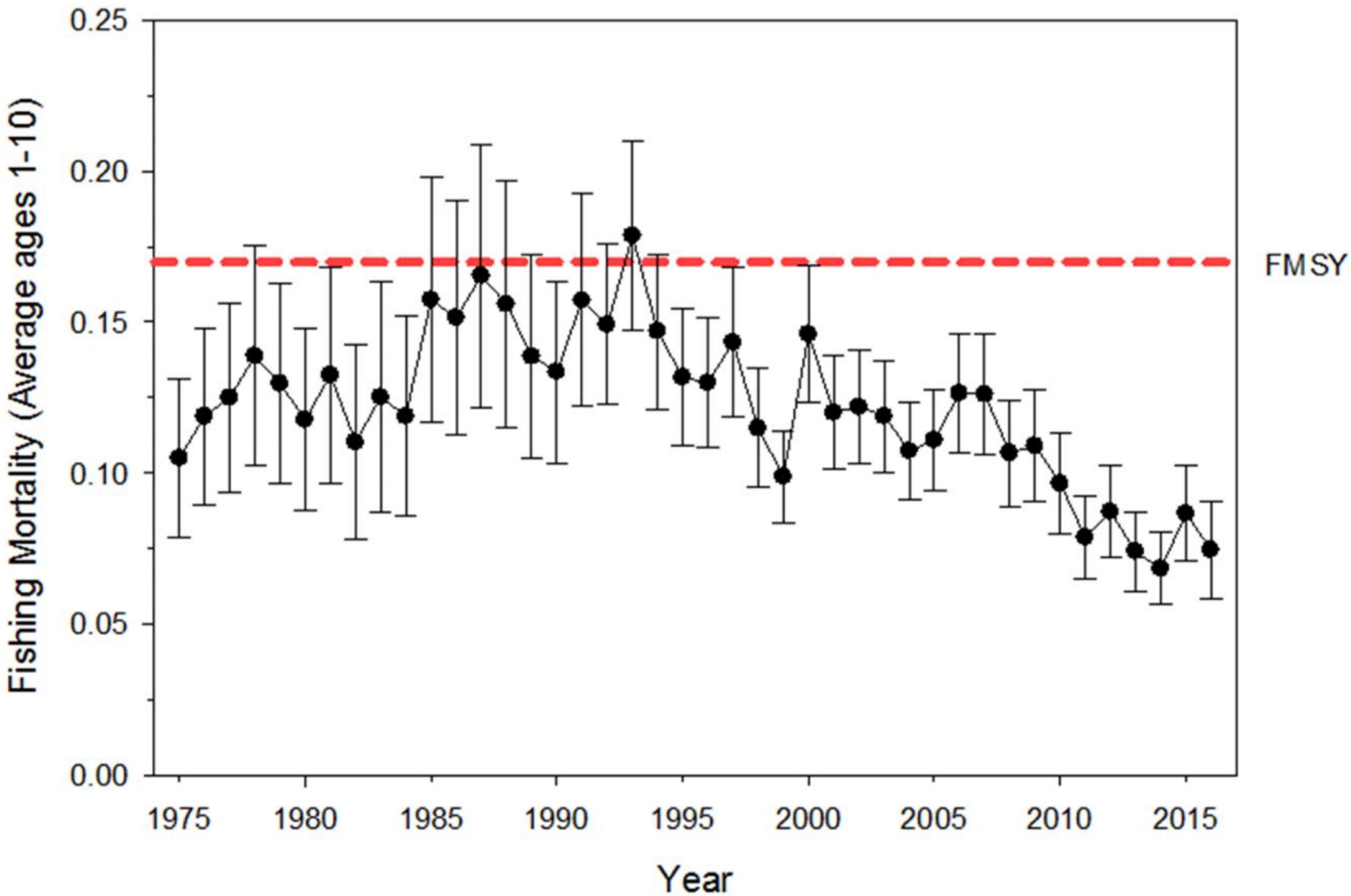
WCNPO Swordfish Spawning Biomass



Trends in Stock Biomass

- Estimates of population biomass and spawning biomass show a decline from 1975 to about 2000 followed by a moderate increasing trend from 2000 to 2016
- Current spawning biomass exceeds B_{MSY}

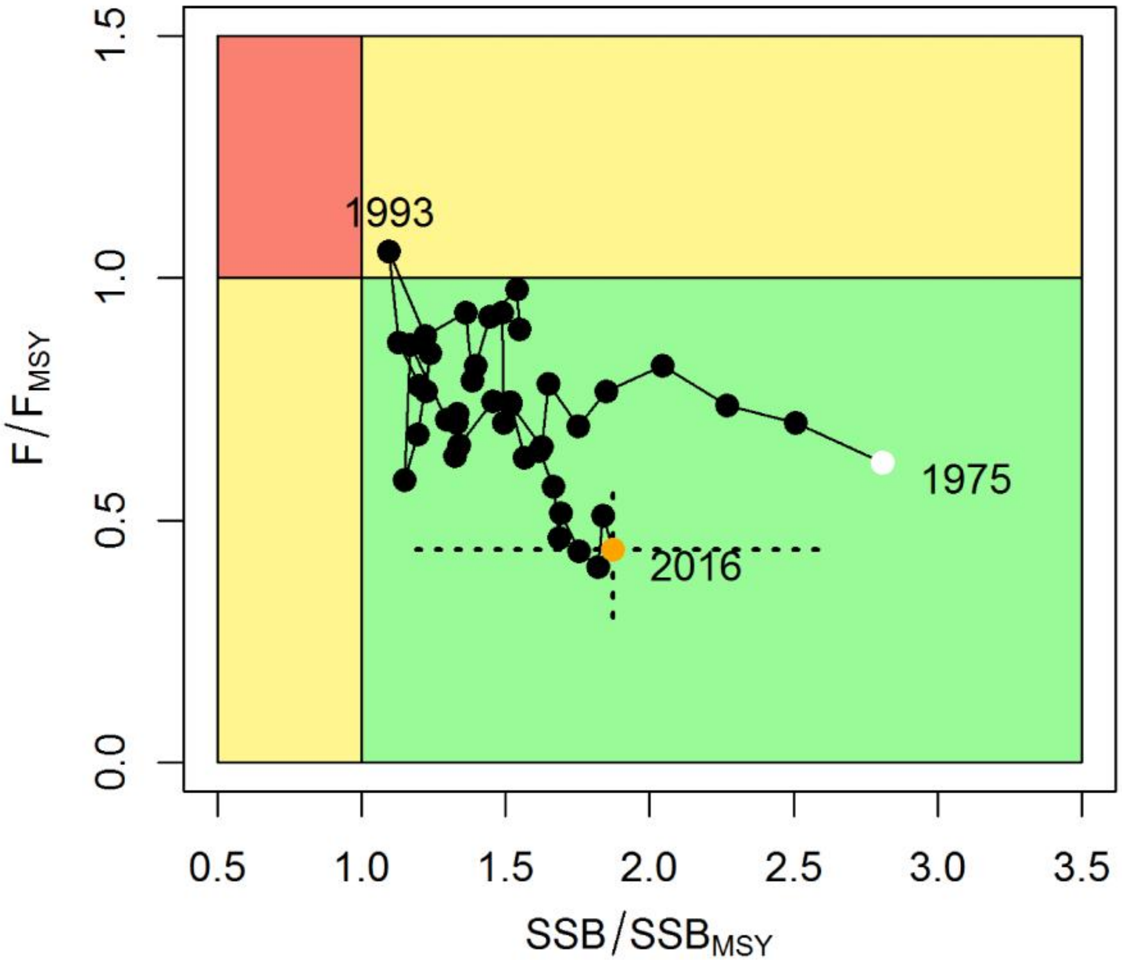
WCNPO Swordfish Fishing Mortality



Information on Stock Status

- Female spawning stock biomass was estimated to be 29,403 mt in 2016, or about 87% above SSB_{MSY} and 71% above 20%SSB(F=0)
- Fishing mortality on the stock (average F, ages 1 to 10) averaged roughly F = 0.08 during 2013-2015, or about 53% below F_{MSY} and 50% below $F_{20\%SSB(F=0)}$
- Results from the base case assessment model indicate that the WCNPO swordfish stock is currently not overfished and is not experiencing overfishing relative to either MSY-based or $F_{20\%SSB(F=0)}$-based biological reference points

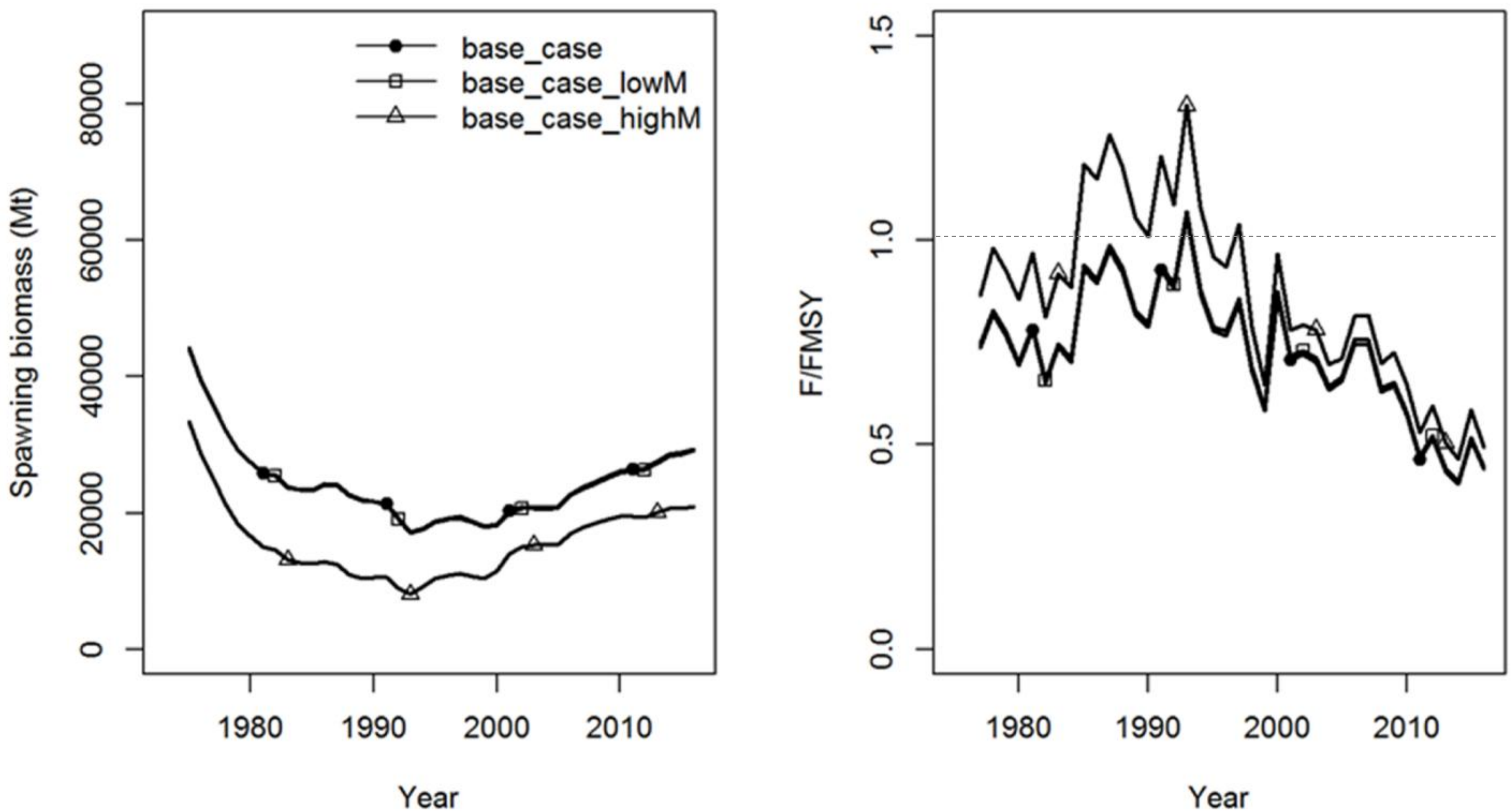
WCNPO Swordfish Kobe Plot
Relative to MSY-Based Reference Points



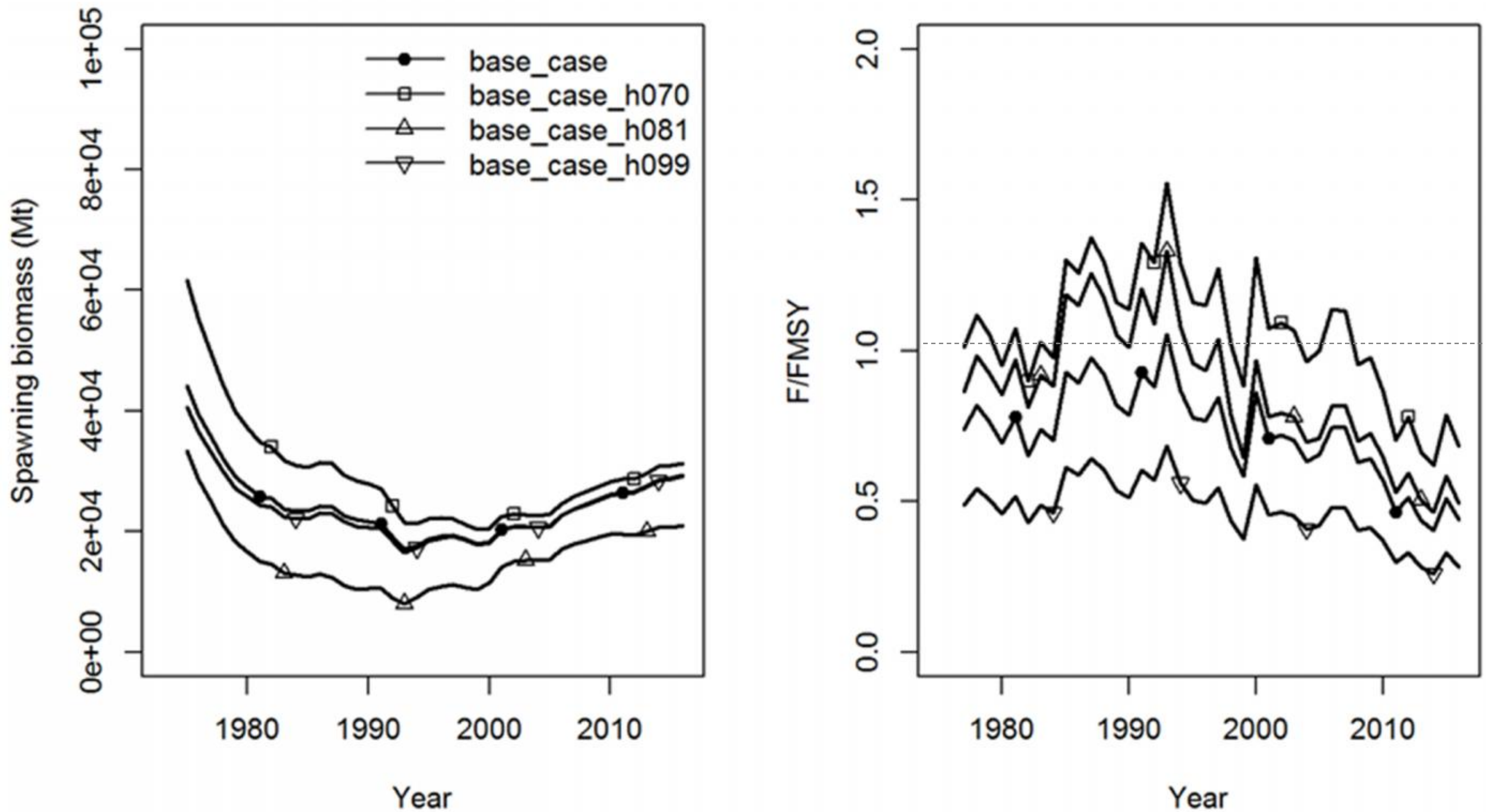
WCNPO Swordfish Sensitivity Analyses

RUN	NAME	DESCRIPTION
	Alternative Life History Parameters: Natural Mortality Rates	
1	base_case_lowM	Alternative natural mortality rates are 10% lower than in the base case
2	base_case_highM	Alternative natural mortality rates are 10% higher than in the base case
	Alternative Life History Parameters: Stock-Recruitment Steepness	
3	base_case_h070	Alternative lower steepness with h=0.70
4	base_case_h081	Alternative lower steepness with h=0.81
5	base_case_h099	Alternative higher steepness with h=0.99
	Alternative Life History Parameters: Growth Curves	
6	base_case_large_Amax	Alternative growth curve with a 10% larger maximum size for each sex.
7	base_case_Sun_Growth	Alternative growth curves using growth parameters from Sun et al. (2002)
	Alternative Life History Parameters: Maturity Ogives	
9	base_case_high_L50	Alternative maturity ogives with L_{50} set 10% higher than base case
10	base_case_low_L50	Alternative maturity ogives with L_{50} set 10% lower than base case
11	base_case_Wang2003	Alternative maturity ogives with converted L_{50} from Wang et al. (2003)

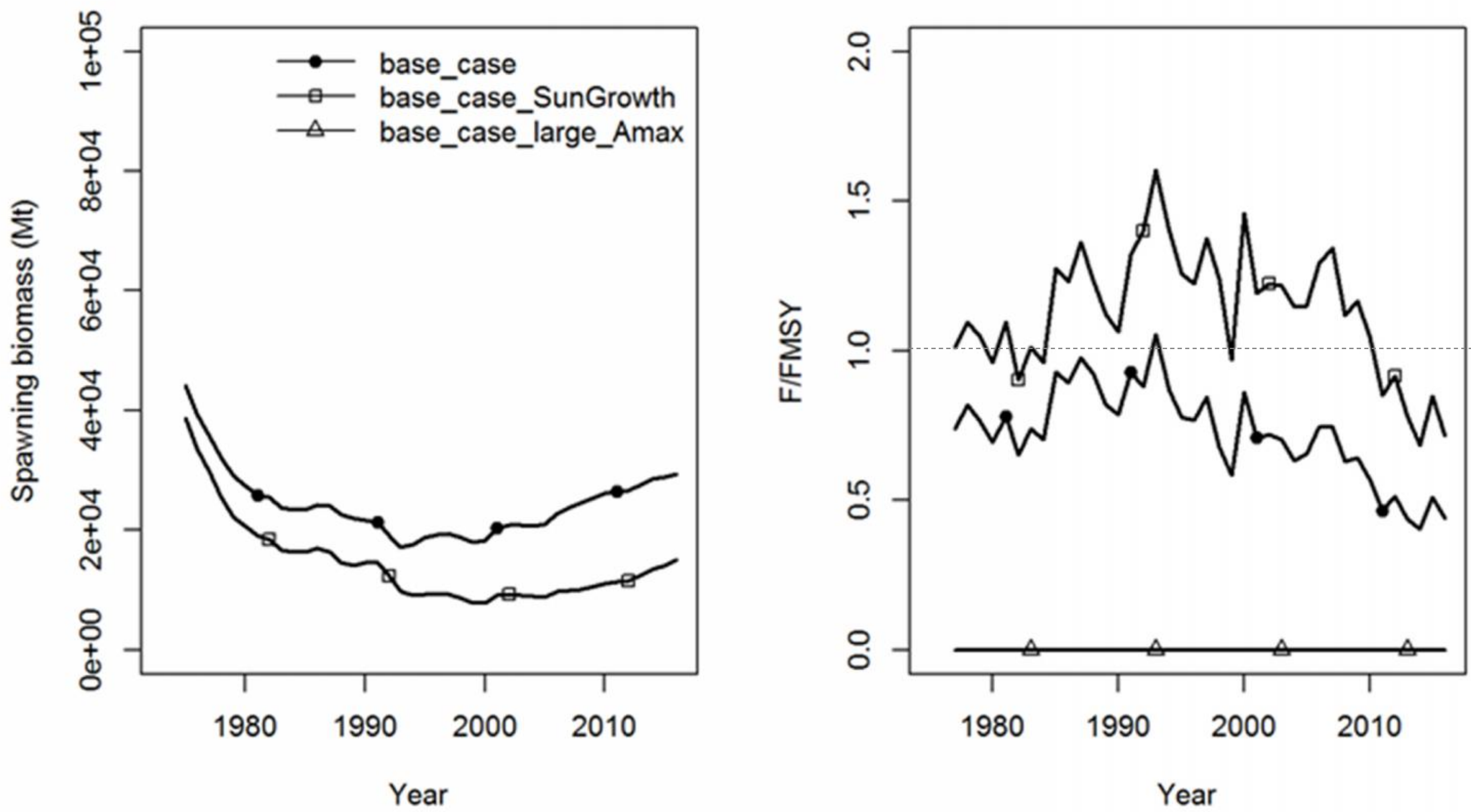
Sensitivity Analyses for Natural Mortality



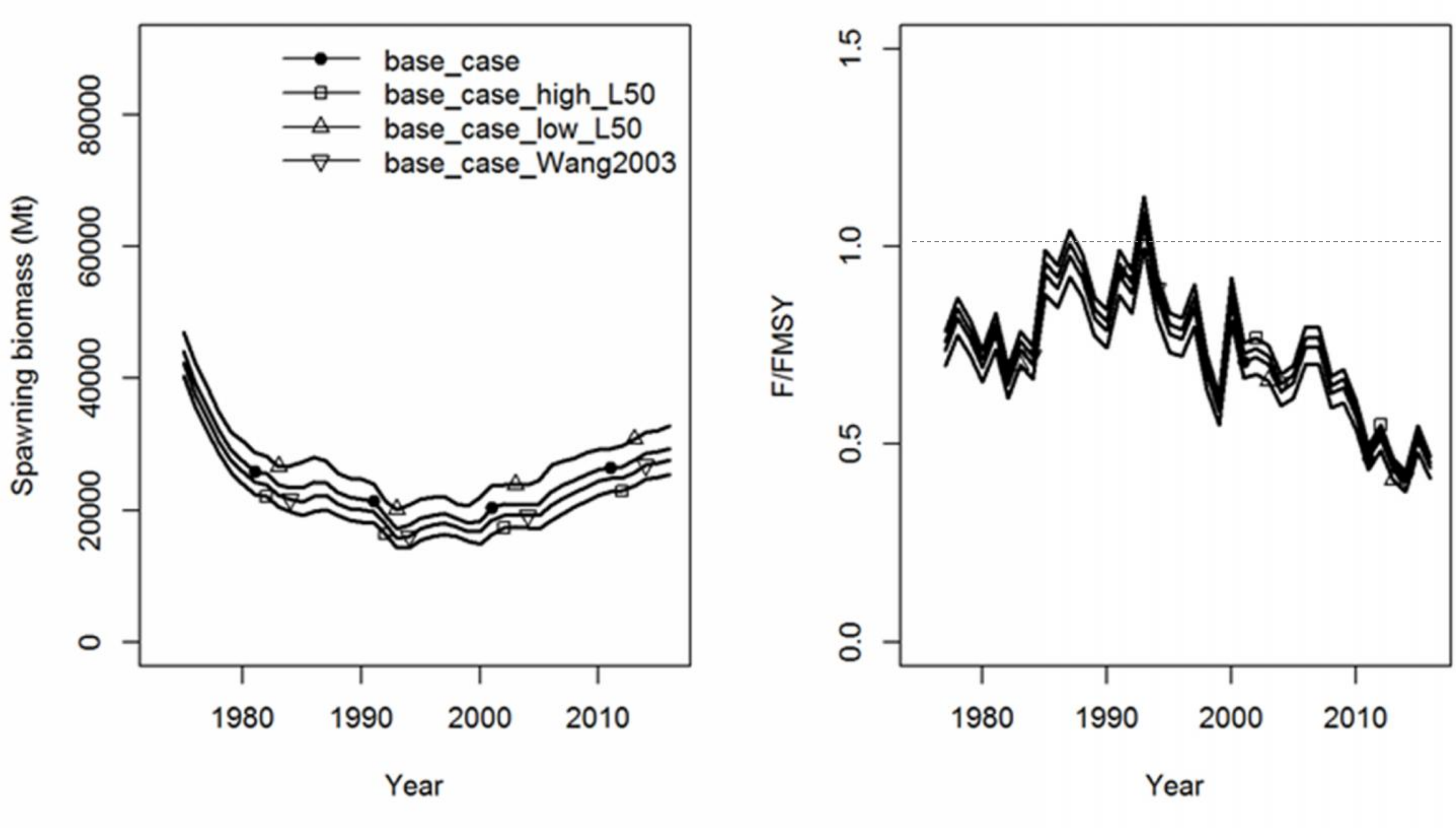
Sensitivity Analyses for Steepness



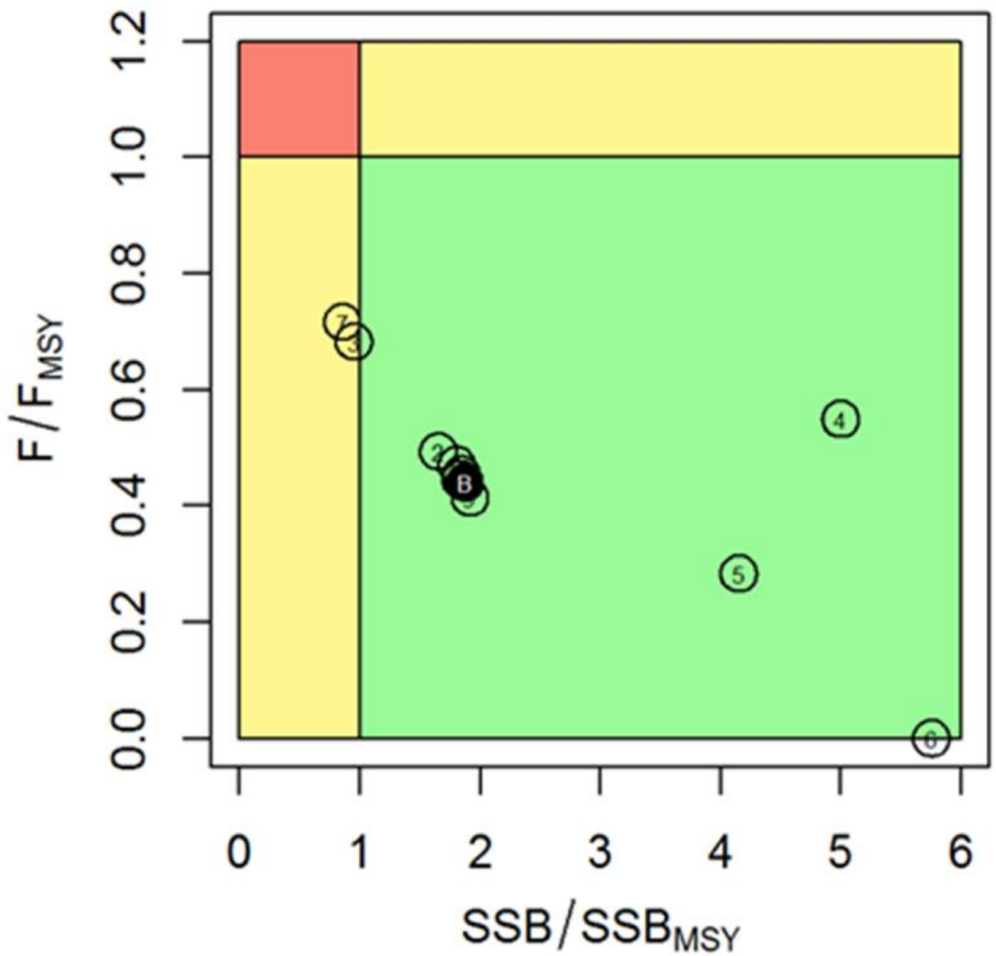
Sensitivity Analyses for Growth



Sensitivity Analyses for Maturation Rate



Kobe Plot for 2018 Sensitivity Results

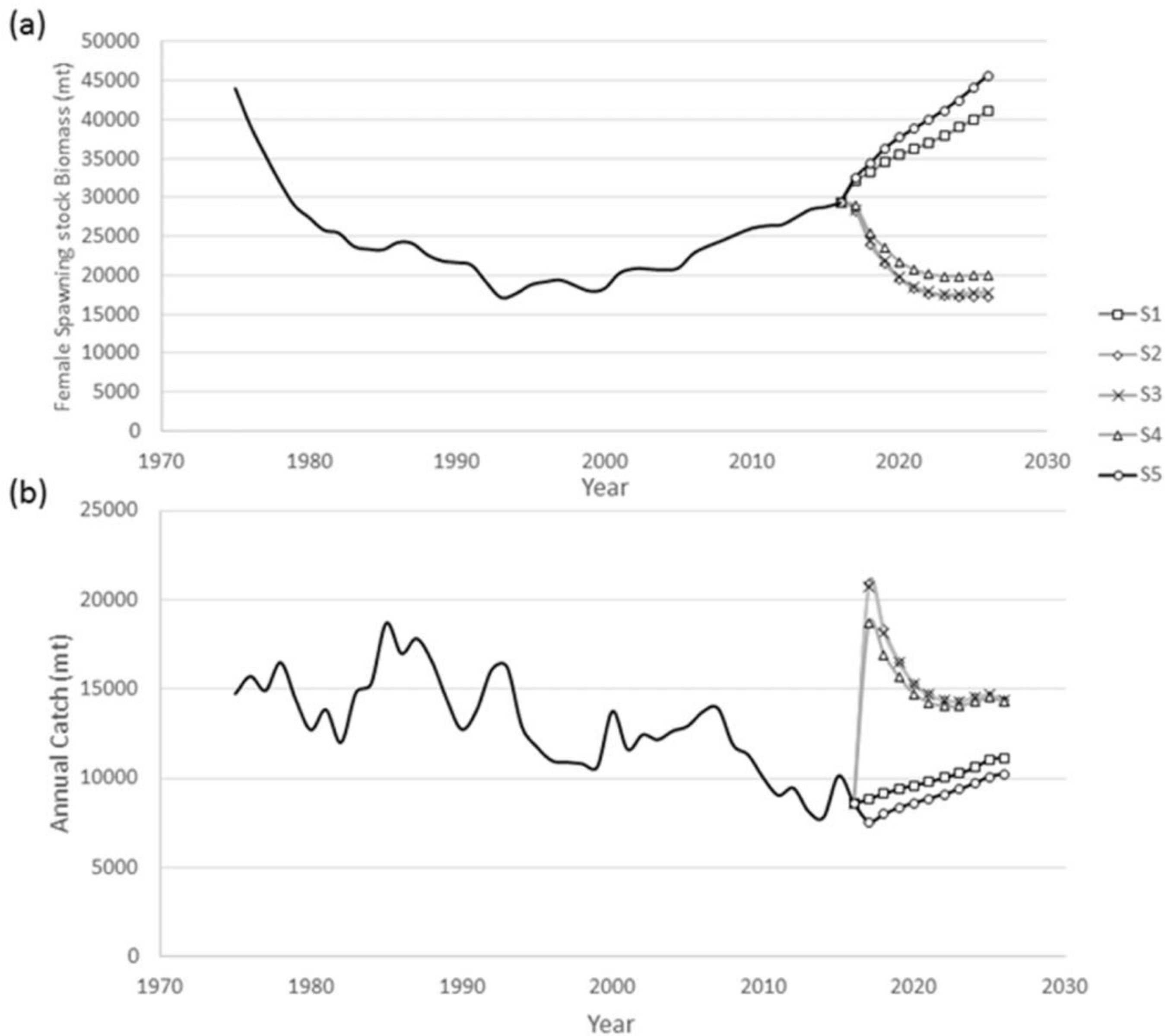


Run 7: Alternative growth parameters based upon Sun et al 2003 (smaller L_{amax})
Run 3: Alternative steepness h=0.7

WCNPO Swordfish Stock Projections

- Five future harvest scenarios were analyzed:
  - F Current Scenario with $F = F_{2013\text{-}2015} = F_{43\%}$
  - F at MSY Scenario with $F = F_{MSY} = F_{18\%}$
  - F at tropical tuna LRP Scenario with $F = F_{20\%SSB(F=0)} = F_{22\%}$
  - F High Scenario with $F = F_{20\%}$
  - F Low Scenario with $F = F_{50\%}$

WCNPO Swordfish Stock Projections



WCNPO Swordfish Stock Projections
Median Spawning Biomass

Harvest scenario	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Average
1. $F_{Status\ quo}$ ($F_{43\%}$)	32118	33207	34599	35476	36270	37082	37951	38967	40083	41087	36684
2. F_{MSY} ($F_{18\%}$)	28267	23963	21443	19458	18303	17618	17293	17197	17253	17263	19806
3. $F_{20\%SSB(F=0)}$ ($F_{22\%}$)	28425	24384	21800	19735	18530	17874	17496	17586	17818	17779	20143
4. F_{High} ($F_{20\%}$)	29007	25431	23527	21763	20736	20131	19893	19883	19981	20066	22042
5. F_{Low} ($F_{50\%}$)	32559	34334	36290	37666	38836	39984	41148	42490	44049	45625	39298

Green shading indicates the projected SSB is greater than MSY level (SSB_{MSY} =15,704 mt)

WCNPO Swordfish Stock Projections
Median Catch Biomass

Harvest scenario	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Average
1. $F_{Status\ quo}$ ($F_{43\%}$)	8851	9135	9407	9599	9794	10022	10275	10595	11053	11142	9987
2. F_{MSY} ($F_{18\%}$)	20885	18323	16509	15294	14666	14353	14308	14520	14650	14348	15786
3. $F_{20\%SSB(F=0)}$ ($F_{22\%}$)	20691	18122	16454	15261	14653	14361	14319	14554	14665	14384	15747
4. F_{High} ($F_{20\%}$)	18680	16933	15657	14726	14242	14033	14050	14292	14496	14253	15136
5. F_{Low} ($F_{50\%}$)	7556	7973	8343	8605	8847	9101	9366	9692	10087	10223	8979

Green shading indicates the projected catch is greater than 80% of MSY or at the pretty good yield level (0.8*MSY=11,954 metric tons)

Stock Status

- For this 2018 benchmark assessment, note that biomass status is based on female spawning stock biomass, whereas for the 2014 update assessment, biomass status was based on exploitable biomass (effectively age-2+ biomass)

Stock Status

- It is also important to note that there are no currently agreed upon reference points for the WCNPO swordfish stock and that retrospective analyses show that the assessment model appears to underestimate spawning stock biomass in recent years

Stock Status

- The WCNPO swordfish stock has produced annual yields of around 10,200 mt per year since 2012, or about 2/3 of the MSY catch amount
- There is no evidence of excess fishing mortality above F_{MSY} ($F_{2013\text{-}2015}$ is 45% of F_{MSY}) or substantial depletion of spawning potential (SSB_{2016} is 87% above SSB_{MSY})

Stock Status

- Overall, the WCNPO swordfish stock is not likely overfished and is not likely experiencing overfishing relative to MSY-based or 20% of unfished spawning biomass-based reference points

Conservation Information

- The results show that projected female spawning biomasses would be expected to increase under all of the harvest scenarios with greater increases expected under lower fishing mortality rates.
- Similarly, projected catch biomasses are expected to increase under each of the five harvest scenarios, with greater increases expected under higher fishing mortality rates.

Research Needs

- The lack of sex-specific size data and the simplified treatment of the spatial structure of swordfish population dynamics remained as two important sources of uncertainty for improving future assessments.
- It was recommended that sex-specific fishery data be collected and management strategy evaluation research be conducted to address these issues for improving future stock assessments.